

# Impact of binocular integrated visual field defects on healthy related quality of life in glaucoma

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## Abstract

To investigate the impact of different types of binocular integrated visual field defects on the quality of life in glaucoma.

Ninety-six patients with primary glaucoma were divided into 5 groups with 25, 24, 11, 15, and 21 patients according to types of the binocular integrated visual field (BVF) defects. The criteria for BVF grouping included mild visual field defect in binocular eyes, mild visual field defect in 1 eye and moderate or advanced defect in the other, moderate and non-overlapping visual field defect in both eyes, overlapping and moderate visual field defect in binocular eyes, and severe defect in both eyes, respectively. The visual field (VF) evaluation was based on H-P-A visual field grading system. Visual acuity, visual field tests and Glaucoma Quality of Life-15 Questionnaire (GQL-15) were performed for enrolled patients, and binocular visual field results were integrated. The changes and correlations of the Visual field index values and quality of life scores were compared among the 5 groups. The main factors affecting the quality of life in glaucoma were analyzed by multiple regression analysis.

The best binocular integrated visual field index (BVFI) and optimal quality of life were observed in group A. The BVFI of group B was better than that of group C or group D, but the peripheral vision glare and dark adaptation were worse. No significant difference was noted between group C and group D in terms of BVFI. However, the glare and dark adaptation in group C were better than that in group D. The BVFI was the lowest and the quality of life was the worst in group E. In all, BVFI and decibels (dB) values were negatively correlated with GQL-15 scores and positively correlated with patients' quality of life.

Binocular integrated visual field accurately reflects the visual function in glaucoma. Higher binocular integrated visual field indices represent a better quality of life for patients with glaucoma. Mild to moderate synchronous or complementary binocular VF defects had a slight effect on the quality of life, while severe and non-compensated VF loss significantly impacts on quality of life in glaucoma patients.

**Abbreviations:** BVF = binocular integrated visual field, BVFI = binocular integrated visual field index, GQL-15 = glaucoma quality of life 15 questionnaire, IOP = intraocular pressure, QOL = quality of Life, VA = visual acuity, VF = visual field, VFI = visual field index.

**Keywords:** cataracts, glaucoma, intraocular lens, visual field

## 1. Introduction

Glaucoma is the first irreversible blinding disease in the world, characterized by concave atrophy of optic disc and progressive visual field defect.<sup>[1–3]</sup> The incidence of glaucoma among people aged from 40 to 80 was 3.54% in the world populations. By

2020, 79.6 million people are estimated to suffer from glaucoma, alarmingly causing 11.2 million people blind, which seriously endanger human health.<sup>[4]</sup> In addition, the diagnosis of glaucoma, the subsequent medications and surgical treatments may result in serious social, economic and psychological burden.

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# CZ and JL contribute equally to this study.

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Furthermore, the progression of glaucoma may also lead to visual field and visual function deterioration and change patients' quality of life. As a psycho physiological disease, accurate assessment of the quality of life in glaucoma is of great significance to the patients and society.

Quality of Life (QOL) refers to the subjective experience of individuals in different cultures and value systems regarding their goals, expectations, standards, and concerns about their living state.<sup>[5]</sup> QOL represents the perception of the disease and the subjective evaluation of the therapeutic effect.<sup>[6]</sup> As a comprehensive evaluated method reflecting health concept and medical model, the assessment of life quality has been used in the clinical evaluation of glaucoma.<sup>[7]</sup> The ultimate goal of clinical treatment for glaucoma is to maintain QOL by sustaining visual function, which is theoretically ahead of the changes in the visual field (VF), intraocular pressure (IOP), and optic disc. Multiple questionnaire measures are reported to involve in the QOL evaluation, including the 25-item National Eye Institute Visual Function Questionnaire, the Short Form-36, the Activities of Daily Vision Scale.<sup>[8–11]</sup> In this study, we used the Glaucoma Quality of Life-15 questionnaire (GQL-15) to distinguish glaucoma patients from normal people because our results suggest that even slight VF loss can be detected by such a powerful method.<sup>[12,13]</sup>

VF loss is the clinical feature of glaucoma, and VF testing is the core criterion for the diagnosis, treatment and follow-up of glaucoma.<sup>[14]</sup> Visual impairment induced by glaucoma, such as visual acuity (VA) decrease and VF defect, may cause some obstacles in reading and writing, walking, dark adaptation, housework, and social activities, leading to a continuous reduction in the QOL of patients with glaucoma as the disease progresses.<sup>[15,16]</sup>

Previously, the visual function evaluation of glaucoma patients was clinically based on monocular static VF analysis, which cannot reflect the real binocular visual function of patients in daily life. subsequently, binocular integrated visual field (BVF) based on monocular VF, was adopted as a better way to evaluate the effect of VF losses on quality of life in glaucoma patients because the BVF contains 4 integration methods, including best location, best eye, average eye and binocular summation<sup>[17]</sup> In fact, BVF of patients is better than a monocular VF, which can more accurately reflect the daily visual function and quality of life, guiding successful therapy and follow-up of glaucoma patients.<sup>[18–20]</sup> Nevertheless, the impact of diverse types of BVF defects on the loss of the quality of life in glaucoma have barely received attention in this scientific world, especially Asia, for example, China.

In this study, we measured VA, VF, and GQL-15 among all enrolled patients and integrated binocular visual field. Patients were divided into 5 groups according to different degrees of BVF defect. The purpose of this study was to investigate the impact of diverse types of BVF defects, and the correlation between objective visual function and subjective vision loss on the quality of life in glaucoma.

## 2. Subjects and methods

### 2.1. Design

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 the First Affiliated Hospital of Kunming Medical University, 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.

