ORIGINAL ARTICLE

Early Refractive Effect of Cataract Surgery in Medically Controlled Glaucoma

Emine Sen[1], Dilara Kocabas[2], Ufuk Elgin[1], Kubra Serbest Ceylanoglu[1]

ABSTRACT

Purpose: To evaluate the refractive outcomes of phacoemulsification in patients with glaucoma under medical treatment.

Materials and Methods: The study group with medically treated glaucoma was prospectively compared with an age-and sex-matched, non-glaucomatous control group. Ocular biometry was measured with Lenstar laser interferometry. The difference between predicted and current postoperative refractive changes was calculated using intraocular lens (IOL) prediction formulae (Haigis, Holladay, Hoffer Q, and SRK-II) pre-operatively and post-operatively at the 1, 7 and 30 days. The difference between the current postoperative and predicted changes was considered 'Mean Error' (ME). The accuracy of different IOL calculation formulae was also compared by examining ME of the groups.

Results: 23 eyes in the study group and 20 eyes in the control group were included. The eyes in the study group had significantly more myopic shift than the control group according to Holladay, Hoffer Q and SRK-II measurements on day 1 postoperatively (p=0.01,p= 0.04,and p=0.001,respectively). Eyes in both groups had myopic shift at day 7 and day 30 according to these 3 formulae, but there was no statistically significant difference (all p >0.05). The Haigis formula had significantly more hyperopic shift in both groups postoperatively, except on day 1 in the study group. No correlation was found between ME and axial length (AL), anterior chamber depth (ACD), and intraocular pressure (IOP) change in all formulae(all p >0.05).

Conclusions: The IOL value can be more accurately calculated using the Holladay, Hoffer Q, and SRK-II formulae.The Haigis formula had significantly more hyperopic shift than the other formulae in both groups.

Keywords: Biometry, cataract surgery, glaucoma, intraocular lens calculation, Lenstar.

INTRODUCTION

Since the introduction of phacoemulsification by Kelman,[1] phacoemulsification with posterior chamber intraocular lens (IOL) implantation has become a standard procedure in cataract surgery. With the advancement of surgical technology and techniques, cataract surgery has evolved into a small-incision surgery with rapid wound healing, good visual outcomes, and minimal complications in most patients. Patient expectations are good refractive outcomes, that can be achieved with accurate biometric data.[2-4] Nowadays, postoperative refractive change is predicted using IOL-power calculation formulae that take into account preoperatively determined biometric variables such as keratometry values, anterior chamber depth (ACD), and axial length (AL). IOL power calculation formulas have been developed to improve the accuracy of refraction prediction, and many calculation formulas have been developed recently.[5]

Many investigators have already reported that ACD and AL decrease after trabeculectomy.[6,7] These postoperative changes may be the cause of incorrect refractive estimation.[8,9] In medical treatment, it is possible to exclude potential dimensional changes of the eyeball caused by surgery and medical treatment does not trigger such changes. For this reason, we propose that in medically controlled glaucoma patients who have undergone cataract surgery,information on optimal refractive outcomes and selection of appropriate IOL formulae.Our aim was to evaluate the accuracy of different IOL power prediction formulae and the refractive outcomes of phacoemulsification in medically treated glaucoma patients and non-glaucomatous control patients.

1- SBÜ, Ulucanlar Göz Eğitim ve Araştırma Hastanesi, Ankara, Türkiye

2- Bilecik State Hospital, Göz, Bilecik, Türkiye

Received: 07.07.2021
Accepted: 07.12.2021

Glo-Kat 2022; 17: 95-100

DOİ: 10.37844/glauc.cat.2022.17.15

Correspondence Adress:
Emine Şen
SBÜ Ulucanlar Göz, Göz, ankara, Türkiye
Phone: +90 312 344 5639
E-mail: eminesentr@yahoo.com

MATERIALS AND METHODS

This prospective observational study was conducted from March1, 2017 to January 1, 2018. Study methods were approved by Ethics Committee and all study procedures were in accordance with the tenets of the Declaration of Helsinki.

