• Clinical Research •

Effect of intraocular lens implantation on visual field in glaucoma and comorbid cataracts

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Abstract

● **AIM:** To investigate the effects of intraocular lens (IOL) implantation on visual field (VF) in patients with glaucoma and comorbid cataracts (G&C) with different disease severities.

● **METHODS:** Totally 56 eyes of 50 patients with primary G&C were included. All patients were divided into three groups based on the severity of the VF defect: the mild, moderate, and severe stage. Phacoemulsification was performed for cataract removal combined with IOL implantation. Visual acuity (VA) and VF tests were performed for all enrolled patients, up to 3mo after surgery. Changes in VF threshold and global VF index in various groups were also recorded before and after surgery. The mean light sensitivity (MS) values and the changes following surgery (DMS) were compared between the three groups. Advanced Glaucoma Intervention Study (AGIS) scoring was analyzed on all VF results for analysis of changes in VF before and after surgery.

● **RESULTS:** Following surgery, the MS values of the three groups of G&C increased significantly, while the AGIS scores decreased statistically in all groups. The DMS values for the three zones in moderate and severe stage but not mild stage were statistically different between zones. The DMS value was significantly higher in zone I than those in zone II and III (zone I>zone II>zone III; $P<0.05$). The DMS was significantly higher in zone I than that in zone III in moderate stage patients (zone I>zone II>zone III; $P<0.01$), while the DMS values in the severe stage patients was significantly higher in zone I than those in zone II and III (zone I>zone II>zone III; $P<0.01$).

● **CONCLUSION:** The mean VF sensitivity of glaucoma patients increased significantly after cataract removal and IOL implantation. Variations in the severity and distribution of characteristics of VF defects result in differences in postoperative VF improvements after cataract surgery. The magnitude of increase in VF sensitivity is associated with VF defect characteristic in glaucoma.

● **KEYWORDS:** cataract; intraocular lens; visual field; glaucoma

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INTRODUCTION

Cataracts are the leading cause of blindness in the world. The lens of cataract patients becomes turbid, which leads to reduction in light sensitive and visual acuity (VA). Visual field (VF) tests show a diffuse reduction in sensitivity and/or varying degrees of VF defect[1-2]. Glaucoma is irreversible, causing blindness and characteristic VF defects that are consistent with changes in intraocular pressure (IOP) and retinal structure, such as nasal step and arcuate scotoma. Therefore, VF tests are extremely important for the disease diagnosis and the resultant glaucoma patients[3]. The incidence of glaucoma and comorbid cataracts (G&C) will increase with age, which may lead to the discovery of more complex effects on VF by the two diseases[4]. Cataract surgery is a form of anti-glaucoma treatment and its use in glaucoma therapy is recognized and the

pattern of VF changes in glaucoma patients with intraocular lens (IOL) implantation is more difficult to determine[5-7]. Accordingly, the effects of IOL implantation on VF in patients with G&C deserve worldwide attention.

Cataract surgery can not only improve the visual quality, but also treat angle-closure glaucoma[8-10], and even control the IOP of open angle glaucoma to a certain extent[11-13]. The incidence of comorbid catatacts and glaucoma increases with age, and more and more glaucoma patients undergo IOL implantation[14-19]. In patients with G&C, general decrease in VF due to cataracts may cover the early VF loss in glaucoma[20]. Meanwhile, advanced glaucoma may present with a VF defect that is inconsistent with changes in IOP and the thickness of retinal never fiber layer[21-22]. How to distinguish the cataract-related VF damage from that of glaucoma is of great significance for the evaluation of the patients and the prediction of the consequences of postoperative surgical effects.

According to prior studies, cataract removal combined with implantation of an IOL can increase the mean light sensitivity (MS) of the VF and alleviate the reduction in sensitivity caused by cataracts[10,23-25]. This surgery also increases the overall VF sensitivity. However, the VF defects due to glaucoma become more significant and prominent, which assists in VF evaluation of patients with glaucoma[26-28]. The previous studies did not combine the glaucomatous and cataract-related VF variation characteristics to make a comprehensive analysis, therefore, only considering the global VF index (VFI%) change to assess the patient's VF and visual function is easy to cause misdiagnoses, especially for early stage glaucoma and reduction of the postoperative expectation of late stage glaucoma.