### 2.2. Subjects and patients

Ninety-six patients diagnosed as glaucoma were selected in the Department of Ophthalmology, the First Affiliated Hospital of Kunming Medical University from 2012 to 2019, including 40 patients with chronic primary angle-closure glaucoma and 56 patients with primary open-angle glaucoma. The diagnostic criteria for these 2 forms of glaucoma were consistent with previous studies,<sup>[21]</sup> 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). All patients were treated with medication to ensure reduction in intraocular pressure to less than 21 mmHg. Patients who successfully completed the GQL-15 questionnaire and had reliable VF tests were enrolled in the study. Besides, inclusion criteria excluded mental illness or cognitive impairment, hearing and/or mobility restriction, and eliminated corneal diseases, retinal optic nerve diseases and other eye diseases. All the patients underwent VF examination by the same experienced technician, and GQL-15 questionnaire were conducted by the same professional personnel.

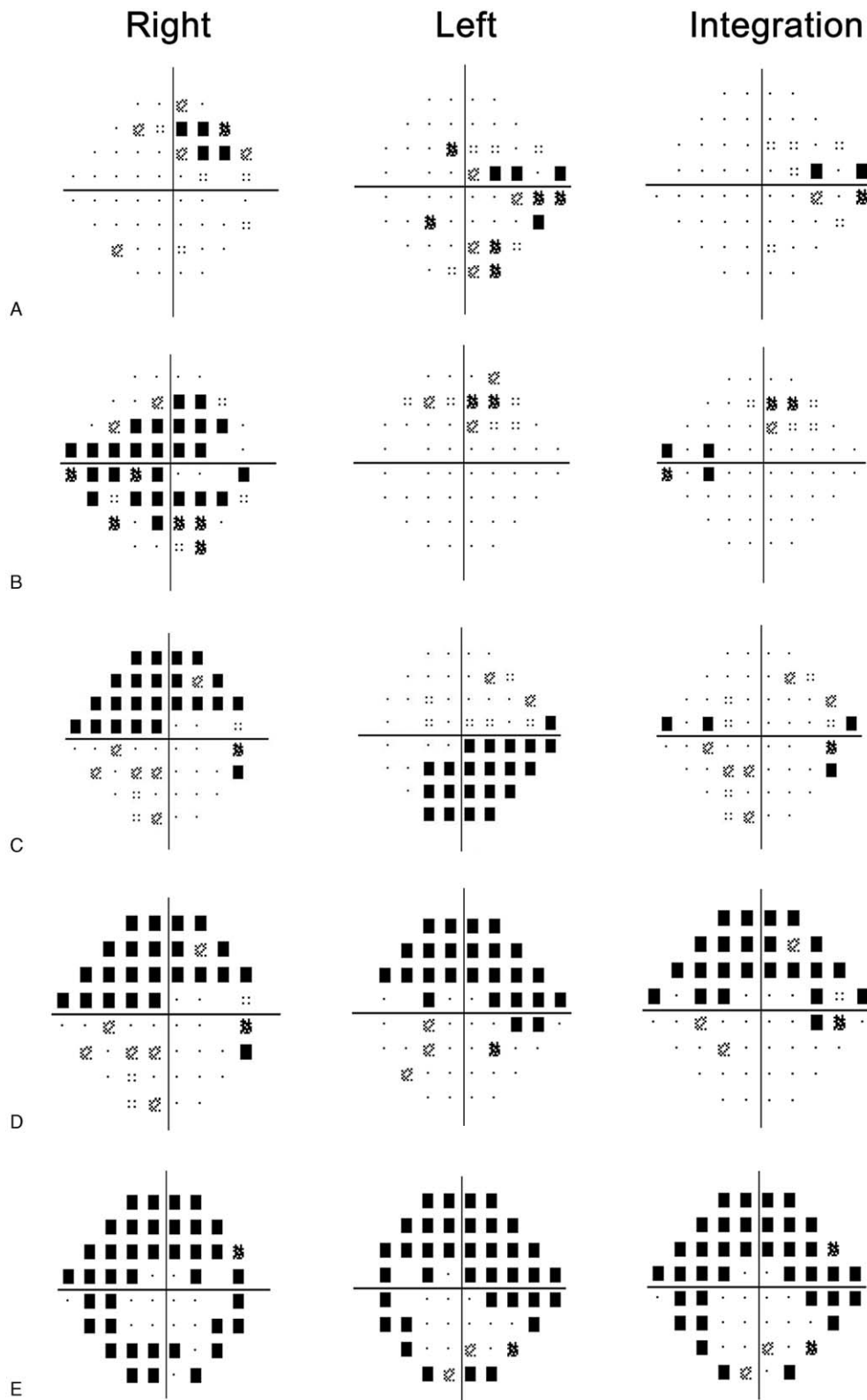
### 2.3. Clinical examination and grouping Criteria

All patients underwent a series of tests that included VA, subjective refraction (RM-8000, Topcon, Japan), slit lamp (SL-D7, Topcon, Japan), ophthalmoscopy (SuperField NC, Volk), intraocular pressure (Goldmann, Haag-Streit, CH) and VF testing (Humphrey 750i, Carl Zeiss Meditec, CA,USA). VF testing was performed using the central 24-2 SITA-Fast program in the Humphrey perimeter 750i analyzer. Mean sensitivity, mean deviation, and pattern standard deviation (PSD) at each spot were recorded. 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.

