Relationship Between Preoperative and Post-phacoemulsification Intraocular Pressure in Primary Open-Angle Glaucoma

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ABSTRACT

Purpose: To evaluate changes in intraocular pressure (IOP) after phacoemulsification with intraocular lens (IOL) implantation in medically-treated primary open-angle glaucoma (POAG) patients with different preoperative IOP levels.

Materials and Methods: This is a retrospective, single-center study. We retrospectively reviewed the data of 89 eyes of 68 medically-treated POAG patients who underwent uneventful phacoemulsification with posterior chamber IOL implantation between January 2017 and March 2021. If surgery was bilateral, one eye was randomly selected for analysis.

Results: Final postoperative IOP was significantly lower than preoperative IOP (13.54±2.88 vs. 16.74±4.52 mmHg, $p<0.001$). When evaluated by preoperative IOP range, the mean postoperative change in IOP was -0.42±2.39 mmHg in the ≤15 mmHg group, -3.48±3.08 mmHg in the 16-20 mmHg group, and -10.1±2.42 mmHg in the ≥21 mmHg group. IOP was significantly lowered in all groups ($p<0.05$). IOP reduction was significantly greater in the preoperative IOP ≥21 mmHg group than the ≤15 mmHg and 16-20 mmHg groups, and greater in the 16-20 mmHg group than the ≤15 mmHg group ($p<0.016$). The number of antiglaucoma medications used at postoperative 6 months (2.26±1.03), 1 year (2.29±1.04), 2 years (2.34±1.01), 3 years (2.00±0.97), and final examination (2.33±1.04) did not differ from preoperatively (2.34±1.06) ($p>0.05$).

Conclusion: Phacoemulsification with IOL implantation in medically treated POAG patients can lower IOP by an average of 10 mmHg in eyes with preoperative IOP ≥21 mmHg, while a much smaller reduction (-0.42 mmHg) at preoperative IOP ≤15 mmHg. IOP reduction is less pronounced at postoperative 3 years compared to the early postoperative period.

Keywords: Phacoemulsification, primary open-angle glaucoma, intraocular pressure, medication.

INTRODUCTION

Glaucoma is an optic neuropathy that leads to progressive visual field damage. The most common form is primary open-angle glaucoma (POAG).[1] Lowering intraocular pressure (IOP) both reduces the incidence of POAG and delays its progression.[2-4] In clinical practice, medical and surgical treatment methods can be used to lower IOP and help prevent disease progression.[5] Cataract extraction has been shown to reduce IOP in open angle eyes.[6] In the last decade, several studies have also demonstrated that cataract surgery is effective as an IOP-lowering procedure and can be performed as glaucoma surgery.[7,8] Even a small effect of cataract surgery on IOP can significantly alter the population's risk of glaucoma.[9] However, parameters to help predict the magnitude of IOP change after cataract surgery would be helpful for clinicians when establishing patient expectations and assessing which patients may need cataract surgery alone or combined surgery.[10] Various studies have investigated the effect of a narrow or wide anterior chamber angle on IOP reduction in patients with glaucoma.[10-12] The aim of this study was to evaluate the relationship between preoperative IOP range and IOP change after phacoemulsification with intraocular lens (IOL) implantation in the subset of POAG patients receiving medical treatment. This may enable an estimation of the target change in IOP with phacoemulsification surgery in patients with POAG. We also aimed to examine the

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relationship between patients' age, sex, and preoperative CCT values and the postoperative change in IOP.

MATERIALS AND METHODS

For this retrospective study, we reviewed the records of 68 medically-treated POAG patients (89 eyes) who underwent uneventful phacoemulsification with posterior chamber IOL implantation in our hospital between January 2017 and March 2021. For patients who had bilateral surgery, one eye was randomly selected for inclusion in the statistical analysis. A total of 68 eyes were included in the study. The study was approved by the hospital ethics committee (the ethical approval number and date: 2021/514/214/4, 30 November 2021) and carried out in accordance with the principles of the Declaration of Helsinki. All patients provided informed consent for surgery.