In this study, phacoemulsification and IOL implantation (Phaco+IOL) were performed on patients with G&C. To prevent decreased VF sensitivity attributed to a spherical IOL, an aspheric IOL was implanted during the surgery. A controlled study on VF before and 3mo after surgery was also conducted on the effects of the IOL on the accuracy of VF evaluation for glaucoma and the understanding of the VF changes after lens implantation in G&C patients with different disease severity.

SUBJECTS AND METHODS

Ethical Approval The design was an effectiveness study, retrospective and clinic-based. This study followed the tenets of the Helsinki Declaration on ethical principles for medical research involving human subjects and was approved by the Ethics Committee of Shandong Eye Hospital, Shandong Provincial Key Laboratory of Ophthalmology, China. The informed written consent was obtained from all patients prior to participation in the study after the nature of the study and the possible outcomes were disclosed.

Subjects Fifty patients (56 eyes) with a confirmed diagnosis of G&C in our hospital were included in this study from 2016 to 2018. The patients underwent cataract surgery. This included 27 patients (30 eyes) with chronic primary angle-closure glaucoma (CPACG) and 23 patients (26 eyes) with primary open angle glaucoma (POAG). The diagnostic criteria for these two forms of glaucoma were consistent with previous studies[29-30], including the presence of glaucomatous optic disc changes, such as increased cup-disc ratio, optic disc asymmetry, retinal nerve fiber layer injury and VF defect. The degree of angle opening was determined by ultrasound biological microscope (UBM, SW-3200L, SUOER electronic technology Co., Ltd., Tianjin, China) and Angle microscope (G-4, Volk, USA). All of the patients were on suitable medication or had surgery to maintain IOP at ≤21 mm Hg for more than 3mo and without new eye surgery history within 3mo. Patients were divided into groups according to the Advanced Glaucoma Intervention Study (AGIS) scores[31] as group A [mild stage; *n*=15 (18 eyes); AGIS score 1-5 points], group B [moderate stage; *n*=20 (22 eyes); AGIS score 6-11 points], and group C [severe stage; *n*=15 (16 eyes); AGIS score 12-18 points].

Examinations and Evaluation of the Visual Field All patients underwent a battery of tests that included VA, subjective refraction (RM-8000, Topcon, Japan), slit lamp (SL-D7, Topcon, Japan), ophthalmoscopy (SuperField NC, Volk, USA), IOP (Goldmann, Haag-Streit, CH), VF (Humphrey 750i, Carl Zeiss Meditec, CA, USA) and eye biometry before surgery and 3mo after surgery. VF testing was performed using the central 24-2 SITA-Fast program in the Humphrey perimeter 750i analyzer. MS, mean deviation (MD), and pattern standard deviation (PSD) at each spot were recorded. For each patient, the distances between the 52 test spots from the central fixation point in the VFs were measured, partitioned and numbered[10]. A total of three regions, the central region (0-5°, zone I), the paracentral region (6°-15°, zone II), and the peripheral region (16°-24°, zone III), were studied. A schematic for a representative right eye was shown and the same method was used to partition the left eye (Figure 1). The MS values of the three regions were calculated. All VF results with a fixation loss rate higher than 20%, a false positive rate and/or a false negative rate greater than 15% were deemed unreliable and removed. In addition, we performed AGIS scoring for the VF of the patients before and after surgery to evaluate more accurately their glaucoma status.

Methods All patients underwent Phaco+IOL by the same experienced surgeon. An aspheric IOL was implanted in all the surgeries. Levofloxacin eye drops (Santen pharmaceutical co., Ltd., Japan) were applied to the eye undergoing surgery once every 2h starting 1d before surgery. Proparacaine hydrochloride eye drops (Alcaine, Alcon NV, Belgium) were

Table 1 General patient information (50 patients)

Parameters	All affected eyes	Mild stage	Moderate stage	Severe stage	*P*
n	56	18	22	16	
Gender (M/F)	22/34	6/12	10/12	6/10	0.466
Age (y)	73.75±6.67	75.11±5.37	74.09±7.25	72.50±5.83	0.697
Eye (right/left)	26/30	8/10	10/12	8/8	0.649
Preop. BCVA (logMAR)	0.76±0.19	0.75±0.17	0.73±0.21	0.79±0.19	0.296

BCVA: Best-corrected visual acuity.

