Original Article

Impact of phacoemulsification with posterior chamber intraocular lens implantation on intraocular pressure and retinal structural parameters in pseudoexfoliation glaucoma and primary open-angle glaucoma

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ABSTRACT

Background: Glaucoma, a leading cause of irreversible blindness, is increasingly prevalent, with pseudoexfoliation glaucoma (PEXG) presenting more severe optic nerve damage than primary open-angle glaucoma (POAG). Phacoemulsification reduces intraocular pressure (IOP), especially in PEXG; however, its effects on retinal structure remain unclear. This study compared the effects of IOP reduction post-phacoemulsification on the ganglion cell complex (GCC) in eyes with PEXG and cataract, POAG and cataract, and cataract alone over 12 months.

Methods: This prospective, quasi-experimental study included age- and axial length-matched patients with PEXG, POAG, or cataract alone undergoing standardized phacoemulsification with posterior chamber intraocular lens (PCIOL) implantation by a single surgeon using consistent techniques. Comprehensive ophthalmic assessments and spectral-domain optical coherence tomography imaging were performed preoperatively and at 3, 6, and 12 months postoperatively. Outcome measures included IOP, GCC thickness, retinal nerve fiber layer (RNFL) thickness, and vertical cup-to-disc ratio (CDR).

Results: Ninety eyes (30 per group) were analyzed. The mean (standard deviation [SD]) ages were 57.8 (5.8) years in the PEXG group, 58.0 (6.3) years in the POAG group, and 56.2 (4.6) years in the control group. There were 14 men (46.7%) and 16 women (53.3%) in both the PEXG and POAG groups, and 12 men (40.0%) and 18 women (60.0%) in the control group. The mean (SD) axial lengths were statistically similar at 23.9 (1.2) mm in the PEXG group, 23.9 (1.8) mm in the POAG group, and 23.8 (1.2) mm in the control group. Preoperatively, the PEXG group displayed higher IOP and thinner RNFL, whereas the POAG group featured thinner GCC and greater vertical CDR. Phacoemulsification significantly reduced IOP in both glaucoma groups (both $P < 0.05$), with a greater reduction in PEXG. However, no significant postoperative changes were observed in GCC thickness, RNFL thickness, or vertical CDR within any group (all $P > 0.05$). Despite this, intergroup differences in GCC, RNFL, and vertical CDR persisted at all follow-up points (all $P < 0.05$), although the PEXG and POAG groups did not significantly differ from each other ($P > 0.05$).

Conclusions: Phacoemulsification with PCIOL implantation significantly reduced IOP in eyes with PEXG and POAG, with a greater reduction observed in PEXG. However, this IOP reduction did not translate into significant changes in GCC thickness, RNFL thickness, or vertical CDR over 12 months. These findings suggest that although cataract surgery offers IOP-lowering benefits in early-stage glaucoma, it may not influence short-term structural progression, highlighting the need for ongoing postoperative monitoring and adjunctive management in glaucomatous eyes.

KEYWORDS

pseudo-exfoliation syndrome, exfoliation glaucoma, primary open angle glaucoma, cataracts, cataract extractions, retinal ganglion cell, nerve fiber, optic nerve head, intraocular pressures

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How to cite this article: Abdelghany AA, Sallam MA. Impact of phacoemulsification with posterior chamber intraocular lens implantation on intraocular pressure and retinal structural parameters in pseudoexfoliation glaucoma and primary open-angle glaucoma. Med Hypothesis Discov Innov Optom. 2025 Spring; 6(1): 22-28. DOI: https://doi.org/10.51329/mehdioptometry218.

Received: 11 February 2025; Accepted: 28 April 2025

INTRODUCTION

Glaucoma remains one of the leading causes of irreversible blindness worldwide. With aging of the global population, the number of individuals affected by glaucoma is expected to rise to approximately 112 million by 2040 [1]. Pseudoexfoliation syndrome (PEX) is a systemic disorder with predominant ocular manifestations. It is characterized by progressive accumulation of granular, amyloid-like fibrillar material in various intraocular structures [2, 3]. PEX is believed to have a primary and possibly genetic etiology, leading to the development of glaucoma—pseudoexfoliation glaucoma (PEXG)—in approximately 15–30% of affected individuals [4]. PEXG is distinguished by excessive production and deposition of elastin fibers, which contributes to increased intraocular pressure (IOP) and more pronounced optic nerve damage compared to that of other glaucoma subtypes [3].

Spectral-domain optical coherence tomography (SD-OCT) enables high-resolution, quantitative assessment of retinal layers affected by glaucoma, particularly the ganglion cell complex (GCC) [5-9]. Compared to eyes with primary open-angle glaucoma (POAG), eyes with PEXG exhibit significantly lower peripapillary and macular vessel density, along with greater reductions in perfused capillary density, despite comparable levels of structural glaucomatous damage [10-13]. Interestingly, the prevalence of choroidal microvasculature dropout appears to be lower in PEXG than in POAG [14].

Phacoemulsification cataract surgery with implantation of a posterior chamber intraocular lens (PCIOL) can significantly lower IOP in glaucoma patients, with a greater IOP reduction observed in PEXG than in POAG [15]. Nevertheless, data remain limited regarding the differential impact of IOP reduction after phacoemulsification on retinal structural parameters—specifically GCC, retinal nerve fiber layer (RNFL), and optic nerve head morphology—in PEXG versus POAG.