The study group included 23 eyes of 23 patients with medically controlled glaucoma and the control group included 20 eyes of 20 patients. Glaucoma patients have to have elevated intraocular pressure (IOP) of greater than 21 mmHg, glaucomatous optic neuropathy, and a reproducible glaucomatous visualfield defect according to the Swedish Interactive Threshold Algorithm of 24-2 perimetry (Humphrey Field Analyzer II; Carl Zeiss Meditec, Dublin, CA, USA). Inclusion criteria were as follows in the study group: the patients with Open Angle Glaucoma (OAG) and early and moderate stage of OAG cases up to MD-12 in the visual field. Exclusion criteria were as follows in the study group: the patients with primary angle closure glaucoma (PACG) and complicated surgeries. The control group was recruited from cataract patients, who had an IOP of less than 21 mmHg, no evidence of glaucomatous optic neuropathy or visual-field defects, and no family history of glaucoma. Subjects were also excluded if they were younger than 40 years of age, had any surgery-related complications, had an ocular or systemic disease that could affect the surgical procedure and/or outcome, or had previously undergone ocular surgery.

All subjects underwent a complete ophthalmic examination prior to surgery, including measurement of best corrected visual acuity (BCVA), IOP by Goldmann applanation tonometry. Subjects also underwent automated keratometry (RK-3, Canon, Tochigiken, Japan) to measure refractive error (spherical equivalent [SE]) and keratometry values. Partial coherence interferometry (Haag-Streit LENSTAR® LS 900 Optical Biometer, Switzerland) was used to determine the keratometric values (Mean K), AL, lens thickness (LT), and the other anterior chamber parameters. Postoperatively on 1st, 7th and 30th day after cataract surgery, BCVA, IOP, SE and keratometry values were measured again.

All surgeries were performed by two experienced surgeons (UE and ES). In standard cataract surgery, phacoemulsification with posterior chamber IOL implantation protocol performed. Phacoemulsification was performed with a temporal clear corneal incision, and single piece acrylic IOL (AcrySof SA60AT IOL; Alcon, Fort Worth, TX, USA) was implanted into the capsular bag. Only uncomplicated cataract surgeries were included in the study. IOL power was determined between +0.50 and -0.50 diopters,whichever was close to emmetropia.

Data before and after surgery were compared between the two study groups, and the mean error (ME) of each group was evaluated. The ME was defined as the mean difference between the actual and predicted postoperative SE. We also compared the accuracy of different IOL calculation formulae (SRK II, Haigis, Holladay, and Hoffer Q) by examining ME in the medically treated glaucoma and control groups. All statistical analyses were performed with SPSS software (version 20.0; SPSS, Inc., Chicago, IL). An independent sample t-test was performed to compare preoperative and postoperative variables such as BCVA, IOP, AL, Mean K, central corneal thickness (CCT), and ACD and SE between groups. Paired sample t-test was performed for preoperative and postoperative variables in the same group. Postoperative ME values were compared between the formulae using the paired sample t-test. A p-value of less than 0.05 was considered to indicate statistical significance.

RESULTS

Forty-three patients (18 female, 25 male; mean age, 64.42±7.47 years) with medically controlled glaucoma and age- and sex- matched non-glaucomatous control subjects were consecutively included. In the study group, 4 out of 23 patients had pseudoexfoliation glaucoma and others had primary OAG (POAG). Subject demographics and preoperative clinical characteristics for each of the study groups are summarized in Table 1. The differences between the preoperative and postoperative data are summarized in Tables 2 and 3.