used for topical anesthesia. A 3.0-mm self-sealing transparent corneal incision was made at the 10:00 position and an auxiliary incision was performed at 2:00 position. Sodium hyaluronate viscoelastic agent was injected into the anterior chamber, followed by a 5.0-5.5 mm-diameter continuous curvilinear capsulorhexis. The nucleus was chopped using phacoemulsification (Stellaris, Bausch & Lomb.Inc, USA) for cataract removal. The posterior capsule was polished and the IOL implanted [Akreos Advanced Optic (AO); Bausch & Lomb, Inc., Rochester, New York, USA] in the capsular bag. Carbamglcholine chloride injection (Furuida Pharmaceutical, Co., Ltd., Shandong, China) and balanced salt solutions (BSS, Alcon, Texas, USA) were respectively used to narrow the pupil and form the anterior chamber. After surgery, tobramycin dexamethasone eye drops (TobraDex, Alcon, Belgium) were applied to the operated eye once every 2h and pranoprofen eyedrops (Pranopulin, Senju Pharmaceutical Co., Ltd., Japan) were administered 4 times daily. According to the changes of IOP after operation, the use of anti-glaucoma eye drops was adjusted appropriately based on the preoperative medication.

Statistical Analysis All quantitative data were expressed as mean±standard deviation. SPSS 19.0 statistics software (IBM Corporation, Armonk, NY, USA) was used for statistical analysis. Paired sample *t*-test, one-way analysis of variance (ANOVA) for randomized groups and the Student-Newman-Keuls test were used for intergroup comparisons. A difference of $P<0.05$ was considered statistically significant.

RESULTS

Patients' Characteristics and Changes of BCVA and Global Visual Field Index There were no significant differences in gender, age, type of eye, and preoperative BCVA among patients in groups A, B, and C (Table 1). The cataract surgeries were successful and no intraoperative complications occurred. The mean preoperative BCVA (logMAR) in patients with G&C was 0.76±0.19 before surgery and increased to 0.05±0.09 after surgery, being statistically significant (Table 2). The types of anti-glaucoma drugs decreased significantly after cataract surgery than before (1.28±0.53 *vs* 1.62±0.65, $P<0.01$). These results suggested that central vision was improved and IOP was reduced substantially after IOL implantation. The VFI% increased from 56.71±27.75 to 67.74±27.33, MDs decreased from -16.12±7.47 to -12.15±8.75 dB, and PSD increased from 7.47±3.32 to 8.10±3.93 dB; being statistically different in the three groups before and after the surgery (Table 2).

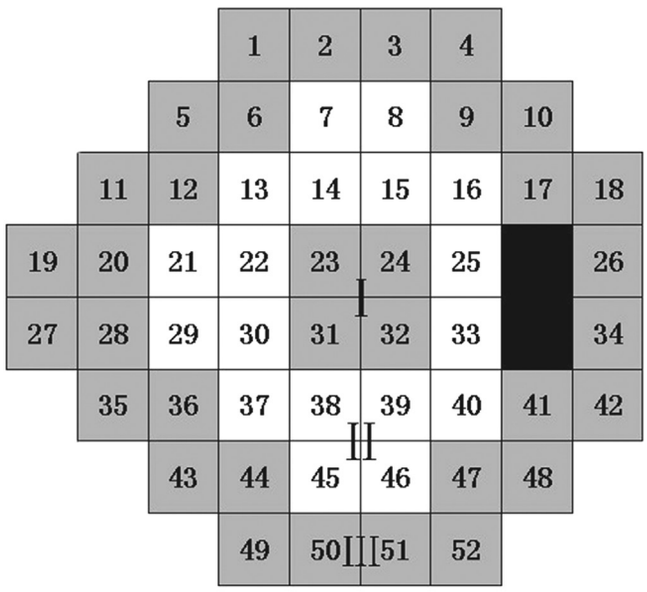

Figure 1 Schematic of the right visual field indicating numbering and clusters of 52 tests locations.

Table 2 BCVA and global visual field index before and after G&C surgery

Parameters	Before G&C surgery	After G&C surgery	*P*
BCVA (logMAR)	0.76±0.19	0.05±0.09	0.000
VFI%±SD	56.71±27.75	67.74±27.33	0.000
MD±SD	-16.12±7.47	-12.15±8.75	0.000
PSD±SD	7.47±3.32	8.10±3.93	0.048

G&C: Glaucoma and comorbid cataracts; VFI%: Visual field index; MD: Mean deviation; PSD: Pattern standard deviation; SD: Standard deviation.