A diagnosis of POAG was made for patients with a pretreatment IOP >21 mmHg, an open anterior chamber angle, and the presence of glaucomatous optic disc excavation or retinal nerve fiber layer defects accompanied by corresponding visual field defects. Inclusion criteria were having a diagnosis of POAG, being followed in our center with medical treatment, and having complete preoperative, peroperative, and postoperative data. Patients with a best-corrected visual acuity (BCVA) of light perception or higher, a postoperative follow-up period of 6 months or longer were included in the study. The glaucoma stages of the patients included in the study were variable. Exclusion criteria were the presence of any ocular disease other than POAG and cataract, complicated cataract surgery, any ocular surgery other than phacoemulsification with posterior chamber IOL implantation, and requiring glaucoma surgery (those patients also had end-stage glaucoma) during postoperative follow-up. Patients with a previous history of ocular trauma, secondary glaucoma, high myopic eyes were excluded. None of the patients had been diagnosed with diabetes mellitus. Patients with cataract types other than nuclear, cortical or posterior capsular cataracts were excluded from the study.

We retrospectively reviewed the patients' sex and age at the time of cataract surgery; preoperative refraction values, BCVA (assessed with Snellen chart and converted to logMAR), central corneal thickness (CCT) values (measured with Scheimpflug camera; Sirius Topography Device, CSO, Firenze, Italy), IOP values (assessed using Goldmann applanation tonometry), number of antiglaucoma medications (determined on the basis of the number of active ingredients), gonioscopic angle evaluations (all eyes in the study had Shaffer grade ≥3 angle in examination with Goldmann three-mirror lens), biomicroscopic anterior segment and fundus examinations, and optic nerve head cup-to-disc ratio (in patients whose fundus could be visualized on slit-lamp examination); BCVA at last postoperative examination; and IOP and number of antiglaucoma medications used at postoperative 6 months, 1 year, 2 years, and 3 years. Final IOP and number of medications were determined based on the patients' last follow-up examination.

Relationships between the patients' sex, preoperative age, CCT, and IOP parameters and change in IOP after phacoemulsification with IOL implantation (postoperative final IOP - preoperative IOP) were examined. The patients were divided into three groups according to preoperative IOP (≤15 mmHg, 15-20 mmHg, and ≥21 mmHg), and postoperative IOP reduction was compared between the groups.

Phacoemulsification with posterior chamber IOL placement

Phacoemulsification with posterior chamber IOL placement was performed under local anesthesia in all patients. For the procedure, a superior clear corneal incision was made with a 2.8 mm knife (Teknomek, Istanbul, Turkey) and the anterior chamber was filled with 1.4% sodium hyaluronate (CrownVisc, Mebs, Istanbul, Turkey). Following continuous curvilinear capsulorhexis and hydrodissection of the nucleus, phacoemulsification was performed with a Stellaris phacoemulsifier (Bausch & Lomb, Rochester, NY, USA) using the stop and chop technique for phacoemulsification of the nucleus. The remaining cortex was removed using a bimanual technique and the bag was filled with viscoelastic. A foldable IOL (Hydrophobic IOL, VSY biotechnology, Amsterdam, Netherlands) was implanted in the bag and the viscoelastic was removed by irrigation and aspiration. Balanced saline solution was used to reform the anterior chamber and hydrate the corneal incision and side ports, which were left unsutured. All eyes received cefuroxime (1 mg/0.1 mL) intracamerally. No other agents (e.g., miotics, anesthetic) were used during the phacoemulsification procedure. At the end of the procedure, all incisions were tested for watertightness to confirm the absence of leakage and topical moxifloxacin hydrochloride (Vigamox, Novartis, Basel, Switzerland) was instilled into the lower conjunctival fornix. Postoperatively, patients continued topical moxifloxacin hydrochloride 5 times a day for 2 weeks and received topical dexamethasone (Maxidex, Novartis, Basel, Switzerland) starting at 6 times a day for 1 week and then tapered over 3 weeks.

Statistical Methods

Descriptive statistics were used for continuous variables (mean, standard deviation, median, minimum, maximum). The normality of continuous variables were investigated by Shapiro-Wilk's test. Spearman correlation analysis was used to analyze the relationship between two continuous variables that did not show normal distribution. Pearson correlation analysis was used to analyze the relationship between two continuous variables with normal distribution. Wilcoxon test was used to compare two dependent variables with non-normal distribution. Friedman test was used for comparisons of more than two dependent continuous variables with non-normal distribution. Mann-Whitney U test was used for comparisons of two independent non-normally distributed variables. The statistical significance level was set at $p < 0.05$. Analyses were performed using IBM SPSS Statistics version 24 package software.