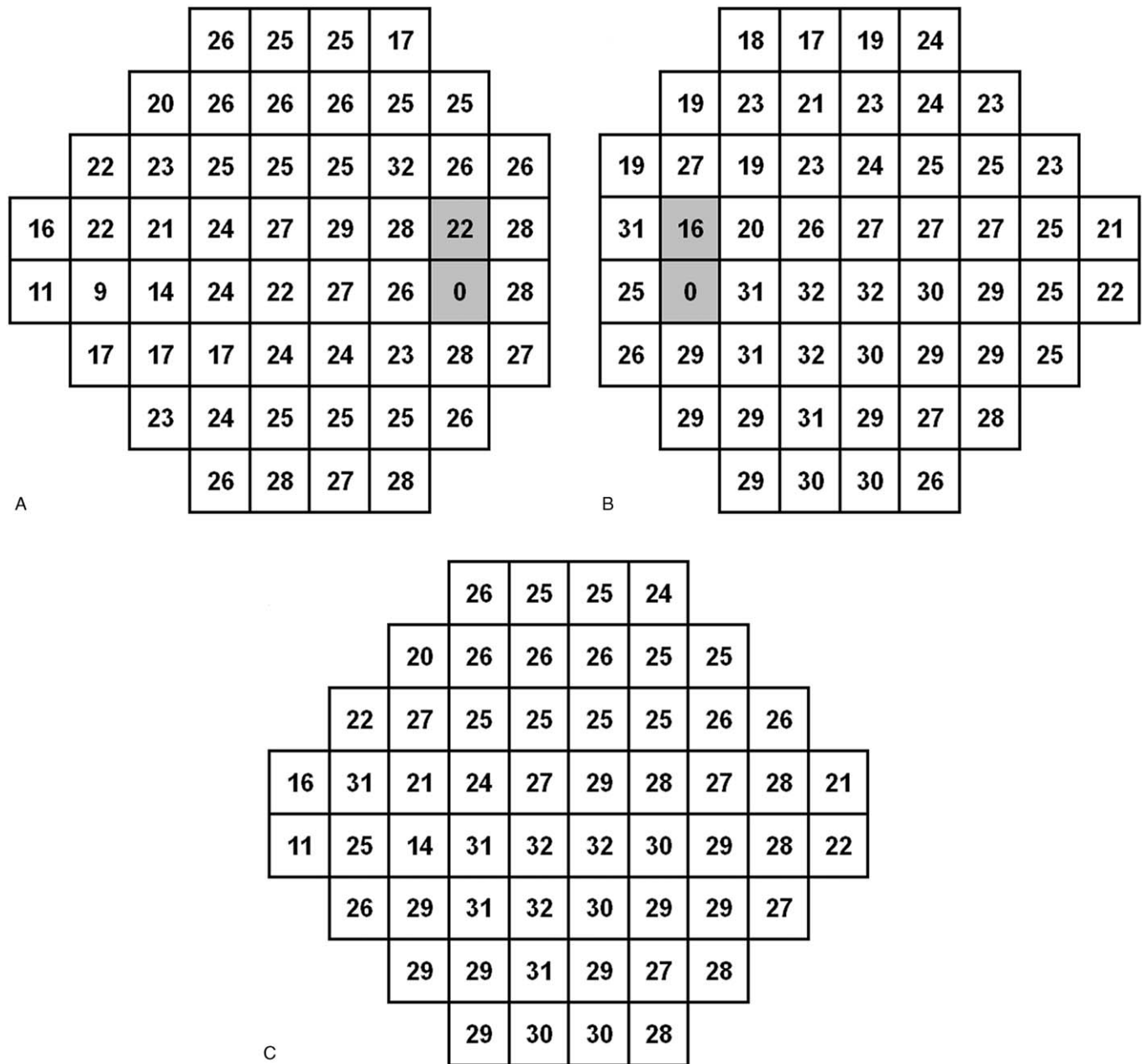
Patients were divided into 5 groups according to the H-P-A visual field grading system.<sup>[22]</sup> Among these patients, 25 patients were in Group A with mild VF defect in binocular eyes; 24 patients were in Group B with mild VF defect in 1 eye and moderate or advanced defect in the other; 11 patients were in Group C with moderate and non-overlapping VF defect in both eyes; Group D contained 15 patients with overlapping and moderate VF defect in binocular eyes, and Group E included 21 patients with severe defect in both eyes (Fig. 1). According to the BVF system, patients in group A, group B and group C were all in the mild stage, patients in group D were in the advanced stage, and patients in group E were in the severe stage.

### 2.4. GQL-15 questionnaire

Glaucoma Quality of Life (GQL-15) questionnaire<sup>[23]</sup> was used to investigate all glaucoma patients in the study. The GQL-15 is a 15-item questionnaire divided into four subscales: central and near vision (two items), peripheral vision (6 items), glare and dark adaptation (6 items), and outdoor mobility (1 item). Response



**Figure 1.** Schematic diagrams of Binocular integrated visual field stage system. (A) Both right and left eyes had mild visual field (VF) defect, and binocular integrated visual field (BVF) showed mild changes; (B) Mild VF defect in one eye and moderate or advanced defect in the other, while BVF represented mild defect; (C) Both right and left eyes had moderate and non-overlapping VF defect, BVF also represented mild VF loss; (D) Both eyes had overlapping and moderate VF defect, BVF represented moderate defect; (E) Monocular and binocular integrated field of VF represented severe defect.



**Figure 2.** Schematic representation of Best Location Binocular integrated visual field analysis. (A) Visual field dB value schematic diagram of the right eye; (B) Visual field dB value schematic diagram of the left eye; (C) Visual field dB value schematic representation of binoculars.

categories for each item are included from 1 (no difficulty) to 5 (severe difficulty), and 0 represents “abstinence from activity due to non-visual reasons”. The questionnaire questions were explained to subjects with informed consent to ensure the accuracy of the consequences. Patients chose the most consistent answers seriously according to their subjective feelings. GQL-15 questionnaire contains central and peripheral vision, glare, dark adaptation, and outdoor activities. Each of the GQL-15 items were described by a code ranging from 1:1 to 5:1, no difficulty, 5, severe difficulty, and 0 equal to “abstinence from activity due to non-visual reasons”. The corresponding scores for each item are accumulated to produce a total GQL-15 score of 75 points. The higher the GQL-15 score is, the worse the quality of life.

### 2.5. Binocular integrated visual field analysis by Best Location method

In this study, BVF analysis was performed by the Best Location method.<sup>[24]</sup> The maximum sensitivity of VF from the 2 overlapping locations in both eyes was ascertained as the integrated sensitivity at that point (Fig. 2). Moreover, the sum of 75% superior eye visual field index (VFI) and 25% inferior eye VFI was quantified as binocular integrated VFI value.