AGIS Visual Field Defect Scores Decrease After G&C Surgery In addition, the postoperative AGIS scores were decreased significantly in all three groups, when compared to preoperative ones ($P<0.05$; AGIS decreased from 4.22±1.39 to 1.44±1.88 in group A, from 10.73±4.61 to 6.91±3.86 in group B, and from 18.25±1.75 to 14.63±1.77 in group C; Table 3).

Mean Light Sensitivity in the Three Zones Increases After Surgery The postoperative MS values of patients with G&C were increased significantly compared with pre-operative ones

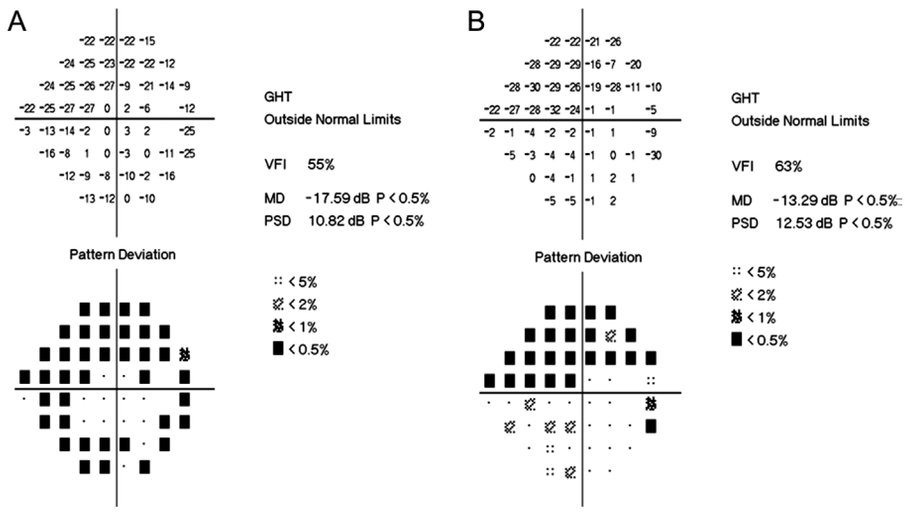

Figure 2 Comparison of visual pattern deviation and visual field index before and after surgery in a patient with G&C A: VF of a G&C patient before operation; B: VF of the same patient after operation. Comparison between preoperative VF and postoperative VF showed that the procedure improved sensitivity, increased MD, and elevated relative scotoma sensitivity. The upper arcuate scotoma VF defect, however, was still present and PSD increased. The arcuate scotoma appeared to be significant and prominent when compared to adjacent spots. VF: Visual field; MD: Mean deviation; PSD: Pattern standard deviation; G&C: Glaucoma and comorbid cataracts.

Table 3 AGIS visual field defect scores before and after G&C surgery

Parameters	Before G&C surgery	After G&C surgery	*P*
Mild stage (*n*=18)	4.22±1.39	1.44±1.88	0.003
Moderate stage (*n*=22)	10.73±4.61	6.91±3.86	0.000
Severe stage (*n*=16)	18.25±1.75	14.63±1.77	0.001
Total (*n*=56)	10.14±7.07	8.32±6.78	0.000

G&C: Glaucoma and comorbid cataracts; AGIS: Advanced Glaucoma Intervention Study.

(*P*<0.05). Among these MS scores, the values for the mild stage increased from 20.21±3.93 to 25.62±3.26 dB, those for the moderate stage increased from 14.13±4.48 to 18.99±4.56 dB, and those for the severe stage increased from 5.40±3.42 to 8.40±3.77 dB, all being statistically significant (Table 4). As shown in Figure 2, in the same patient, the preoperative VF showed an upper and lower arcuate VF defect, while the postoperative VF demonstrated a significant improvement in the general sensitivity due to cataract. Although MD was increased after surgery, relative dark point sensitivity was enhanced, and lower quadrant VF defect significantly improved compared with that before surgery, the VF defect of the superior arcuate caused by glaucoma still existed, and PSD was markedly elevated.

The postoperative MS values in the three zones in patients with G&C were significantly higher when compared with preoperative MS scores. The postoperative MS scores in the three zones at various stages of the disease were also significantly elevated when compared with preoperative ones (Table 5).