The eyes in the study group had significantly more myopic shift postoperatively than the control group on day 1 after SRK-II, Holladay, and Hoffer Q IOL formulas. The eyes had myopic shift on day 7 and 30 in both groups and on day 1 in the control group according to SRK-II, Holladay, and Hoffer Q IOL formulae, but there was no statistically significant difference (all p>0.05). However, the Haigis formula resulted in a significantly greater hyperopic shift than the other formulae for all measurements in the control group and for on day 7 and day 30 in the study group (Table 4). Between day 7 and day 30, ME was not significantly different for all formulae (SRK-II p=0.362, Holladay p=0.117, Hoffer Q p=0.118, Haigis p=0.416 in the study group; SRK-II p=0.466, Holladay p=0.271, Hoffer Q p=0.10, Haigis p=0.953 in the control group). In each group almost the expected refraction value was achieved on day 7. No correlation was found between refraction outcome (actual - expected) and IOP change for both groups (for all formulae, p >0.05). No correlation was found between ME and AL, ACD and IOP change in all formulae (all p >0.05). Also, there was no correlation

Table 1: *Baseline characteristics of medically controlled (study) and no glaucoma history (control) groups.*

	Study Group (n=23)	Control Group (n=20)	P
Age (years)	63.43±6.6	61.15±6.7	0.27*
Male/female	13/10	12/8	0.818**
IOP (mmHg)	19.34±5.8	16.70±2.8	0.071*
Predicted IOL Power (D)	20.91±3.0	20.83±2.0	0.717*
BCVA (Snellen)	0.22±0.15	0.21±0.13	0.922*
LT (mm)	4.47±0.46	4.22±0.34	0.51*
AL (mm)	23.20±1.24	23.58±0.95	0.277*
ACD (mm)	3.19±0.50	3.42±0.43	0.126*
CCT (µm)	533.57±33.92	538.75±32.81	0.615*
Mean K (diopter)	43.69±1.36	43.08±1.60	0.191*

Data are expressed as mean±standard deviation or as n, as appropriate.
n, number; IOP, intraocular pressure (average of 2); D, diopter; BCVA, best corrected visual acuity; LT, lens thickness; AL, axial length; ACD, anterior chamber depth; CCT, central corneal thickness; K keratometry.
*Independent sample t test, ** Chi-square test.

Table 2: *30th day ocular characteristics after cataract surgery.*

	Study Group (n=23)	Control Group (n=20)	P*
IOP (mmHg)	14.09±3.1	14.65±2.6	0.531
BCVA (Snellen)	0.70±0.14	0.93±0.10	**0.00001**
AL (mm)	23.10±1.22	23.53±0.92	0.208
ACD (mm)	5.19±0.66	5.34±0.46	0.393
CCT (µm)	546.30±48.85	545.65±36.04	0.961
Mean K (diopter)	44.08±1.34	43.14±1.88	0.067

Data are expressed as mean±standard deviation.
*Independent sample t test, P values in bold are statistically significant P<0.05.
IOP, intraocular pressure (average of 2); BCVA, best corrected visual acuity; AL, axial length; ACD, anterior chamber depth; CCT, central corneal thickness; K, keratometry.

Table 3: *Differences between preoperative and postoperative 30th days ocular characteristics.*

Variables	**Study Group (n=23)**	**Control Group (n=20)**	P*
IOP	-5.26±5.8	-2.050±2.799	**0.031**
BCVA	0.490±0.208	0.721± 0.138	**0.0001**
AL	-0.098±0.075	-0.047± 0.069	**0.026**
ACD	-1.996±0.496	-1.921±0.455	0.612
CCT	12.73±25.50	6.90±14.80	0.373
Mean K	-0.091±0.604	-0.091± 0.489	0.366
SE	0.795±1.802	0.882±1.887	0.879

Data are expressed as mean±standard deviation
n= number of patients; IOP, intraocular pressure; BCVA, best-corrected visual acuity; AL, axial lenght; ACD, anterior chamber depth; CCT, central corneal thickness; K, keratometry value; SE, spherical equivalan.
*Independent sample t test, Values in bold are statistically significant P<0.05.