### 2.6. Statistical analysis

All quantitative data were expressed as mean ± standard deviation. SPSS 19.0 statistics software (IBM Corporation,

Armonk, NY) was used for statistical analysis. Linear regression analysis was used to analyze the correlation between GQL-15 score and BVFI value, and the dB value of BVF was plotted for  $R^2$  values. One-way analysis of variance for randomized groups and the Student-Newman-Keuls test were used for intergroup comparisons.  $P < .05$  was considered statistically significant.

### 3. Results

#### 3.1. Patients' characteristics

Ninety-six patients with glaucoma meeting the diagnostic criteria were enrolled. The demographic and clinical characteristics of subjects among the groups of patients were shown in Table 1. The mean age (SD) was 55.91 (16.12) years, ranging from 17 to 79 and female patients are predominated ( $n=56$ , 58.3%). Approximately two-thirds patients had a high school or college education, and more than half earned more than \$5,000 a year, and 14 (14.6%) patients had a family history of glaucoma. This cross-sectional study included 40 patients with chronic primary angle-closure glaucoma and 56 patients with primary open-angle glaucoma. On average, all patients received  $1.53 \pm 0.66$  anti-glaucoma medications. The average the logarithm of minimal angle of resolution score VA of the better eyes in the 96 patients was significantly better than that of the worse eyes ( $0.44 \pm 0.41$  vs  $0.87 \pm 0.85$ ,  $P < .001$ ). The mean of lower IOP of the subjects was  $14.39 \pm 3.43$  mmHg, while the higher IOP was  $16.86 \pm 3.13$

mmHg ( $P < .001$ ). Moreover, the average smaller cup-to-disc ratio was  $0.58 \pm 0.26$ , whereas the bigger 1 was  $0.73 \pm 0.24$  ( $P < .001$ ).

#### 3.2. Visual function index of glaucoma patients

The visual function index of the BVFI, dB value of BVF, VFI, and VA of the better eye were significantly different among the 5 groups ( $P < .001$ ) (Table 2). The patients in the mild stage had a distinct better index and dB of BVF with  $95.72 \pm 0.59\%$  and  $28.33 \pm 0.49$  than those in the severe stage, with a superior VA and VFI of  $0.68 \pm 0.03$  and  $97.92 \pm 0.39\%$ , respectively. The VF index of group E decreased remarkably with BVFI of  $26.67 \pm 4.43\%$ , dB of BFI of  $8.25 \pm 1.36$ , VFI, and VA of the better eye of  $31.29 \pm 4.84\%$  and  $0.33 \pm 0.05$  respectively.

In details, compared with the binocular integrated visual function in the 5 groups, the BVFI, dB of BVF and VFI of the better eye showed significant differences between group A and other four groups ( $P < .001$ ), while the VA of the better eye had no difference among them ( $P > .05$ ). As shown in Fig. 3, comparison between group B and group D revealed similar results, in which index and dB of BVF and VFI of the better eye in group B was significantly increased ( $P < .01$ ), except for VA of the better eye between the 2 groups ( $P > .05$ ). However, the VFI of the better eye of group B and group C, group C and group D were remarkably different ( $P < .05$ ), except for dB and index of BVF and VA of the better eye among the 3 groups ( $P > .05$ ). In

**Table 1**  
Demographic and clinical characteristics of subjects among the groups of patients.

Parameter	Group A	Group B	Group C	Group D	Group E	Total
N	25	24	11	15	21	96
Age (yr)	$53.44 \pm 15.34$	$55.26 \pm 15.71$	$53.45 \pm 16.08$	$58.25 \pm 15.51$	$58.67 \pm 17.23$	$55.91 \pm 16.12$
Gender						
Male	7 (28.0%)	10 (41.7%)	5 (45.5%)	7 (46.7%)	11 (52.4%)	40 (41.7%)
Female	18 (72.0%)	14 (58.3%)	6 (54.5%)	8 (53.3%)	10 (47.6%)	56 (58.3%)
Level of Education						
Primary	5 (20.0%)	8 (33.3%)	3 (27.3%)	5 (33.3%)	6 (28.6%)	27 (28.1%)
High school graduate	8 (32.0%)	11 (45.9%)	4 (36.35%)	6 (40.0%)	10 (47.6%)	39 (40.6%)
College graduate	12 (48.0%)	5 (20.8%)	4 (36.35%)	4 (26.7%)	5 (23.8%)	30 (31.3%)
Income level						
Less than \$5,000/year	13 (52.0%)	10 (41.7%)	4 (36.4%)	6 (40.0%)	12 (57.1%)	46 (47.9%)
Between \$5,000 and \$10,000/year	8 (32.0%)	9 (37.5%)	5 (45.4%)	6 (40.0%)	5 (23.8%)	32 (33.3%)
More than \$10,000/year	4 (16.0%)	5 (20.8%)	2 (18.2%)	3 (20.0%)	4 (19.1%)	18 (18.8%)
Glaucoma family history	4 (16.0%)	3 (12.5%)	2 (18.2%)	2 (13.3%)	3 (14.3%)	14 (14.6%)
Types of glaucoma						
POAG	13 (52.0%)	12 (50%)	8 (72.7%)	10 (66.7%)	13 (61.9%)	56 (58.3%)
CPACG	12 (48.0%)	12 (50%)	3 (27.3%)	5 (33.3%)	8 (38.1%)	40 (41.7%)
Surgery or NOT						
Surgery	2(8%)	5(20.8%)	3(27.3%)	6(40%)	15(71.4%)	31(32.3%)
Laser	10(40%)	9(37.5%)	3(27.3%)	4(26.7%)	4(19.0%)	30(31.2%)
Medications Types	$1.28 \pm 0.63$	$1.26 \pm 0.71$	$1.55 \pm 0.69$	$1.63 \pm 0.57$	$1.68 \pm 0.72$	$1.53 \pm 0.66$
BCVA of both eyes						
Log MAR of better eye	$0.27 \pm 0.25$	$0.28 \pm 0.19$	$0.27 \pm 0.39$	$0.33 \pm 0.27$	$0.76 \pm 0.46$	$0.44 \pm 0.41$
Log MAR of worse eye	$0.41 \pm 0.32$	$0.44 \pm 0.37$	$0.45 \pm 0.59$	$0.96 \pm 0.72$	$1.68 \pm 0.82$	$0.87 \pm 0.85$
IOP of both eyes (mmHg)						
Lower	$14.96 \pm 2.96$	$14.75 \pm 2.72$	$15.27 \pm 3.07$	$14.46 \pm 3.72$	$13.46 \pm 3.66$	$14.39 \pm 3.43$
Higher	$16.88 \pm 2.71$	$17.10 \pm 2.85$	$16.82 \pm 3.40$	$17.37 \pm 3.39$	$16.43 \pm 3.22$	$16.86 \pm 3.13$
C/D of both eyes						
Smaller	$0.38 \pm 0.18$	$0.40 \pm 0.12$	$0.56 \pm 0.14$	$0.51 \pm 0.22$	$0.83 \pm 0.15$	$0.58 \pm 0.26$
Bigger	$0.46 \pm 0.21$	$0.67 \pm 0.15$	$0.72 \pm 0.11$	$0.78 \pm 0.17$	$0.89 \pm 0.14$	$0.73 \pm 0.24$