Table 4 Mean light sensitivity values before and after G&C surgery

Parameters	Before G&C surgery	After G&C surgery	*P*
Mild stage (*n*=18)	20.21±3.93	25.62±3.26	0.000
Moderate stage (*n*=22)	14.13±4.48	18.99±4.56	0.000
Severe stage (*n*=16)	5.40±3.42	8.40±3.77	0.000
Mean (*n*=56)	13.59±7.05	18.10±7.85	0.000

G&C: Glaucoma and comorbid cataracts.

Table 5 MS in three zones before and after surgery at different G&C stages

Stage	Zone	Preop.	Postop.	*P*
Mild (*n*=18)	I	24.19±3.68	30.67±1.68	0.000
	II	21.41±4.25	27.19±2.96	0.000
	III	18.96±4.02	24.01±3.86	0.000
Moderate (*n*=22)	I	21.11±4.07	26.30±4.68	0.000
	II	14.91±4.37	19.48±5.06	0.000
	III	12.91±5.06	17.74±4.82	0.000
Severe (*n*=16)	I	13.22±7.54	21.47±7.65	0.000
	II	6.37±4.22	10.13±4.06	0.000
	III	4.01±3.63	5.83±4.72	0.004
Total (*n*=56)	I	19.35±7.35	26.32±6.11	0.000
	II	14.56±7.25	19.29±7.87	0.000
	III	12.24±7.39	16.29±8.58	0.000

G&C: Glaucoma and comorbid cataracts; MS: Mean sensitivity.

Changes in MS Values Between the Three Zones Before and After Surgery Regarding the changes in pre- and postoperative MS values (DMS) in the three zones in patients with G&C, the DMS value was significantly higher in zone I

than those in zone II and III (zone I>zone II>zone III; $P<0.05$). However, the DMS values between zone II and III was not statistically different. No statistically significant differences were observed in the DMS values among the three zones in patients at the mild stage (zone I>zone II>zone III). Analysis of the DMS values in the three zones in patients at the moderate stage revealed that DMS was significantly higher in zone I than that in zone III (zone I>zone II>zone III; $P<0.01$), but not when DMS values in zone I and II or zones II and III was compared. Comparison of the DMS values in the three zones in severe stage patients indicated that the DMS was significantly higher in zone I than those in zone II and III (zone I>zone II>zone III; $P<0.01$). DMS in all of the G&C patients was statistically significant between zone I and II and between zone I and III, but not between zone II and III (Figure 3).

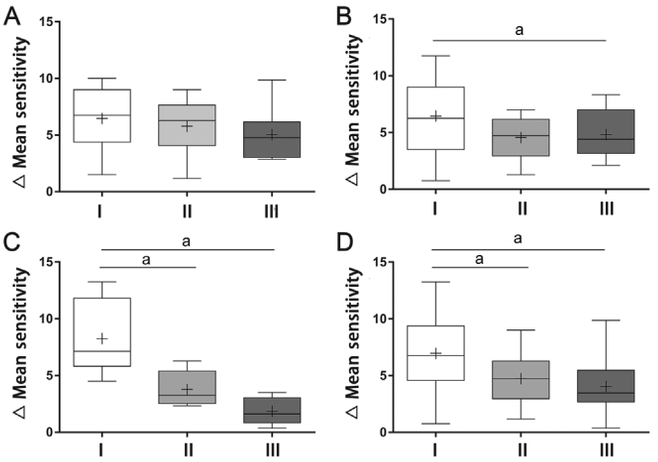

Figure 3 Changes in MS values before and after surgery A: In the mild stage group, no significant differences were noted in the DMS values among the three zones; B: In the moderate stage group, the differences were statistically significant between zone I and III, but not between zone I and II or between zone II and III; C: In the severe stage group, there were significant differences between zone I and II and between zone I and III, but not between zone II and III; D: In the total G&C group DMS values were statistically significant between zone I and II and between zone I and III, but not between zone II and III. Data from the three zones (I, II, III) in patients with mild, moderate, and severe G&C were compared using ANOVA and Student-Newman-Keuls test. [a]$P<0.01$.