In this study, we compared the effects of IOP reduction following phacoemulsification on the progression of GCC thinning in eyes with PEXG and cataract, POAG and cataract, and cataract alone. Longitudinal changes in GCC thickness, RNFL thickness, and vertical cup-to-disc ratio (CDR) were assessed throughout a follow-up period of 12 months.

METHODS

This prospective quasi-experimental study consecutively recruited eyes undergoing uneventful phacoemulsification cataract surgery with PCIOL implantation who attended the outpatient ophthalmology clinic of Suez Canal University Hospital between January 2015 and December 2017. The study was approved by the Research Ethics Committee of the Faculty of Medicine, Suez Canal University, and was conducted in accordance with the tenets of the Declaration of Helsinki. Written informed consent was obtained from all participants before enrollment.

The study included individuals aged 50–65 years with senile cataract scheduled for phacoemulsification and PCIOL implantation, with equal numbers allocated to three groups: (1) eyes with PEXG, (2) eyes with POAG, and (3) eyes without glaucoma. All glaucoma patients were selected at the same stage of disease—defined as mild glaucomatous damage with a mean deviation (MD) not worse than −6.00 dB—based on a reliable full threshold 30-2 standard automated perimetry printout (Humphrey Field Analyzer, Carl Zeiss Meditec, Dublin, CA, USA) [16]. The three groups were matched for age and axial length to minimize potential confounding variables. All patients with PEXG or POAG were under dual antiglaucoma therapy, either dorzolamide 2% combined with timolol 0.5%, or travoprost 0.004% combined with timolol 0.5%. We excluded individuals younger than 50 years; aphakic eyes; eyes with other forms of glaucoma such as primary or secondary angle-closure glaucoma, pigmentary glaucoma, inflammatory glaucoma, neovascular glaucoma, red cell glaucoma, or angle recession glaucoma; and those with prior ocular surgery, the presence of pseudoexfoliation without glaucoma, and end-stage glaucoma.

All participants underwent a comprehensive preoperative ophthalmic evaluation, including measurement of uncorrected and best-corrected distance visual acuity, IOP assessment using Goldmann applanation tonometry (Haag-Streit, Koniz, Switzerland), and biometry. Central anterior chamber depth and axial length were measured using contact A-scan biometry with the EZ Scan AB5500+ (Sonomed Inc., Lake Success, NY, USA). A detailed undilated anterior segment examination was performed with a slit-lamp biomicroscope (SL-D7; Topcon Corp., Tokyo, Japan) with gonioscopic evaluation using a Goldmann three-mirror lens (Volk Optical, Inc., Mentor, OH, USA) to assess the angle structures. This was followed by a dilated examination under maximal mydriasis, achieved using topical 1% tropicamide (Mydriacyl®; Alcon Laboratories Inc., Fort Worth, TX, USA) and 2.5% phenylephrine hydrochloride (Bausch & Lomb, Laval, Canada), for the detection of pseudoexfoliative material. Dilated fundus examination was conducted using a non-contact condensing lens at the slit lamp to evaluate the optic nerve head and posterior segment.

SD-OCT (Optovue Avanti Widefield SD-OCT, Version 0.9.3; Fremont, CA, USA) was used to evaluate GCC thickness using a 3D volumetric scan (7.0 × 7.0 mm cube – 512 × 128 data points), RNFL thickness using a 3D volumetric scan (6.0 × 6.0 mm cube – 512 × 256 data points), and vertical CDR.

All patients underwent phacoemulsification cataract surgery with PCIOL implantation (AcrySof IQ; Alcon Laboratories), performed by a single experienced surgeon (M.A.S.) using the same phacoemulsification system (Whitestar Signature System; Abbott Medical Optics Inc., Santa Ana, CA, USA). A standardized surgical approach was used through a 2.2-mm temporal clear corneal incision, following an established phacoemulsification protocol [17]. Postoperatively, all eyes received topical ofloxacin 0.3% ophthalmic solution (Ocuflox®; Alcon Laboratories) five times daily for 4 weeks and prednisolone acetate 1% ophthalmic suspension (Prednefrin®; AbbVie Inc., North Chicago, IL, USA) five times daily, which was tapered weekly over a 4-week period.

The primary outcome measures included IOP, GCC thickness, RNFL thickness, and vertical CDR, assessed preoperatively and at 3, 6, and 12 months postoperatively. Statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS), Version 20.0 (IBM Corp., Armonk, NY, USA). The Kolmogorov–Smirnov test was used to assess the normality of data distribution. Continuous variables are summarized as means (standard deviations [SDs]), whereas categorical variables are presented as frequencies (percentages). Intragroup and intergroup comparisons of continuous variables over time were conducted using one-way analysis of variance (ANOVA). When ANOVA indicated statistical significance, post hoc pairwise comparisons were performed using Tukey's honestly significant difference (HSD) test. A *P*-value < 0.05 was considered statistically significant. Line graphs were generated to illustrate longitudinal trends in the primary outcome measures across the study groups.