Table 4: *Mean error following cataract surgery in subjects.*

		SRK-II	Haigis	Holladay	Hoffer Q
Study Group	Preop Predictive SE	-0.015±0.110	-0.048±0.421	-0.036±0.293	-0.115±0.361
	Postop 1st day ME	-0.643±0.812 **p=0.001**	0.284±1.264 p=0.194	-0.558±0.778 **p=0.010**	-0.579± 0.820 **p=0.04**
	Postop 7th day ME	-0.401± 1.087 p=0.094	0.840±1.593 **p=0.012**	-0.388±0.993 p=0.154	-0.376±1.070 p=0.343
	Postop 30th day ME	-0.302±0.931 p=0.147	0.942±1.506 **p=0.003**	-0.259±0.889 p=0.326	-0.215± 0.940 p=0.709
Control Group	Preop Predictive SE	-0.042±0.119	0.098±0.386	-0.033±0.224	-0.013±0.311
	Postop 1st day ME	-0.217±0.529 p=0.149	1.314±0.825 **p=0.0001**	-0.147±0.483 p=0.353	-0.157±0.441 p=0.255
	Postop 7th day ME	-0.165±0.452 p=0.253	1.452±0.884 **p=0.0001**	-0.164±0.396 p=0.205	-0.181±0.354 p=0.139
	Postop 30th day ME	-0.078±0.562 p=0.766	1.438±0.953 **p=0.0001**	-0.012±0.566 p=0.869	0.091±0.645 p=0.474

Data are expressed as mean±standard deviation. Preop: preoperative; Postop: Postoperative; SE: spherical equivalent; ME: mean error. *Paired sample t test, Values in bold are statistically significant P

between LT and postoperative SE (on day 1, 7, and 30) in the study and control groups (all p >0.05).

DISCUSSION

Good refractive outcomes after cataract surgery can be achieved with accurate biometric data. In all patients undergoing cataract extraction with intraocular lens implantation, the most important parameters for determining the lens power to be used are the manufacturer's lens constant, keratometry value, ACD, and AL of the eye.[2,3] Despite our best efforts to enhance measurements and IOL calculations, refractive surprises still occur.[10] In a study from the Swedish National Cataract Registry, Kugelberg and Lundström[4] found that glaucoma was significantly associated with a large deviation from the postoperative target refraction in eyes scheduled for cataract surgery. It has been reported that AL, ACD, and keratometry values were affected by trabeculectomy surgery.[6,7,9] Possible dimensional changes of the eyeball due to surgery can be excluded in the patients with glaucoma under medical treatment. Also, many factors in glaucoma patients as presence of pseudoexfoliation, zonullar weakness, condition of the angle, variety of medical treatment used, duration and difficulty of surgery may be affected postoperative refraction. In this study, we investigated accuracy of different formulae for predicting IOL power and early refractive outcomes of phacoemulsification in patients with open angle glaucoma under medical treatment and in control patients. Our results showed that the SRK-II, Hoffer Q, and Holladay IOL formulae all had a slight tendency toward miyopia in both groups, but there was no statistically significant difference except for the measurements on the first day in the study group. The Haigis formula had a significantly greater hyperopic shift than the other formulae in both groups in our study except for day 1.

Variables used in calculating IOL power, such as ACD, keratometry readings, and AL,may be affected by trabeculectomy surgery, as shown by many studies.[6,7,9,11,12] Zhang et al.[6] compared eyes undergoing phacoemulsification with IOL implantation after trabeculectomy with controls (glaucoma patients under medical treatment or without glaucoma) at the first visit after achieving final refraction (32 days).They reported that the factors affecting postoperative refractive surprise in cataract surgery after trabeculectomy were IOP change and AL. They also reported that an increase of 2 mmHg resulted in a shift of 0.36 diopters between predicted and actual refraction. The difference from the expected refractive outcome was -0.36 (more myopic) in trabeculectomy eyes compared to+0.40 (more hyperopic) in glaucoma eyes under control and +0.23 (more hyperopic) in non-glaucoma control eyes.[6] They explained the reason for the myopic shift in trabeculectomy eyes by the increase in AL, which occurred in eyes with higher IOP rise after phacoemulsification, but they did not explain the reason for the hyperopic shift in glaucoma eyes under medical control and in control eyes.[6] Also, ME was calculated only according to the SRK-II or SRK-T formulae.[6] Contrary to the study of Zhang et al.[6], in our study in both groups the ME calculated by the SRK-II, Holladay and Hoffer Q IOL formulae was myopic, and only early refractive effects of cataract surgery was evaluated. There was no study in the literature on early refractive effects of cataract surgery in patients with glaucoma under medical treatment. Myopic shift was a mild degree of refractive error that was not clinically significant in our study. Also, no correlation was found between ME and IOP change and AL in both groups. The reason might be that the eyes with normal range AL were included in our study.