RESULTS

A total of 68 eyes were included in the study. The patients' mean age at time of cataract surgery was 67.18±8.29 (range, 50-90) years; 44.1% (n=30) of the patients were women and 55.9% (n=38) were men. Mean postoperative follow-up time was 21,43±13,15 (6-48) months.

The mean IOP, number of antiglaucoma medications, CCT, cup-to-disc ratio, and BCVA values of the eyes are shown in Table 1.

There was a statistically significant difference between preoperative and postoperative IOP values ($p<0.05$). The results of post-hoc pairwise comparisons showed that mean IOP was significantly lower at postoperative 6 months, 1 year, 2 years, and 3 years when compared with preoperative mean IOP, while the mean IOP at postoperative 3 years was significantly higher than at postoperative 6 months (Wilcoxon with Bonferroni correction $p<0.005$). The final postoperative mean IOP was significantly lower than the preoperative mean IOP (13.54±2.88 vs. 16.74±4.52 mmHg, Wilcoxon $p<0.001$) (Table 2). The mean decrease in postoperative final IOP compared to preoperative IOP was 19.1%. When evaluated according to preoperative IOP range, the mean postoperative change in IOP (final postoperative IOP - preoperative IOP) was -0.42±2.39 mmHg in the ≤15 mmHg group, -3.48±3.08 mmHg in the 16-20 mmHg group, and -10.1±2.42 mmHg in the ≥21 mmHg group (Figure 1). Postoperative IOP lowering

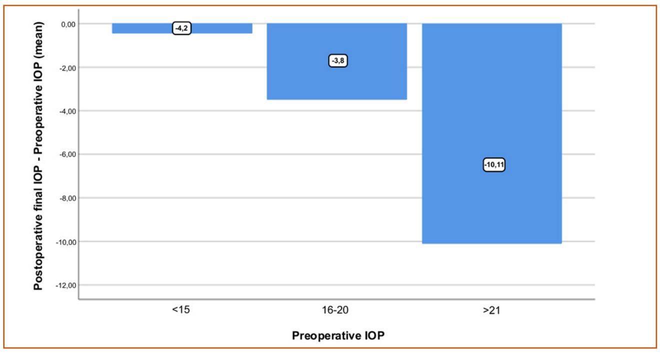

Figure 1: *Distribution of postoperative IOP change according to preoperative IOP range.*

Table 1: *Distribution of parameters.*

Mean±SD Med. (Min.-Max.)	Preoperative N=68	Postoperative 6 months N=68	Postoperative 1 year N=42	Postoperative 2 years N=29	Postoperative 3 years N=16	Last postoperative follow-up N=68	Last postoperative follow-up – Preoperative N=68
IOP (mmHg)	16.74±4.52 17 (9-29)	13.79±3.17 14 (8-21)	13.45±3.05 14 (8-19)	13.45±2.96 14 (8-19)	14.69±2.21 15 (10-19)	13.54±2.88 14 (8-19)	-3.19±4.1 -3 (-14-4)
No. of glaucoma medications	2.34±1.06 2 (1-4)	2.26±1.03 2 (1-4)	2.29±1.04 2 (1-4)	2.34±1.01 2 (1-4)	2±0.97 2 (1-4)	2.34±1.04 2 (1-4)	0±0.69 0 (-2-2)

	N	Preoperative	Postoperative
CCT (μm)	68	555.19±36.68 554.5 (490-630)	
C/D	60	0.65±0.99 0.5 (0.1-1)	
BCVA (logMAR)	68	0.47±0.34 0.4 (0.03-1.3)	0.06±0.08 0 (0-0.3)

SD: Standard deviation, Med.: Median, Min: Minimum, Max: Maximum, IOP: Intraocular pressure, CCT: Central corneal thickness, C/D: Cup to disc ratio, BCVA: Best corrected visual acuity

Table 2: *Comparison of IOP levels at different follow-up times.*

Mean±SD Med. (Min.-Max.)	Pre-operative N=68	Post-operative 6 months N=68	Post-operative 1 year N=42	Post-operative 2 years N=29	Post-operative 3 years N=16	Last post-operative follow-up N=68	p	p*	
IOP (mmHg)	16.74±4.52 17 (9-29)	13.79±3.17 14 (8-21)	13.45±3.05 14 (8-19)	13.45±2.96 14 (8-19)	14.69±2.21 15 (10-19)	13.54±2.88 14 (8-19)	**0.004**	**0.001***	
	Post-Hoc pairwise comparisons (p*)								
Pre-operative vs. Post-operative 6 months	Pre-operative vs. Post-operative 1 year	Pre-operative vs. Post-operative 2 years	Pre-operative vs. Post-operative 3 years	Post-operative 6 months vs. 1 year	Post-operative 6 months vs. 2 years	Post-operative 6 months vs. 3 years	Post-operative 1 year vs. 2 years	Post-operative 1 year vs. 3 years	Post-operative 2 years vs. 3 years
<0.001	**<0.001**	**<0.001**	**0.004**	0.422	0.548	**<0.001**	0.640	0.385	0.478