RESULTS

A total of 90 individuals were included, with 30 participants in each of the three age-matched groups: (1) eyes with PEXG, (2) eyes with POAG, and (3) eyes with senile cataract without glaucoma (control group). The mean (SD) ages were 57.8 (5.8) years in the PEXG group, 58.0 (6.3) years in the POAG group, and 56.2 (4.6) years in the control group. There were 14 men (46.7%) and 16 women (53.3%) in both the PEXG and POAG groups, and 12 men (40.0%) and 18 women (60.0%) in the control group. The mean (SD) axial lengths were statistically similar at 23.9 (1.2) mm in the PEXG group, 23.9 (1.8) mm in the POAG group, and 23.8 (1.2) mm in the control group. The mean (SD) durations of glaucoma from the time of diagnosis were 3.4 (0.4) years for the PEXG group and 3.7 (0.5) years for the POAG group.

Preoperatively, the PEXG group demonstrated significantly higher mean IOP and thinner RNFL than both the POAG and control groups. In contrast, the POAG group exhibited significantly thinner GCC and a greater vertical CDR than the PEXG and control groups (Table 1).

Table 1. Comparison of IOP, GCC thickness, RNFL thickness, and vertical CDR among study groups, at baseline and across visits, during postoperative follow-up after cataract extraction with PCIOL implantation

Outcome measures	PEXG Group	POAG Group	Control Group	[1] *P*-value
Magnitude of IOP reduction (mmHg), Mean ± SD				
Preoperative	28.2 ± 2.7	26.7 ± 2.0	17.5 ± 1.8	**< 0.001**
At 3 months	20.0 ± 2.6 [2] ***P* < 0.001**	23.6 ± 2.0 [2] ***P* < 0.024**	14.9 ± 1.5	**< 0.001**
At 6 months	19.6 ± 2.5 [2] ***P* < 0.001**	22.8 ± 1.8 [2] ***P* < 0.036**	15.1 ± 1.5	**0.014**
At 12 months	19.0 ± 2.4 [2] ***P* < 0.001**	22.1 ± 1.1 [2] ***P* < 0.038**	15.07 ± 1.5	**0.021**
[1] *P*-value	**< 0.001**[a]	**< 0.001**[a]	0.052[a]	
GCC thickness changes over time (µm), Mean ± SD				
Preoperative	83.7 ± 13.7	80.6 ± 11.3	108.4 ± 5.3	**< 0.001**
At 3 months	83.5 ± 13.9	80.1 ± 11.7	108.4 ± 5.4	**< 0.001**
At 6 months	81.6 ± 13.5	79.6 ± 11.9	108.0 ± 5.4	**< 0.001**
At 12 months	81.5 ± 13.5	79.6 ± 12.0	107.5 ± 5.5	**< 0.001**
[1] *P*-value	0.447	0.571	0.229	
RNFL thickness changes over time (µm), Mean ± SD				
Preoperative	90.6 ± 22.2	91.4 ± 17.8	108.3 ± 6.8	**< 0.001**
At 3 months	91.2 ± 22.7	89.6 ± 18.5	108.4 ± 6.7	**< 0.001**
At 6 months	91.6 ± 23.7	88.6 ± 17.7	107.8 ± 6.8	**< 0.001**
At 12 months	86.3 ± 22.9	81.4 ± 16.0	106.7 ± 17.5	**< 0.001**
[1] *P*-value	0.337	0.348	0.271	
Vertical CDR changes over time(ratio), Mean ± SD				
Preoperative	0.6 ± 0.3	0.7 ± 0.2	0.4 ± 0.2	**< 0.001**
At 3 months	0.6 ± 0.3	0.7 ± 0.2	0.4 ± 0.2	**< 0.001**
At 6 months	0.6 ± 0.3	0.7 ± 0.2	0.4 ± 0.2	**< 0.001**
At 12 months	0.7 ± 0.3	0.8 ± 0.2	0.4 ± 0.2	**< 0.001**
[1] *P*-value	0.294	0.747	0.528	

Abbreviations: IOP, intraocular pressure; GCC, ganglion cell complex; RNFL, retinal nerve fiber layer; CDR, cup-to-disc ratio; PCIOL, posterior chamber intraocular lens; PEXG, pseudoexfoliation glaucoma; POAG, primary open-angle glaucoma; mmHg, millimeters of mercury; SD, standard deviation; µm, micrometer. Note: *P*-values < 0.05 are shown in bold; [1] *P*-value, *P*-value derived from one-way analysis of variance (ANOVA); [2] *P*-value, *P*-value derived from Post-hoc analysis: Tukey's honestly significant difference (HSD) test.

As shown in Figure 1A and Table 1, cataract extraction with PCIOL implantation significantly reduced mean IOP throughout the postoperative follow-up period in both the PEXG and POAG groups (both $P < 0.05$), but not in the control group ($P > 0.05$). Pairwise comparisons between follow-up time points confirmed the significance of IOP reduction in the PEXG and POAG groups (all $P < 0.05$). Importantly, mean IOP remained significantly different between the three groups at all follow-up visits (all $P < 0.05$), with greater IOP reduction in the PEXG group than in the POAG group.