DISCUSSION

Glaucoma and cataract are two diseases that cause different types of VF defects[32]. In patients with G&C, reduction in sensitivity caused by cataracts may mask VF defects in the mild stage glaucoma, while VF defects that are not consistent with changes in IOP or retinal anatomy may occur in the moderate and the severe stages[33]. Therefore, reduction in sensitivity caused by cataracts will cause difficulty in evaluating the glaucoma status in patients. How to accurately interpret the preoperative and postoperative VF results, distinguish the cataract-induced VF loss from the actual local VF defect of glaucoma and identify the relevant changes characteristic of postoperative VF in such patients is of great significance for the evaluation of glaucoma patients and the prediction of postoperative surgical effects. Therefore, it is important to understand the changes in VF and visual function in patients with G&C following surgery. In this study, the patients with G&C underwent Phaco+IOL surgery, and pre- and postoperative VF test results were examined for changes after implantation of IOL in patients with both diseases.

Previous studies showed that the elimination of the effects of cataracts caused the overall significantly increased VF sensitivity in glaucoma patients[26,34], while the original localized VF defects due to glaucoma became more significant and prominent. Our research demonstrated that Phaco+IOL surgery in patients with G&C resulted in significant increases in postoperative BCVA, VFI%, and MD, but caused a decrease in PSD, which is similar to some previous studies[10,29,35]. Importantly, cataract surgery combined with IOL implantation increased the sensitivity of relative scotomas to some extent. This reduced the localized VF defect caused by uneven turbidity of the lens. The overall VF sensitivity of glaucoma patients was greatly increased after the effects due to cataracts were eliminated, but the localized, irreversible VF defects due to glaucoma were still significant and prominent when compared to adjacent spots. Comparison of the MS in the three zones before and after surgery in G&C patients demonstrates that the MS values of the three zones in the mild, the moderate, and the severe stage groups increase significantly after surgery. Regardless of glaucoma stages, disease severity and type of VF defects, such as nasal steps at the mild stage, arcuate scotoma at the moderate stage, and tunnel vision in the severe stage, simple Phaco+IOL surgery increases the MS of patients as well. Even in the site of glaucoma VF defect, sensitivity can also be improved, mainly reflected in the improvement of relative scotoma sensitivity. Moreover, our study found that there were some <0 dB spots in the dB value figure for the severe stage glaucoma. The sensitivity of these spots was increased after surgery to become >0 dB relative scotomas. This can increase visual function to some extent and has significance for patients with the severe and the moderate-to-severe stage glaucoma.

Cataract surgery can recover the decline in sensitivity caused by a turbid lens, but the VF defects caused by glaucoma still maintain its special features and characteristics[36]. As shown in Figure 3, in mild stage of glaucoma in which the VF defect is relatively minor, there are no significant changes when compared with the central and peripheral VFs. In moderate stage glaucoma, significant defects often appear from the periphery. Following cataract surgery, the light sensitivities in

the central and paracentral zones were increased consistently. However, the improvement in sensitivity was significantly lower in the peripheral glaucomatous VF defect zones. In severe stage glaucoma, VF improvement after cataract surgery is significant in the central zone. However, the enhancement in light sensitivity at the paracentral and peripheral zones is lower due to severe glaucomatous VF damage[37-38].

In addition, the results showed that the AGIS scores of the eyes in mild, the moderate, and in the severe stage were all significantly decreased, indicating that although AGIS adopted a pattern-deviation probability map for glaucoma evaluation and calculations were used to remove the effects of turbid dioptric media as much as possible[39-40], the reduction in sensitivity caused by cataracts cannot be adequately eliminated, which should be noted during clinical evaluation of visual function in glaucoma. We also found that when the IOLs were implanted into the eyes with glaucoma after cataract surgery, their AGIS scores were significantly reduced. These data suggest that VF evaluation for glaucoma in G&C patients is still affected by cataracts. Cataract surgery can reduce this effect, leading to a more accurate determination of visual defects. This point must be considered when performing VF evaluation and follow-up analysis for glaucoma patients. Moreover, cataract surgery should be viewed as a turning point for the patient, and baseline VF measurements should be administered in a timely manner to accurately reflect the VF changes caused by glaucoma, rather than those caused by cataracts and dioptric media.

In summary, the mean VF sensitivity of glaucoma patients increased significantly after cataract removal and IOL implantation. Although VF sensitivity was improved in patients with mild, moderate, and severe glaucoma after implantation of IOL, variations in the severity and distribution of characteristics of VF defects resulted in differences in postoperative improvements after cataract surgery. The magnitude of increases in VF sensitivity is associated with different characteristics of VF defect and severity of glaucoma. Absolute scotoma can be converted into relative scotoma after cataract surgery in the severe stage of glaucoma, which could improve the visual function of the severe-stage patients.

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