POAG=primary open-angle glaucoma, CPACG=chronic primary angle-closure glaucoma, BCVA=best-corrected visual acuity, Log MAR=the logarithm of minimal angle of resolution score, IOP=intracocular pressure, MD=mean deviation, C/D=cup-to-disc ratio.



**Table 2**  
Visual function index of glaucoma patients.

Parameter	Group A	Group B	Group C	Group D	Group E	P Value
BVFI (%)	95.72 ± 0.59	76.13 ± 1.69	75.18 ± 2.22	70.80 ± 2.34	26.67 ± 4.43	<.001
DB value of BVF	28.33 ± 0.49	24.01 ± 0.75	23.26 ± 0.90	20.01 ± 0.88	8.25 ± 1.36	<.001
Better VFI (%)	97.92 ± 0.39	91.88 ± 1.42	80.18 ± 2.62	73.13 ± 2.54	31.29 ± 4.84	<.001
VA of better eye	0.68 ± 0.03	0.59 ± 0.04	0.69 ± 0.07	0.60 ± 0.06	0.33 ± 0.05	<.001

VFI=visual field index, BVFI=binocular integrated visual field index, VA=visual acuity.

addition, the binocular visual function of group E, including the BVFI, dB of BVF, VFI, and VA of the better eye, markedly decreased when compared with other 4 groups ( $P < .001$ ).

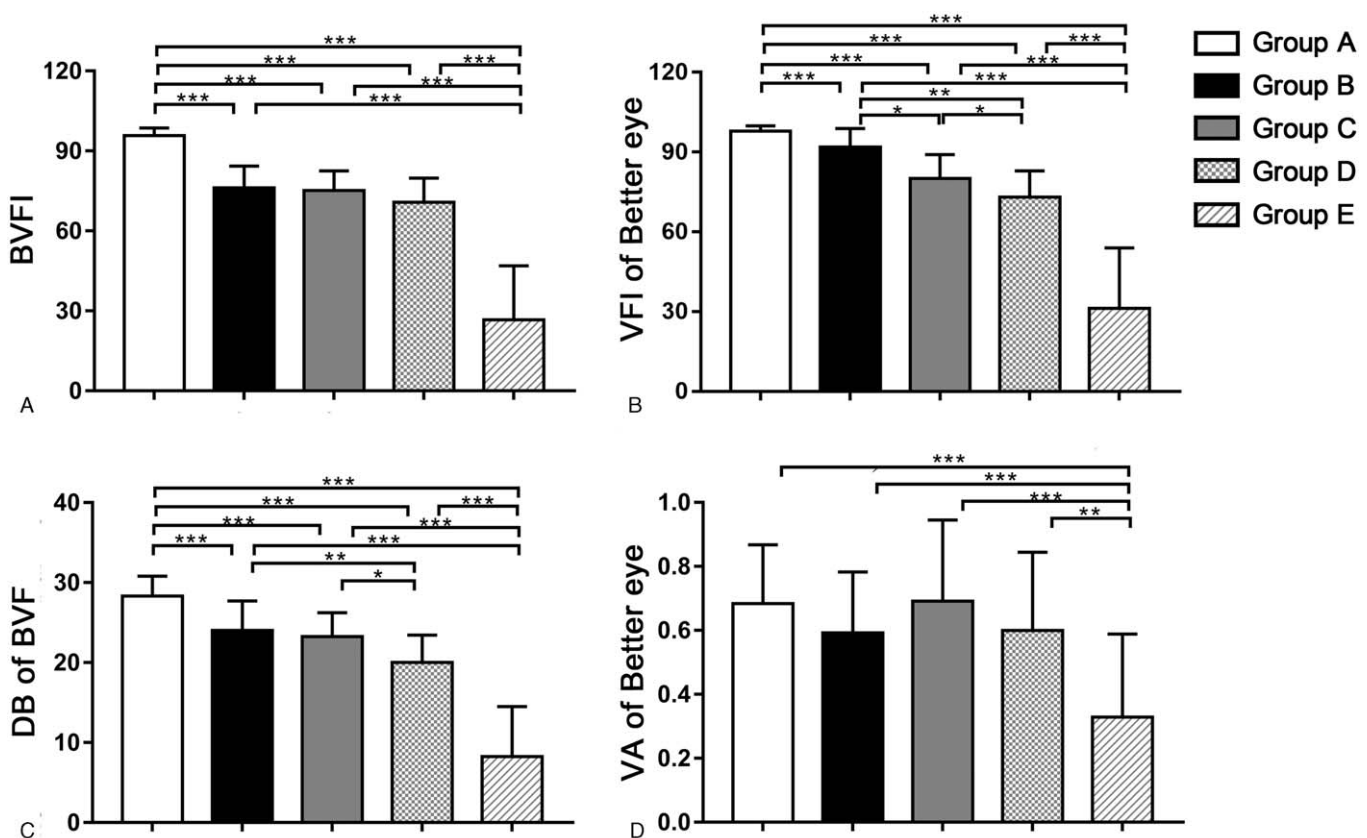
**3.3. Glaucoma Quality of Life scores of patients**

The Glaucoma Quality of Life scores of the GQL-15, central and near VA, peripheral VA, dark adaptation and outdoor activity capacity scores were significantly different among the 5 groups (Table 3). The patients in the mild stage had a prominent better GQL-15 score than that in the severe stage, with central and near VA score  $2.12 \pm 0.07$ , peripheral VA  $6.24 \pm 0.12$ , dark adaptation  $7.20 \pm 0.24$  and outdoor activity capacity score of  $1.04 \pm 0.04$  respectively. The glaucoma quality of life scores from group E increased significantly compared with those from the other 4 groups. Comparison of Glaucoma Quality of Life scores among

the 5 groups showed significant differences, showing that better visual function was closely associated with lower GQL-15 score ( $P < .001$ ).