In our study, almost the expected refraction value was achieved in each group on the 7th day, and between the 7th and 30th days ME was not significantly different for all formulae. Therefore, we thought that the final refraction in our study was almost reached on the 7th day. However, Zhang et al.[6] found that in the study group (cataract patients post trabeculectomy), it took an average of 32 days longer to stabilize and reach their final refraction compared with the control groups. However, final visual acuity was not affected by the difference in refraction as in our study.[6]In our study, final visual acuity was significantly higher in the control group at 30days. The reason for low visual acuity in the study group might be due to glaucomatous defect.

Since the final refraction took time, we think that the statistically significant myopic shift (according to SRK II, Holladay, Hoffer Q formulae), which occured at the 1st day examination in study group, was not clinically significant. In the presbyopic age group, we think that the minimal myopic shift that occurs with SRK-II, Hoffer Q, and Holladay formulae does not bother the patients, it is not high enough to affect the visual acuity, and it may be more tolerable.

Using the Pentacam, Dooley et al.[13] studied the effects of uncomplicated cataract surgery on anterior segment morphology in normal, nonglaucomatous eyes and found that IOP decreased by an average of 3.2 mmHg, while anterior chamber angle, depth, and volume increased postoperatively. We found that postoperative IOP was lower than that before surgery in the study group than the control group (-5.26 vs -2.05) and ACD was deeper than preoperatively (-1.99 vs -1.92). In both glaucomatous and normal eyes, cataract surgery increases ACD and decreases IOP, as we found in our study.

The Haigis formula had significantly more hyperopic refractive shift than the other formulae in both groups in our study. Joo et al.[14] and Seo et al.[15] reported that the Haigis formula produced the most hyperopic results in PACG patients. It is more appropriate to use the Hoffer Q formula to predict IOL powers in eyes with PACG.[12,13] The Haigis formula considers corneal curvature, AL, pre-operative ACD for in calculation of effective lens position.[16] The Haigis formula is especially more sensitive to the magnitude of the pre-operative ACD and post-operative ACD difference (delta ACD).[14] An increase of 1 mm ACD results in the post-operative refraction in the Haigis formula of 0.4 to 0.6 diopter.[13] Mature cataract, zonular weakness, angle closure glaucoma may effect delta ACD. It was reported that phacoemulsification induced more significant changes in patients with pseudoexfoliation compared to normal patients.[17] Although in our study, the delta ACD was -1.996±0.496 in the study group and -1.921±0.455 in the control group, no correlation was found between ME and delta ACD and AL in all formulae ($p > 0.05$).

Our study has some limitations. The first limitation was that there were few patients in the glaucoma subgroups such as pseudoexfoliative glaucoma (that may cause zonular weakness or pupil dilation difficulties that may complicate the surgery and prolong the surgical time), so the difference in pseudoexfoliative subgroups could not be evaluated. Larger studies with subgroups are needed to determine accuracy the IOL power of all formulae. The second limitation was that we only evaluated early refractive effect of cataract surgery in glaucoma patients under medical treatment. New studies that compares early and long-term refractive effects of cataract surgery in glaucoma patients receiving medical or surgical treatment will be more informative in this regard. The third limitation was that the factors such as cataract type and zonular weakness of the patients were not evaluated. Another important limitation was that pre-operative and post-operative anti-glaucomatous drugs could not be compared. Unfortunately, only four IOL formulae were used in our study. New studies using more modern formulae could be useful the literature in elucidating early refractive changes.

In summary for IOL calculation in medically treated glaucoma patients who are scheduled for cataract surgery, the probable myopic shift should be kept in mind. Although the factors such as ACD, AL and IOP change that affect calculation of IOL formulae had no effect on ME in our study, medically treated glaucoma patients should be informed about refraction shift before cataract surgery. Haigis formula had significantly more hyperopic shift than the other formulae. SRK-II, Hoffer Q, and Holladay IOL formulae had slight tendency toward myopic shift in both groups. IOL value may be calculated with SRK-II, Hoffer Q, and Holladay formulae may be more tolerable in the presbyopic age group than the Haigis formula.