*Friedman test, Wilcoxon test (Preoperative vs. Last postoperative follow-up)**
SD: Standard deviation, Med.: Median, Min: Minimum, Max: Maximum, IOP: Intraocular pressure

was found to be statistically significant in all three groups (Kruskal-Wallis p<0.05). The reduction in IOP was significantly greater in the preoperative IOP ≥21 mmHg group compared to the ≤15 mmHg and 16-20 mmHg groups, and greater in the 16-20 mmHg group compared to the ≤15 mmHg group (Mann-Whitney U with Bonferroni correction p<0.016).

Postoperative change in IOP showed no significant difference according to patient age, sex, or preoperative CCT (p=0.353, p=0.055, and p=0.126, respectively) (Table 3).

Number of antiglaucoma medications showed no significant difference between preoperative (2.34±1.06) and postoperative 6 months (2.26±1.03), 1 year (2.29±1.04), 2 years (2.34±1.01), 3 years (2.00±0.97), and final examination values (2.33±1.04) (Friedman p>0.05) (Table 4).

When the patients' data were examined, we noted that 5 patients had a preoperative IOP≥21 mmHg and 3 or more antiglaucoma medications. We determined that these patients had dense cataracts that made it difficult to visualize the fundus.

DISCUSSION

In this study, we determined that the mean IOP was lower at all postoperative follow-ups (6 months, 1 year, 2 years, and 3 years) than preoperative IOP. Although mean IOP was higher at 3 years than at 6 months, final postoperative IOP was significantly lower than preoperative levels. We detected no significant relationship between postoperative IOP decrease and factors such as preoperative age, sex, and CCT, and phacoemulsification with IOL implantation had no effect on the number of antiglaucoma medications used. Postoperative IOP lowering was significant in all groups when the eyes were divided according to preoperative IOP (≤15 mmHg, 16-20 mmHg, and ≥21 mmHg), with the ≥21 mmHg group showing the greatest IOP reduction and the ≤15 mmHg group showing the smallest reduction.

Several studies have demonstrated that cataract extraction has an important role in the control of IOP in comorbid glaucoma.[8,11,13,14] In some previous studies, it was reported that changes in anterior segment anatomy due to cataract surgery may contribute to IOP reduction in open angle eyes[10,11,15], with some authors speculating that the IOP-lowering effect may be related to phacoemulsification surgery[16] or the effects of phacoemulsification surgery on the trabecular network.[17] Several authors have reported that uncomplicated phacoemulsification with IOL implantation lowered IOP by 2 mmHg or 13% in eyes with open-angle glaucoma and a preoperative IOP range of 15 to 17 mmHg.[18-20] The results of a meta-analysis indicated that phacoemulsification generally lowers IOP by 2 to 4 mmHg.[21] Baek et al.[22] determined in their study of 106 open-angle glaucoma patients that IOP decreased from 14.25 mmHg preoperatively to 13.06 mmHg at postoperative 6 months, 13.17 mmHg at 1 year, 13.89 mmHg at 2 years, and 14.17 mmHg at 3 years. Hsia et al.[11] found in their study of 53 POAG patients that the mean IOP was 14.72±3.50 mmHg preoperatively and 13.21±2.59 mmHg postoperatively, with a mean change of -1.50±2.63 mmHg. Slabaugh et al.[9] also noted that eyes with higher IOP before cataract surgery had the largest mean IOP reduction, while Baek et al.[22] reported that phacoemulsification was a reliable option for

Table 3: *Comparison of postoperative IOP change based on preoperative variables.*