Changes in GCC thickness over time are presented in Figure 1B and Table 1. There were no statistically significant changes in GCC thickness within any group throughout the follow-up period (all $P > 0.05$), indicating that postoperative IOP reduction did not significantly affect the progression of GCC thinning. Nonetheless, GCC thickness differed significantly between the three groups at each follow-up visit (all $P < 0.05$), although no significant differences were observed between the PEXG and POAG groups ($P > 0.05$).

Similarly, RNFL thickness remained stable within each group throughout the follow-up period (Figure 1C and Table 1), with no statistically significant intragroup changes (all $P > 0.05$). These findings suggest that IOP reduction had no significant effect on the rate of RNFL thinning. However, significant intergroup differences in RNFL thickness were observed at each visit (all $P < 0.05$), although no significant differences were noted between the PEXG and POAG groups ($P > 0.05$).

Figure 1D and Table 1 depict changes in vertical CDR over time. No statistically significant changes in vertical CDR were observed within any group throughout the follow-up period (all $P > 0.05$), suggesting that IOP reduction did not significantly alter the rate of optic disc cupping. Nevertheless, vertical CDR values differed significantly between the three groups at each time point (all $P < 0.05$).

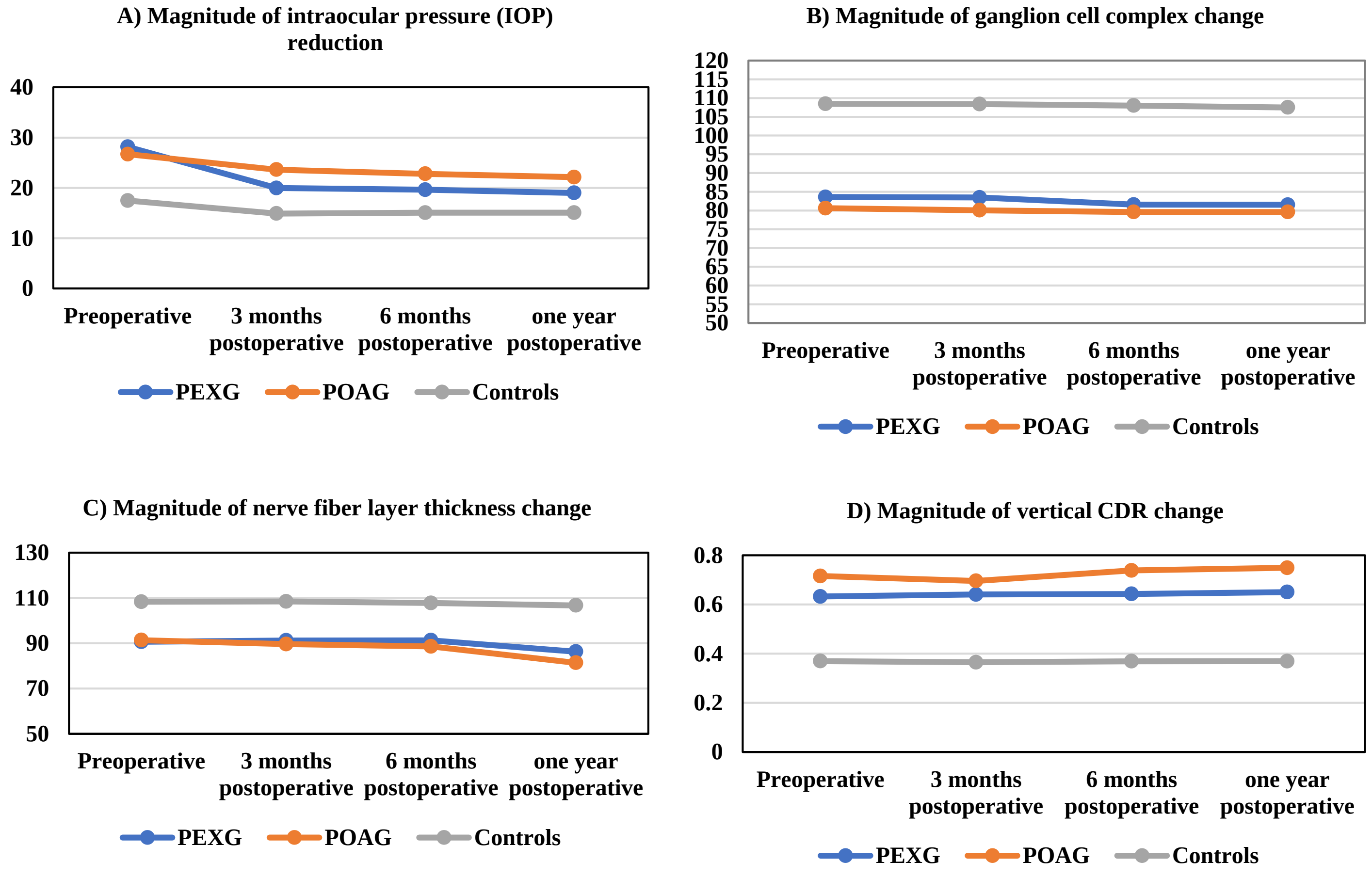

Figure 1. Postoperative changes in (A) intraocular pressure (IOP), (B) ganglion cell complex (GCC) thickness, (C) retinal nerve fiber layer (RNFL) thickness, and (D) vertical cup-to-disc ratio (CDR) following cataract extraction with PCIOL implantation in the pseudoexfoliative glaucoma (PEXG), primary open-angle glaucoma (POAG), and control groups. Note: Error bars represent standard deviations. Statistical comparisons were conducted using one-way analysis of variance (ANOVA) with post-hoc analysis: Tukey's honestly significant difference (HSD) test for pairwise group comparisons. (A) Mean IOP significantly decreased from baseline in both PEXG and POAG groups throughout the postoperative follow-up period (both $P < 0.05$), with greater reduction in the PEXG group. No significant change was noted in the control group ($P > 0.05$). (B) No significant change in mean GCC thickness was observed within any group across the follow-up period (all $P > 0.05$), although significant intergroup differences in GCC thickness were evident at each time point (all $P < 0.05$). (C) RNFL thickness remained stable within each group across follow-up visits (all $P > 0.05$), with significant differences detected between the three groups at each time point (all $P < 0.05$). (D) Vertical CDR showed no significant change within each group across follow-up visits (all $P > 0.05$), whereas significant intergroup differences persisted at all follow-up visits (all $P < 0.05$).

DISSCUSSION

Our study compared the effects of phacoemulsification and PCIOL implantation on glaucoma control in patients with both cataract and glaucoma (either PEXG or POAG) and those with cataract only, in terms of GCC thickness, RNFL thickness, and vertical CDR. At the end of follow-up, the amount of IOP reduction after cataract surgery was lowest in the control group without glaucoma, intermediate in the POAG group, and greatest in the PEXG group. Other outcome measures remained comparable to baseline values in each group.