**3.4. Correlation between visual function index and GQL-15 scores**

The visual function index of the glaucoma patients, including the BVFI, VFI of the better eye, dB of the BVF, and VA of the better eye, showed a negative linear relationship with the GQL-15 score. Excellent visual function index represented a high quality of life with a low GQL-15 score. The value of BVFI, VFI of the better eye and dB of the BVF showed a significantly negative correlation with GQL-15 score by  $R^2$  values of 0.675, 0.657 and 0.635, respectively (Fig. 4A-C). There was a low negative correlation between better eye VA and GQL-15 score ( $R^2 = 0.419$ ) (Fig. 4D).



**Figure 3.** Visual function index of glaucoma patients among different groups. (A) Binocular integrated Visual Field Index; (B) Visual Field Index of the better eye; (C) dB of the Binocular integrated Visual Field; (D) Visual Acuity of the better eye. \* $P < .05$ ; \*\* $P < .01$ ; \*\*\* $P < .001$ .

**Table 3**  
**Glaucoma quality of life scores of patients.**

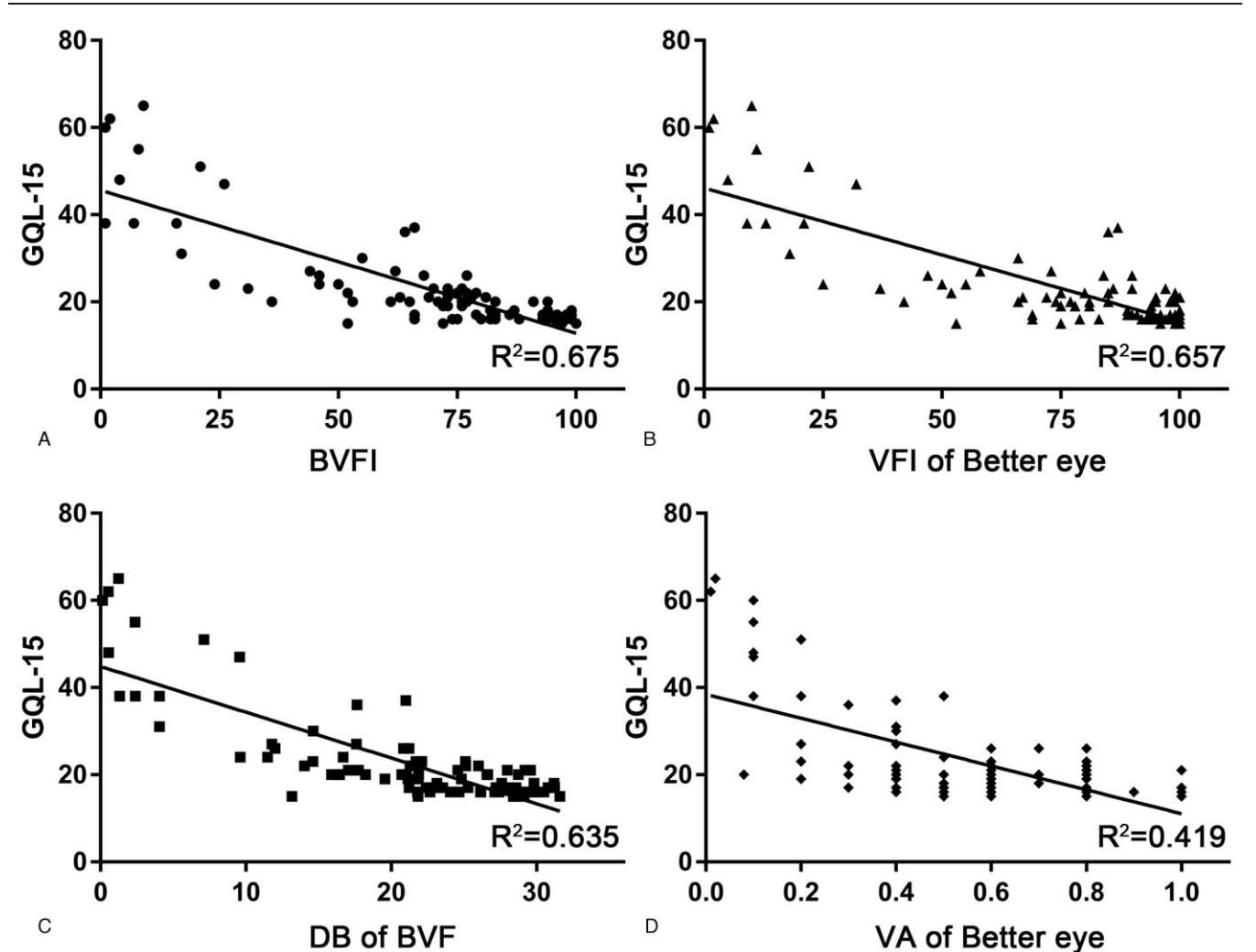
Scores	Group A	Group B	Group C	Group D	Group E	P Value
GQL-15	16.56±0.26	20.71±1.13	17.27±0.54	19.53±0.66	42.71±2.81	<.001
Central & near VA	2.12±0.07	2.51±0.15	2.18±0.12	2.40±0.19	4.14±0.29	<.001
Peripheral VA	6.24±0.12	8.21±0.48	6.27±0.19	6.87±0.26	14.57±1.24	<.001
Dark adaptation	7.20±0.24	9.71±0.49	7.82±0.40	9.27±0.45	15.90±1.39	<.001
Outdoor Activity	1.04±0.04	1.08±0.05	1.18±0.12	1.17±0.07	2.81±0.29	<.001

GQL-15=glaucoma quality of life-15, VA=visual acuity.