Funding No funding was received for this research.

Compliance with ethical standards

Conflict of interest The authors declare that they have no affiliations with or involvement in any organization or entity with any financial or non-financial interest in the subject matter or materials discussed in this manuscript.

Ethical approval All procedures performed in this study involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Informed consent Written informed consent form was obtained from the patients whose images were used.

REFERENCES

1. Kelman CD. Phaco-emulsification and aspiration. A new technique of cataract removal. A preliminary report. Am J Ophthalmol 1967;64:23-35.
2. Olsen, T. Calculation of intraocular lens power: a review. Acta Ophthalmol Scand 2007;85:472-85.
3. Sanders DR, Retzlaff JA, Kraff MC, et al. Comparison of the SRK/T formula and other theoretical and regression formulae. J Cataract Refract Surg 1990;16:341-6.
4. Kugelberg M, Lundstrom M. Factors related to the degree of success in achieving target refraction in cataract surgery: Swedish National Cataract Register study. J Cataract Refract Surg 2008;34:1935-9.
5. Savini G, Taroni L, Hoffer KJ. Recent developments in intraocular lens power calculation methods-update 2020. Ann Transl Med 2020;8:1553.
6. Zhang N, Tsai PL, Catoira-Boyle YP, et al. The Effect of Prior Trabeculectomy on Refractive Outcomes of Cataract Surgery. Am J Ophthalmol 2013;155:858-63.
7. Cashwell LF, Martin CA. Axial length decrease accompanying successful glaucoma filtration surgery. Ophthalmology 1999;106:2307-11.
8. Alvani A, Pakravan M, Esfandiari H, et al. Ocular Biometric Changes after Trabeculectomy. J Ophthalmic Vis Res 2016;11:296-303.
9. Lee YC, Su CC, Wang TH, et al. Refractive outcomes of cataract surgery in patients receiving trabeculectomy-a comparative study of combined and sequential approaches. J Formos Med Assoc 2021;120:415-21.
10. Durr GM, Ahmed IIK. Intraocular Lens Complications: Decentration, Uveitis-Glaucoma-Hyphema Syndrome, Opacification, and Refractive Surprises. Ophthalmology. 2021;128: e186-e194.
11. Bae HW, LeeYH, Kim DW, et al.Effect of trabeculectomy on the accuracy of intraocular lens calculations in patients with open-angle glaucoma. Clin Exp Ophtalmol 2016;44:465-71.
12. Yeh OL, Bojikian KD, Slabaugh MA, et al. Refractive Outcome of Cataract Surgery in Eyes With Prior Trabeculectomy: Risk Factors for Postoperative Myopia. J Glaucoma 2017;26:65-70.
13. Dooley I, Charalampidou S, Malik A, et al. Changes in intraocular pressure and anteriorsegment morphometry after uneventful phacoemulsification cataract surgery. Eye (Lond) 2010;24:519-26.
14. Joo J, Whang WJ, Oh TH, et al. Accuracy of Intraocular Lens Power Calculation Formulae in Primary Angle Closure Glaucoma. Korean J Ophthalmol 2011;25:375-9.
15. Seo S, Lee CE, Kim YK, et al. Factors affecting refractive outcome after cataract surgery in primary angle-closure glaucoma. Clin Exp Ophthalmol 2016;44:693-700.
16. Jeong J, Song H, Lee JK, et al. The effect of ocular biometric factors on the accuracy of various IOL power calculation formulae.BMC Ophthalmol 2017;17:6.
17. Gür Güngör S, Akman A, Asena L, et al. Changes in Anterior Chamber Depth after Phacoemulsification in Pseudoexfoliative Eyes and their Effect on Accuracy of Intraocular Lens Power Calculation. Turk J Ophthalmol. 2016;46:255-8.