Recently, there has been a widely accepted concept that cataract surgery alone can be performed for IOP reduction in eyes affected by both cataract and glaucoma [18, 19]. Phacoemulsification has several advantages for managing glaucoma, as it carries a low surgical risk, fast recovery, and better visual outcome, accompanied by a considerable IOP reduction and widening of the anterior chamber angle. In addition, preserving the conjunctiva and sclera maintains the anatomical integrity of the eye and decreases the risk of filtration failure in subsequent glaucoma surgeries [18]. Our participants with coexisting POAG or PEXG experienced a significant reduction in IOP throughout the 12-month follow-up.

Cataract surgery significantly reduces IOP in patients with POAG [20-22]. Phacoemulsification with PCIOL implantation has significantly reduced IOP and antiglaucoma medication burden in patients with medically controlled POAG over a mean follow-up of 16.4 months [23]. These outcomes verified that IOP reduction after cataract surgery is a function of the baseline IOP (i.e., the greater the baseline IOP, the greater the postoperative IOP reduction) [21, 24].

The mechanism of IOP reduction after phacoemulsification in patients with POAG remains unclear [25]. However, Wang et al. suggested that the ultrasound energy provokes IOP reduction by decreasing the glaucoma-induced stress response in the trabecular meshwork. The ultrasonic vibrations stimulate production of interleukins and tissue necrosis factor by the trabecular cells, activating the synthesis of matrix metalloproteinases and enzymes that catalyze remodeling of tissues. This reduces extracellular matrix resistance, leading to an increase in the outflow facility [26]. Other mechanisms include reduced aqueous humor secretion and changes in the blood–aqueous barrier [25]. In addition, increased traction on the zonules during cataract surgery might improve the patency of the trabecular meshwork [27]. The current study found a significant IOP reduction in eyes with senile cataract and coexisting primary or secondary open-angle glaucoma after cataract extraction with PCIOL implantation.

Among our study groups, the magnitude of IOP reduction after cataract surgery was greatest in patients with PEXG. This conforms to the findings of Shingleton et al. [28], who concluded that eyes with pseudoexfoliation experienced significantly greater IOP reduction following bilateral phacoemulsification than the fellow eyes without pseudoexfoliation. They also reported stable and sustained control of IOP following phacoemulsification in patients having pseudoexfoliation with and without glaucoma [28]. Additionally, the role of phacoemulsification in moderate IOP reduction in patients with PEXG has been reported [29]. This may be due to viscodissection and washing out of the pseudoexfoliative material from the anterior chamber angle, which reduces the outflow resistance [30].

Kung et al. recommended reassessment of the optic nerve and visual field after cataract surgery [31]. Macular GCC thickness has been considered an important parameter in assessing vision-related quality of life in glaucoma patients, as it assists in early detection and management of eyes with glaucoma as well as suspected glaucoma [32, 33]. In the present study, the mean RNFL thickness and mean GCC thickness were unchanged at 3 months postoperatively compared to the baseline values, but their mean values were slightly reduced at 6 months and 1 year. However, these changes remained non-significant until the end of follow-up. The vertical CDRs remained comparable in eyes having PEXG, POAG, and no glaucoma throughout the 1-year postoperative follow-up.