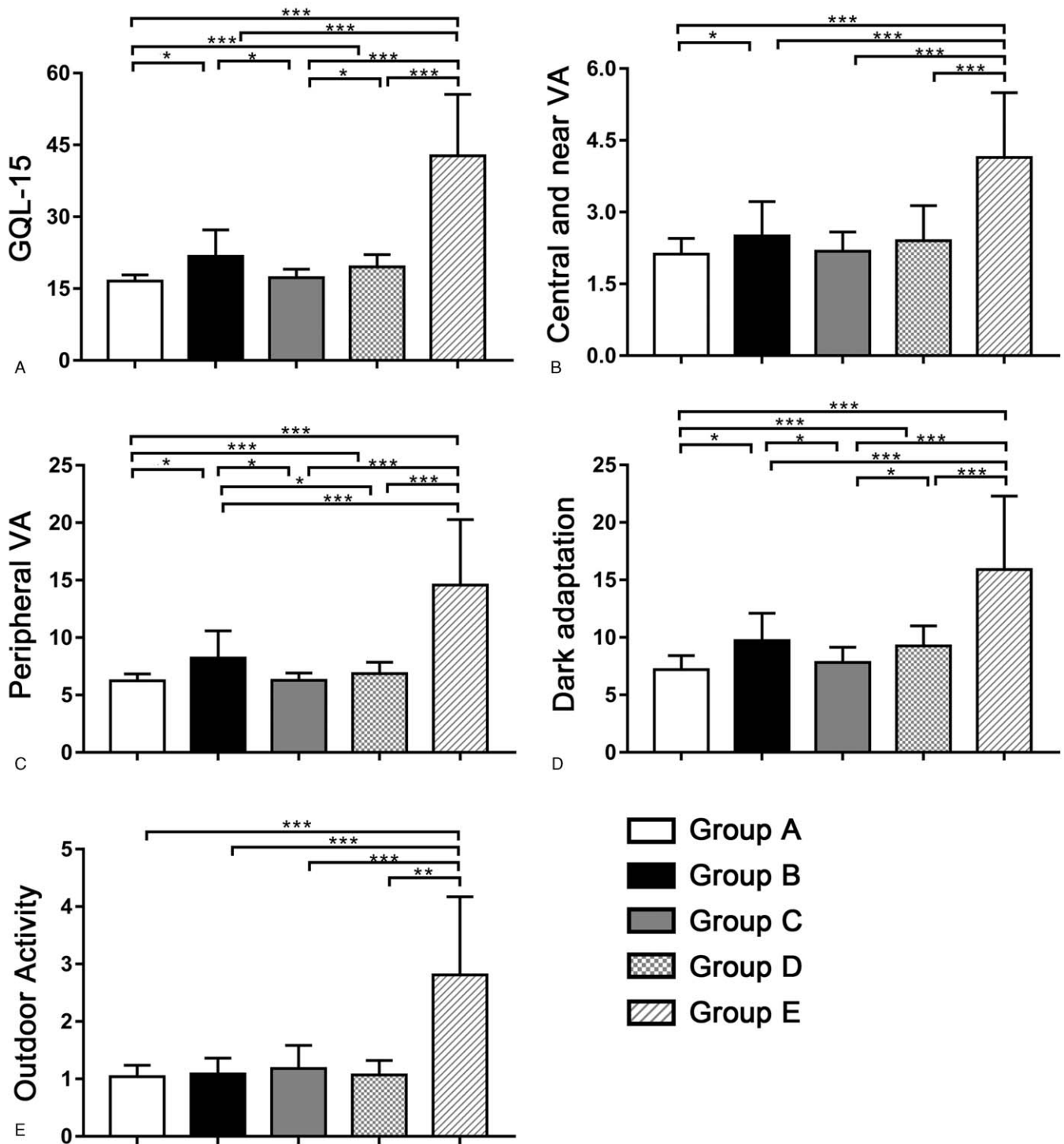
**3.5. Intergroup comparisons analysis among different types of BVF defects**

Compared with the binocular integrated visual function of the 5 groups, the GQL-15, central and near VA, peripheral VA and glare and dark adaptation scores showed significant differences between group A and group B ( $P < .05$ ), while the outdoor activity capacity scores were not statistically different between the 2 groups ( $P > .05$ ). As shown in Fig. 5, the GQL-15, peripheral VA and glare and dark adaptation scores of group A

and group D ( $P < .001$ ), group B and group C were remarkably different ( $P < .05$ ), while there were only statistical differences in peripheral VA between group B and D ( $P < .05$ ). Glaucoma quality of life between group C and group D were significantly different in GQL-15 and glare and dark adaptation ( $P < .05$ ). In addition, the glaucoma quality of life scores from group E, including the GQL-15, central and near VA, peripheral VA, glare and dark adaptation and outdoor activity capacity scores, markedly increased compared with those from the other 4 groups ( $P < .001$ ).



**Figure 4.** Correlation between visual function index and GQL-15 scores. (A) Correlation between binocular integrated visual field index and GQL-15 scores; (B) Relation of visual field index of the better eye and GQL-15 scores; (C) Pertinence between DB of the binocular integrated visual field and GQL-15 scores; (D) Correlation between visual acuity of the better eye and GQL-15 scores.



**Figure 5.** Glaucoma Quality of Life scores of patients among different groups. (A) Glaucoma Quality of Life (GQL-15) scores among different groups; (B) Central and near visual acuity scores; (C) Peripheral visual acuity scores; (D) Dark adaptation scores; (E) Outdoor activity capacity scores. \* $P < .05$ ; \*\* $P < .01$ ; \*\*\* $P < .001$ .