Mean±SD Med. (Min.-Max.)		Last postoperative -Preoperative IOP	p^1
Sex	**Male**	-3.97±4.19 -3.5 (-12-4)	0.055
	Female	-2.2±3.83 -1 (-14-3)	
Preoperative CCT (µm)	**<520**	-1.7±3.3 -1 (-8-4)	0.116
	>520	-3.69±4.2 -3 (-14-3)	
Preoperative IOP (mmHg)	**<15 mmHg**	-0.42±2.39 0 (-5-4)	**<0.001**[2]
	16-20 mmHg	-3.48±3.08 -3 (-10-3)	
	≥21 mmHg	-10.1±2.42 -10 (-14- -7)	
Post-hoc pairwise comparisons [1]	**≤15 vs. 16-20 mmHg**	**≤15 vs. ≥21 mmHg**	**16-20 vs. ≥21 mmHg**
Preoperative IOP (mmHg)	**<0.001**	**<0.001**	**<0.001**
		Last postoperative -Preoperative IOP	
Age (years)	**r**	-0.114	
	p^2	0.353	
Preoperative CCT (µm)	**r**	-0.187	
	p^2	0.126	

Mann-Whitney U test[1], *Kruskal-Wallis test* [2], *Pearson's correlation test*[2]
SD: Standard deviation, Med.: Median, Min: Minimum, Max: Maximum, IOP: Intraocular pressure, CCT: Central corneal thickness

IOP control in patients with higher preoperative IOP levels. Although the mean postoperative IOP reduction in our study is slightly higher than rates reported in the literature, this may be due to the high preoperative maximum IOP in our patients. The higher preoperative mean IOP in our study may also explain the greater IOP reduction than in the study by Hsia et al.[11] We also observed in this study that phacoemulsification with IOL implantation could reduce mean IOP by 10 mmHg in eyes with preoperative IOP ≥21 mmHg, and that the degree of postoperative IOP lowering decreased as preoperative IOP decreased. These results are consistent with the literature and demonstrate that phacoemulsification with IOL implantation alone may be considered as a first option for eyes with high preoperative IOP and cataract in patients who are suitable in terms of other preoperative parameters.

In their meta-analysis, Armstrong et al.[13] determined that the initial IOP-lowering effect gradually diminished after postoperative 2 years but lasted for at least 3 years. We also observed that the reduction in IOP remained significant at postoperative 3 years. However, mean IOP level was significantly higher at 3 years compared to 6 months, indicating that the postoperative decrease in IOP tended to decrease over time as reported by Armstrong et al..[13] Armstrong et al.[13] also noted that phacoemulsification performed as a stand-alone procedure reduced IOP and dependence on topical glaucoma medications in patients with POAG. Hayashi et al.[23] reported in their study including 68 patients with POAG that the average IOP and number of medications decreased after phacoemulsification and IOL implantation. In contrast, Guan et al.[24] reported no change in the number of glaucoma medications, which was 1.5±1.3 both before and after cataract surgery. In our study, although there was a significant decrease in the

Table 4: *Comparison of number of glaucoma medications used.*

Mean±SD Med. (Min.-Max.)	Pre-operative N=68	Pos-toperative 6 months N=68	Post-operative 1 year N=42	Post-operative 2 years N=29	Post-operative 3 years N=16	Last post-operative follow-up N=68	Last post-operative follow-up – Pre-operative N=68	p	p*
No. of glaucoma medications	2.34±1.06 2 (1-4)	2.26±1.03 2 (1-4)	2.29±1.04 2 (1-4)	2.34±1.01 2 (1-4)	2±0.97 2 (1-4)	2.34±1.04 2 (1-4)	0±0.69 0 (-2-2)	**0.517**	**0.961***

*Friedman test, Wilcoxon test (Preoperative vs. Last postoperative follow-up)**
SD: Standard deviation, Med.: Median, Min: Minimum, Max: Maximum

mean IOP level, there was no significant change in the number of medications used postoperatively compared to the preoperative period. Our results are similar to those of Guan et al.[24], whereas the higher preoperative IOP (20.7±5.4 mmHg) in the open-angle glaucoma groups in the study by Hayashi et al.[23] compared to our study may have resulted in a greater IOP reduction in their patients, thus lowering the number of postoperative medications compared to preoperative levels.