Roh et al. reported that the mean macular ganglion cell-inner plexiform layer (mGC-IPL) thickness was greater than the preoperative value at 1 and 3 months following cataract surgery in both normal and glaucomatous eyes [34]. Sari et al. reported that mGC-IPL thickness significantly increased through the first month after cataract surgery and returned to preoperative values after 3 months [35]. The authors suggested that surgically induced inflammation may affect ganglion cells, resulting in a potential postoperative increase in mGC-IPL thickness. Another possible explanation for the increase in mGC-IPL thickness after cataract surgery is a preoperative measurement error resulting from low signal strength attributable to the cataract itself [36]. Accordingly, in our study, RNFL and GCC thicknesses were measured at 3 months postoperatively to exclude causes other than glaucoma that may affect GCC thickness. The longer follow-up in our study revealed additional losses in RNFL and GCC below the baseline values at the end of the first postoperative year. These losses, however, were not statistically significant. Roh et al. [34] noted an increase in GCC thickness, attributing this to certain limitations of their study, such as a small sample size and a short follow-up period [34]. In our study, the GCC and RNFL thicknesses were statistically similar in the PEXG and POAG groups. Using scanning laser polarimetry, Kozobolis et al. reported a significant reduction in RNFL thickness in eyes with PEX compared to healthy controls, whereas RNFL thicknesses were similar between eyes having POAG or PEXG with mild or advanced disease, indicating comparable structural damage profiles [37].

The strengths of this study include its prospective design, well-matched groups, and standardized surgical technique performed by a single surgeon, minimizing confounding variables. However, limitations include the relatively short follow-up duration and the focus on early-stage glaucoma, which may limit generalizability to those with more advanced disease. Additionally, structural outcomes were not complemented with functional visual field assessments. Further research should incorporate longer follow-up periods, broader glaucoma severity spectra, multimodal imaging, and functional evaluations to better elucidate the long-term structural and functional impact of IOP reduction after cataract surgery in glaucomatous eyes.

CONCLUSIONS

Phacoemulsification with PCIOL implantation yielded a significant and sustained IOP reduction in eyes with PEXG or POAG, demonstrating a more pronounced effect in the PEXG group. Despite this meaningful IOP reduction, no significant changes were detected in GCC thickness, RNFL thickness, or vertical CDR over a 12-month follow-up, suggesting that cataract surgery alone may not influence early structural progression in eyes with mild glaucomatous changes. These findings underscore the effectiveness of phacoemulsification as an IOP-lowering strategy in glaucoma management, particularly in PEXG, and they also highlight the need for continued postoperative glaucoma surveillance. Further studies with longer follow-up durations, larger sample sizes, and adjunctive functional assessments are warranted to verify our preliminary findings.

ETHICAL DECLARATIONS

Ethical approval: The study was approved by the Research Ethics Committee of the Faculty of Medicine, Suez Canal University, and was conducted in accordance with the tenets of the Declaration of Helsinki. Written informed consent was obtained from all participants before enrollment.

Conflict of interests: None.

FUNDING

None.

ACKNOWLEDGMENTS

None.

REFERENCES

1. Tham YC, Li X, Wong TY, Quigley HA, Aung T, Cheng CY. Global prevalence of glaucoma and projections of glaucoma burden through 2040: a systematic review and meta-analysis. Ophthalmology. 2014 Nov;121(11):2081-90. doi: 10.1016/j.ophtha.2014.05.013. Epub 2014 Jun 26. PMID: 24974815.
2. Tekin K, Inanc M, Elgin U. Monitoring and management of the patient with pseudoexfoliation syndrome: current perspectives. Clin Ophthalmol. 2019 Mar 1;13:453-464. doi: 10.2147/OPTH.S181444. PMID: 30880906; PMCID: PMC6402616.
3. Tuteja S, Zeppieri M, Chawla H. Pseudoexfoliation Syndrome and Glaucoma. 2023 May 31. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2025 Jan–. PMID: 34662036.
4. Yüksel N, Yılmaz Tuğan B. Pseudoexfoliation Glaucoma: Clinical Presentation and Therapeutic Options. Turk J Ophthalmol. 2023 Aug 19;53(4):247-256. doi: 10.4274/tjo.galenos.2023.76300. PMID: 37602651; PMCID: PMC10442753.
5. Hwang JC, Konduru R, Zhang X, Tan O, Francis BA, Varma R, Sehi M, Greenfield DS, Sadda SR, Huang D. Relationship among visual field, blood flow, and neural structure measurements in glaucoma. Invest Ophthalmol Vis Sci. 2012 May 17;53(6):3020-6. doi: 10.1167/iovs.11-8552. PMID: 22447865; PMCID: PMC3378085.
6. Wheat JL, Rangaswamy NV, Harwerth RS. Correlating RNFL thickness by OCT with perimetric sensitivity in glaucoma patients. J Glaucoma. 2012 Feb;21(2):95-101. doi: 10.1097/IJG.0b013e31820bcfbe. PMID: 21336150; PMCID: PMC3636548.
7. Schuman JS. Spectral domain optical coherence tomography for glaucoma (an AOS thesis). Trans Am Ophthalmol Soc. 2008;106:426-58. PMID: 19277249; PMCID: PMC2646438.
8. Paunescu LA, Schuman JS, Price LL, Stark PC, Beaton S, Ishikawa H, Wollstein G, Fujimoto JG. Reproducibility of nerve fiber thickness, macular thickness, and optic nerve head measurements using StratusOCT. Invest Ophthalmol Vis Sci. 2004 Jun;45(6):1716-24. doi: 10.1167/iovs.03-0514. PMID: 15161831; PMCID: PMC1993821.
9. Vance SK, Khan S, Klancnik JM, Freund KB. Characteristic spectral-domain optical coherence tomography findings of multifocal choroiditis. Retina. 2011 Apr;31(4):717-23. doi: 10.1097/IAE.0b013e318203c1ef. PMID: 21386760.
10. Rebolleda G, Pérez-Sarriegui A, De Juan V, Ortiz-Toquero S, Muñoz-Negrete FJ. A comparison of two optical coherence tomography-angiography devices in pseudoexfoliation glaucoma versus primary open-angle glaucoma and healthy subjects. Eur J Ophthalmol. 2019 Nov;29(6):636-644. doi: 10.1177/1120672118805882. Epub 2018 Oct 14. PMID: 30318904.
11. Park JH, Yoo C, Girard MJA, Mari JM, Kim YY. Peripapillary Vessel Density in Glaucomatous Eyes: Comparison Between Pseudoexfoliation Glaucoma and Primary Open-angle Glaucoma. J Glaucoma. 2018 Nov;27(11):1009-1016. doi: 10.1097/IJG.0000000000001062. PMID: 30134370.
12. Philip S, Najafi A, Tantraworasin A, Chui TYP, Rosen RB, Ritch R. Macula Vessel Density and Foveal Avascular Zone Parameters in Exfoliation Glaucoma Compared to Primary Open-Angle Glaucoma. Invest Ophthalmol Vis Sci. 2019 Mar 1;60(4):1244-1253. doi: 10.1167/iovs.18-25986. PMID: 30924849; PMCID: PMC6440528.
13. Suwan Y, Geyman LS, Fard MA, Tantraworasin A, Chui TY, Rosen RB, Ritch R. Peripapillary Perfused Capillary Density in Exfoliation Syndrome and Exfoliation Glaucoma versus POAG and Healthy Controls: An OCTA Study. Asia Pac J Ophthalmol (Phila). 2018 Mar-Apr;7(2):84-89. doi: 10.22608/APO.2017318. Epub 2017 Nov 22. PMID: 29165935.