#### 4. Discussion

Glaucoma, which accounts for about one-fifth of the world's blind, has become a major public health problem, causing great damage to individuals, families, and society. As a long-term and chronic disease, different treatment and complications of glaucoma bring comprehensive effects to patients. Under the premise of active treatment and protection of visual function, the

focus of the therapeutic effect of glaucoma should gradually shift from relieving clinical symptoms to improving patients' quality of life. The assessment of QOL can comprehensively and versatily reflect the effects of glaucoma on patients, as well as the different therapies and adverse reactions, to guide physicians to determine the most effective treatment measures for patients.<sup>[2,3]</sup>



VF is the main criterion to evaluate visual function in patients with glaucoma. Previous studies mainly focused on the monocular visual field and QOL, which could not effectively represent patients' real binocular visual function.<sup>[25,26]</sup> It was reported that the QOL in glaucoma was significantly correlated with visual impairment of physical function, social activities and psychosocial factors,<sup>[27-30]</sup> among which binocular visual function has the most intimate relationship.<sup>[31,32]</sup> In addition, once glaucoma is diagnosed, many patients' QOL decreases significantly, mainly due to inconvenient treatment and afraid of blindness.<sup>[33]</sup> During clinical practice, patients with the same stage of VF defect showing various QOL, or same QOL demonstrate diverse severity of VF defect, which might not be explained by visual function assessment based on monocular VF loss. Therefore, we combined BVF staging, severity and site of VF defect, and GQL-15 scale to analyze the patients' real visual function and quality of life.

The individual response and visual impairment collectively influence the QOL that individual patient shows different visual impairment, visual function and QOL in glaucoma.<sup>[34]</sup> In this study, we investigated 96 patients with glaucoma by GQL-15 questionnaire and VF examination, with significant correlations between them. VFI and dB value of BVF and VFI value of eye with better VF sensitivity were significantly negatively correlated with GQL-15 score, while VA was mildly negatively related with GQL-15 score. Consequently, lower GQL-15 score and better visual function signify preferable QOL for glaucoma patients, especially with obvious VFI and dB values of BVF (Fig. 4).

The results of intergroup comparisons analysis among different types of BVF defect demonstrated that patients in group A, B, C, and D all had higher visual function indexes and quality of life than those in group E, further suggested that the preferable QOL depended on better binocular visual function (Table 2, Fig. 3). Patients in group A, B and C were all in the mild stage, patients of group D were in the advanced stage, and patients in group E were in the severe stage. Patients with mild and moderate binocular integration VF had better visual function than that from severe ones, including central and near vision, peripheral vision, glare and dark adaptation and outdoor activity ability. The QOL of patients with severe impairment of visual function were affected to some extent. In addition, there was no difference in VA between mild and moderate stage, which prominently increased from that of advanced-stage patients. Therefore, the impairment of visual function in the severe stage was not only represented as VF defect but also reflected by damages in the patient's central vision (Table 3, Fig. 5).

According to our research, no matter which types of mild BVF defect, better VA and outdoor activity ability had no significant difference among them and were close to normal levels. However, even though BVFs were different in the early stage, the QOL of patients with more serious VF impairment decreased significantly. The peripheral vision of binocular visual function was affected by severe VF damage in 1 eye, which impacted the QOL of patients. Moreover, mild VF defect in both eyes, which was complementary and little different in the degree of VF damage, have had slightly effects on the quality of life. The complementary VF compensates for the visual function damage caused by monocular VF defect and invariably maintained the BVF in a mild state. The difference of binocular VF was imperceptible. In addition, the VF defect induced by glaucoma caused less physiological, psychological and mental pressure, and therefore, has less impact on the quality of life. On the other hand, severe VF

defect cannot be fully compensated by superior eye, leading to patients' predisposition to perceive glare and dark adaptation, resulting in obvious discomfort and fear feelings, thus affecting the QOL of patients.

Compared with the mild stage, there was no difference in the central and near vision, and outdoor activity ability among the patients with moderate BVF defect, indicating that the central vision and outdoor activity ability had not been seriously damaged in the early-stage patients. Visual function of patients with moderate BVF and overlapping defects visibly was reduced compared with that in the mild stage, mainly appearing as poor peripheral vision, glare and dark adaptation. The visual function and quality of life of the patients showed a downward trend with the progress of the disease, which was firstly manifested as reduction in peripheral vision, glare and dark adaptation, consistent with the peripheral to central development of glaucoma VF defect.<sup>[35]</sup> In addition, the dB value of BVF preferably embodied the real visual function of patients with moderate and complementary monocular VF defect. With the gradual aggravation of VF impairment, the difficulty in glare and dark adaptation was markedly elevated.

The limitations of this study lie in the single-center, non-randomized controlled study, small sample size and short follow-up time. Next, larger samples, longer follow-up, controlled studies, and more complete eye screening programs would be tested to verify the findings.

## 5. Conclusions

In summary, BVF is a functional evaluation criterion based on monocular VF, which accurately reveal the authentic visual function of patients in glaucoma. Higher BVF indices represent better QOL for patients with glaucoma. Mild to moderate synchronous or complementary binocular VF defects had a slight influence on the QOL, while severe and non-compensated VF loss significantly impact on that of patients. GQL assessment of glaucoma based on BVF comprehensively reflects the health concept and humanistic medicine. In all, BVF accurately reflect the physiological, psychological and social effects of glaucoma and ensure the optimal selection of screening, diagnosis, treatment and follow-up for patients, which compensates the deficiencies of traditional evaluation methods, to significantly improve the QOL in patients with glaucoma.

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## Author contributions

CZ, YTZ and HZ conceived and designed the study. CZ, JL and YJT supervised the study and oversaw the data collection. QC and WYY collected the data. CZ and HZ guided the data analysis. JL conducted the analysis; CZ wrote the first draft of the paper. HZ, ST and YTZ reviewed and revised the manuscript. All authors read and approved the final manuscript.

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