In clinical practice, IOP responses after cataract surgery can vary widely, even among patients with the same type of glaucoma.[25] Several previous studies demonstrated that lens extraction by phacoemulsification provides satisfactory IOP reduction in patients with primary angle-closure glaucoma (PACG) and poorly controlled IOP.[23,26-28] In eyes with PACG, cataract surgery has been shown to deepen and widen the anterior chamber postoperatively compared to preoperatively, resulting in a decrease in IOP.[29] Studies have also demonstrated that cataract surgery reduces IOP in POAG patients.[11,25] However, the mechanism underlying this decline in IOP is not entirely clear. In one study it was reported that lens removal resulted in contraction of the lens capsule and traction on the ciliary body via the zonules, leading to a reduction in aqueous humour production and consequent decrease in IOP.[30] In another study, it was reported that changes in postoperative IOP after cataract surgery may be associated with changes in aqueous humour dynamics and the blood-aqueous barrier.[31] Yet another report stated that the increase in the width and depth of the anterior chamber angle after lens removal was observed not only in patients with angle closure but also in patients with open-angle glaucoma, and that this increased aqueous outflow.[32] Kim et al.[25] reported in their study that lens removal may have caused the anterior chamber angle to widen, creating more space for aqueous to pass into the trabecular network. They observed that in PACG patients with a preoperative peak IOP less than 42 mmHg, less than 3 antiglaucoma medications, and less than 4 clock hours of peripheral anterior synechiae, IOP was reduced by -2.5±2.0 mmHg at last postoperative follow-up (36 months), while POAG patients with a preoperative peak IOP less than 31 mmHg and less than 3 antiglaucoma medications showed a reduction of -1.7±2.1 mmHg.[25] The authors stated that cataract surgery did not provide a significant change in the number of postoperative medications in POAG patients meeting these criteria, but that cataract surgery alone was effective in controlling IOP in these patients.[25] In our study, similar to the study by Kim et al.[25], there was no significant decrease in number of antiglaucoma medications postoperatively. The reason for the greater IOP decrease in our study compared to the results of Kim et al.[25] may be that our mean follow-up period was less than 36 months. Because few patients had a postoperative follow-up period of 36 months or more, we did not perform a separate analysis of IOP lowering at 3 years. Ongoing follow-up with our patients will allow us to obtain more information about this. Although post-cataract surgery IOP lowering was previously shown to be greater in PACG patients than POAG patients[23], in our study we noted that POAG patients also had a significant IOP reduction after cataract surgery, similar to PACG patients.

In patients with concomitant glaucoma and cataract, performing glaucoma surgery first can significantly lower IOP but may cause more rapid cataract progression.[33] Cataract surgery performed after glaucoma surgery may impact the functioning of the existing filtration bleb, resulting in an increase in IOP.[34,35] Combined cataract and glaucoma surgery reduces the number of surgeries performed, but may be less effective in maintaining the filtration bleb and reducing IOP compared to filtration surgery alone.[36-38] Cataract surgery is generally safer than glaucoma surgery, immediately improves vision, and reduces IOP to a certain extent. Therefore, it may be an effective surgical option in many patients. In our study, there were 5 patients with preoperative IOP ≥ 21 mmHg and 3 or more antiglaucoma medications. We opted to perform cataract surgery alone before glaucoma surgery in these patients because they had dense cataract that made fundus examination difficult. We believe this approach is beneficial because it avoids the high complication risk of combined surgery, and viewing the fundus after glaucoma surgery is important in the follow-up of complications such as serous choroidal detachment[39], suprachoroidal hemorrhage[39], and hypotony maculopathy[39]. We think that primary cataract surgery alone can be considered as an early treatment option in POAG patients with dense cataracts.

A limitation of our study is its retrospective design. Another limitation is that we were not able to create a separate control group consisting of patients with PACG. In addition, comparing preoperative and postoperative measurements based on parameters such as lens thickness, anterior chamber depth, and anterior chamber angle may have allowed us to better interpret the changes in anterior segment anatomy and the mechanism of IOP reduction associated with lens removal. Finally, if the number of our patients were more, it would be possible to evaluate patients according to their glaucoma stages.

However, we evaluated a specific patient group by conducting this study exclusively with medically treated POAG patients, not all open-angle glaucoma patients, and analyzed them according to preoperative IOP range, and for this reason we believe that our results may serve as a guide for clinicians to predict the decrease in postoperative IOP when planning cataract surgery for patients with POAG.

In conclusion, phacoemulsification with IOL implantation in medically-treated POAG patients can lower IOP by an average of 10 mmHg in eyes with a preoperative IOP of 21 mmHg or higher, while the decrease is much smaller in eyes with a preoperative IOP level of 15 mmHg or lower. Although the significant reduction in preoperative IOP persisted at postoperative 3 years, it was less pronounced than in the earlier postoperative period (6 months).

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