14. Pradhan ZS, Rao HL, Dixit S, Sreenivasaiah S, Reddy PG, Venugopal JP, Puttaiah NK, Devi S, Weinreb RN, Mansouri K, Webers CAB. Choroidal Microvascular Dropout in Pseudoexfoliation Glaucoma. Invest Ophthalmol Vis Sci. 2019 May 1;60(6):2146-2151. doi: 10.1167/iovs.19-26844. PMID: 31108546; PMCID: PMC6528839.

15. Merkur A, Damji KF, Mintsioulis G, Hodge WG. Intraocular pressure decrease after phacoemulsification in patients with pseudoexfoliation syndrome. J Cataract Refract Surg. 2001 Apr;27(4):528-32. doi: 10.1016/s0886-3350(00)00753-7. PMID: 11311618.

16. De Moraes CG, Liebmann JM, Levin LA. Detection and measurement of clinically meaningful visual field progression in clinical trials for glaucoma. Prog Retin Eye Res. 2017 Jan;56:107-147. doi: 10.1016/j.preteyeres.2016.10.001. Epub 2016 Oct 20. PMID: 27773767; PMCID: PMC5313392.

17. Gurnani B, Kaur K. Phacoemulsification. 2023 Jun 11. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2025 Jan–. PMID: 35015444.

18. Eid TM. Primary lens extraction for glaucoma management: A review article. Saudi J Ophthalmol. 2011 Oct;25(4):337-45. doi: 10.1016/j.sjopt.2011.07.004. Epub 2011 Jul 30. PMID: 23960947; PMCID: PMC3729315.

19. Ling JD, Bell NP. Role of Cataract Surgery in the Management of Glaucoma. Int Ophthalmol Clin. 2018 Summer;58(3):87-100. doi: 10.1097/IIO.0000000000000234. PMID: 29870412; PMCID: PMC5992498.

20. Shingleton BJ, Pasternack JJ, Hung JW, O'Donoghue MW. Three and five year changes in intraocular pressures after clear corneal phacoemulsification in open angle glaucoma patients, glaucoma suspects, and normal patients. J Glaucoma. 2006 Dec;15(6):494-8. doi: 10.1097/01.ijg.0000212294.31411.92. PMID: 17106361.

21. Poley BJ, Lindstrom RL, Samuelson TW. Long-term effects of phacoemulsification with intraocular lens implantation in normotensive and ocular hypertensive eyes. J Cataract Refract Surg. 2008 May;34(5):735-42. doi: 10.1016/j.jcrs.2007.12.045. PMID: 18471626.

22. Mathalone N, Hyams M, Neiman S, Buckman G, Hod Y, Geyer O. Long-term intraocular pressure control after clear corneal phacoemulsification in glaucoma patients. J Cataract Refract Surg. 2005 Mar;31(3):479-83. doi: 10.1016/j.jcrs.2004.06.046. PMID: 15811734.

23. Kim DD, Doyle JW, Smith MF. Intraocular pressure reduction following phacoemulsification cataract extraction with posterior chamber lens implantation in glaucoma patients. Ophthalmic Surg Lasers. 1999 Jan;30(1):37-40. PMID: 9923491.

24. Leelachaikul Y, Euswas A. Long-term intraocular pressure change after clear corneal phacoemulsification in Thai glaucoma patients. J Med Assoc Thai. 2005 Nov;88 Suppl 9:S21-5. PMID: 16681047.

25. Iancu R, Corbu C. Intraocular pressure after phacoemulsification in patients with uncontrolled primary open angle glaucoma. J Med Life. 2014 Mar 15;7(1):11-6. Epub 2014 Mar 25. PMID: 24653751; PMCID: PMC3956089.

26. Wang N, Chintala SK, Fini ME, Schuman JS. Ultrasound activates the TM ELAM-1/IL-1/NF-kappaB response: a potential mechanism for intraocular pressure reduction after phacoemulsification. Invest Ophthalmol Vis Sci. 2003 May;44(5):1977-81. doi: 10.1167/iovs.02-0631. PMID: 12714632; PMCID: PMC1950284.

27. Johnstone MA. The aqueous outflow system as a mechanical pump: evidence from examination of tissue and aqueous movement in human and non-human primates. J Glaucoma. 2004 Oct;13(5):421-38. doi: 10.1097/01.ijg.0000131757.63542.24. PMID: 15354083.

28. Shingleton BJ, Nguyen BK, Eagan EF, Nagao K, O'Donoghue MW. Outcomes of phacoemulsification in fellow eyes of patients with unilateral pseudoexfoliation: single-surgeon series. J Cataract Refract Surg. 2008 Feb;34(2):274-9. doi: 10.1016/j.jcrs.2007.09.040. PMID: 18242453.

29. Chen PP, Lin SC, Junk AK, Radhakrishnan S, Singh K, Chen TC. The Effect of Phacoemulsification on Intraocular Pressure in Glaucoma Patients: A Report by the American Academy of Ophthalmology. Ophthalmology. 2015 Jul;122(7):1294-307. doi: 10.1016/j.ophtha.2015.03.021. Epub 2015 May 2. PMID: 25943711.

30. Benekos K, Katsanos A, Laspas P, Vagiakis I, Haidich AB, Konstas AG. Intraocular Pressure Reduction Following Phacoemulsification in Patients with Exfoliation: A Systematic Review and Meta-Analysis. J Clin Med. 2024 Nov 11;13(22):6774. doi: 10.3390/jcm13226774. PMID: 39597918; PMCID: PMC11594855.

31. Kung JS, Choi DY, Cheema AS, Singh K. Cataract surgery in the glaucoma patient. Middle East Afr J Ophthalmol. 2015 Jan-Mar;22(1):10-7. doi: 10.4103/0974-9233.148343. PMID: 25624668; PMCID: PMC4302462.

32. Nishida T, Moghimi S, Mohammadzadeh V, Wu JH, Yamane MLM, Kamalipour A, Mahmoudinezhad G, Micheletti E, Liebmann JM, Fazio MA, Girkin CA, Zangwill LM, Weinreb RN. Association Between Ganglion Cell Complex Thinning and Vision-Related Quality of Life in Glaucoma. JAMA Ophthalmol. 2022 Aug 1;140(8):800-806. doi: 10.1001/jamaophthalmol.2022.2140. PMID: 35771529; PMCID: PMC9247856.

33. Rolle T, Briamonte C, Curto D, Grignolo FM. Ganglion cell complex and retinal nerve fiber layer measured by fourier-domain optical coherence tomography for early detection of structural damage in patients with preperimetric glaucoma. Clin Ophthalmol. 2011;5:961-9. doi: 10.2147/OPTH.S20249. Epub 2011 Jul 13. PMID: 21792286; PMCID: PMC3141860.

34. Roh HC, Park CY, Kim M. Changes of the Macular Ganglion Cell-Inner Plexiform Layer Thickness after Cataract Surgery in Glaucoma Patients. J Ophthalmol. 2016;2016:9785939. doi: 10.1155/2016/9785939. Epub 2016 Dec 22. PMID: 28101378; PMCID: PMC5214588.

35. Sari ES, Ermis SS, Yazici A, Koytak A, Sahin G, Kilic A. The effect of intracameral anesthesia on macular thickness and ganglion cell-inner plexiform layer thickness after uneventful phacoemulsification surgery: prospective and randomized controlled trial. Graefes Arch Clin Exp Ophthalmol. 2014 Mar;252(3):433-9. doi: 10.1007/s00417-013-2557-3. Epub 2014 Jan 5. PMID: 24390400.

36. Nakatani Y, Higashide T, Ohkubo S, Takeda H, Sugiyama K. Effect of cataract and its removal on ganglion cell complex thickness and peripapillary retinal nerve fiber layer thickness measurements by fourier-domain optical coherence tomography. J Glaucoma. 2013 Aug;22(6):447-55. doi: 10.1097/IJG.0b013e3182894a16. PMID: 23429634.

37. Kozobolis VP, Glynatsis M, Labiris G, Katsanos A, Fanariotis M, Koukoula S, Alvanos S, Toufexis G. Retinal nerve fiber layer thickness in patients with exfoliation, exfoliative glaucoma, and primary open angle glaucoma. Eur J Ophthalmol. 2010 Jan-Feb;20(1):142-8. doi: 10.1177/112067211002000120. PMID: 19882545.