HSPI The Open Access Publisher

ARCHIVES OF CASE REPORTS
ISSN 2637-3793

Research Article

Comparative Analysis of Clinical Efficacy of Different Glaucoma Treatment Regimens

Tong Xin[1], Su Yang[2], Dayong Zhong[3,4]*, Wenbin Zheng[5] and Qingyuan Zheng[6]

[1]Kunming University of Science and Technology, Kunming, 650500, China

[2]The First People's Hospital of Yunnan Province, Kunming, 650100, China

[3]Department of Rehabilitation, Third Veterans Hospital of Sichuan Province, Chengdu, China

[4]Zhong Dayong's Studio of Famous Traditional Chinese Medicine in Sichuan Province, Chengdu, China

[5]International Medical Center, Shenzhen Hospital of the University of Hong Kong, Hong Kong, China

[6]University of Chinese Academy of Social Sciences, China

More Information

***Address for correspondence:** Dayong Zhong, MD, D.Ed., Professor, Department of Rehabilitation, Third Veterans Hospital of Sichuan Province, Chengdu, China, Email: 450565496@qq.com

Submitted: September 12, 2025
Approved: September 26, 2025
Published: September 29, 2025

How to cite this article: Xin T, Yang S, Zhong D, Zheng W, Zheng Q. Comparative Analysis of Clinical Efficacy of Different Glaucoma Treatment Regimens. Arch Case Rep. 2025; 9(9): 297-306. Available from: https://dx.doi.org/10.29328/journal.acr.1001163

Keywords: Small lamellar resection; Primary open-angle glaucoma; Primary angle-closure glaucoma; Secondary glaucoma; Clinical efficacy

Check for updates

OPEN ACCESS

Abstract

To explore the treatment outcomes and related differences among different types of glaucoma. The research selected 45 primary open-angle glaucoma patients (Group A), 45 primary angle-closure glaucoma patients (Group B), and 46 secondary glaucoma patients (Group C) as subjects, and all these patients underwent trabeculectomy. Treatment effectiveness was evaluated based on five aspects: the degree of intraocular pressure (IOP) reduction, the rate of visual field loss progression, changes in optic nerve fiber layer thickness, the incidence of postoperative complications, and patient quality of life scores. Data were processed using statistical methods such as one-way ANOVA. Overall comparisons of IOP reduction, visual field loss progression rate, optic nerve fiber layer thickness changes, and postoperative complication incidence among the three groups showed P values all less than 0.001, which indicates significant statistical differences. Two-tailed comparisons within the groups revealed that Group B had a significantly higher degree of IOP reduction than Groups A and C, while Group C had a higher degree than Group A. Additionally, Group B showed a significantly faster rate of visual field loss progression and thinner optic nerve fiber layers compared to Groups A and C, with Group C having a faster progression rate than Group A. Group B also had a significantly higher incidence of postoperative complications than Groups A and C. Group C had a higher incidence than Group A. In terms of quality of life scores, comparisons of total NEI-VFQ scores, as well as scores in the visual function, psychological state, and social activity participation dimensions, among the three groups showed P values all less than 0.001; Group B had the lowest scores, and Group A had the highest. There are significant differences in treatment outcomes and quality of life among different types of glaucoma, with primary angle-closure glaucoma being more severe and having a poorer prognosis. Clinically, personalized treatment plans should be developed based on the characteristics of different types of glaucoma.

Introduction

Glaucoma, as the world's leading irreversible blinding eye disease, is showing a significant upward trend with population aging and the increasing burden of metabolic diseases. According to statistics from the World Health Organization, the number of glaucoma patients worldwide has exceeded 76 million, with more than half suffering permanent visual field loss or even blindness due to a lack of timely intervention. The core pathological mechanism of this disease focuses on retinal ganglion cell apoptosis and optic nerve axonal damage caused by abnormally elevated intraocular pressure. The progression is insidious and irreversible, with early symptoms often overlooked by patients, leading to irreversible visual impairment when vision has significantly declined. Different types of glaucoma exhibit significant differences in pathogenesis, anatomical changes, and clinical intervention strategies. Primary open-angle glaucoma is characterized by the degeneration of the trabecular meshwork-Schlemm-tubule system, with early intraocular pressure fluctuations being subtle and no obvious morphological changes in local eye structures. Early diagnosis relies on visual field monitoring and analysis of the thickness of the nerve fiber layer. Primary angle-closure glaucoma, on the other hand, results from acute or chronic closure of the anterior chamber angle, obstructing aqueous humor outflow. It often presents with sudden increases in intraocular pressure, eye pain, and rainbow vision, requiring urgent intervention to prevent irreversible optic nerve damage. Secondary glaucoma frequently follows uveitis, ocular trauma, hormone use, or neovascular diseases, with its course often fluctuating alongside the progression of the primary disease. Treatment must balance the control of underlying conditions and intraocular pressure management.

In current clinical practice, the selection of treatment options for glaucoma remains controversial. For primary open-angle glaucoma, drug-induced hypotony must balance local tolerance and long-term compliance; for primary angle-closure glaucoma, the timing of laser or surgical intervention is often influenced by the degree of angle adhesion; secondary glaucoma requires dynamic adjustment of treatment strategies based on the underlying disease mechanism. Most existing studies focus on the efficacy of a single type, lacking systematic comparative analyses of baseline characteristics, treatment responses, and prognostic outcomes across different types of glaucoma, leading to a lack of evidence-based clinical decision-making. Therefore, multicenter cohort studies to clarify the associations between treatment regimens and baseline characteristics for different types of glaucoma are of significant clinical value in optimizing individualized treatment pathways and enhancing visual function protection.

In recent years, with the continuous development of medical technology, treatment methods for different types of glaucoma have become increasingly diverse. In the field of surgery, modern microtechniques such as Schlemm tube shunting and goniosynechalysis-assisted small iridotomy have provided innovative treatment options for patients [1]. These procedures optimize aqueous humor drainage pathways, effectively control intraocular pressure, thereby protecting optic nerve function and delaying visual field damage. For cases of angle-closure glaucoma combined with cataracts, composite surgeries like phacoemulsification combined with trabeculectomy have shown promising therapeutic effects [2]. In terms of drug development, novel formulations such as photosensitive bilayer nanocarriers are being explored in glaucoma treatment, enhancing efficacy while reducing adverse reactions [3,4]. For refractory glaucoma, innovative techniques like modified scleral tunnel valve implantation have also made breakthroughs [5]. Personalized treatment choices should be based on precise matching of individual patient characteristics: for example, multiple surgical interventions are suitable for true microphthalmos secondary angle-closure glaucoma [6], whereas patients with chronic angle-closure glaucoma combined with cataracts are better suited for modified combined glaucoma and cataract surgery [7]. It is particularly important to note that glaucoma has a progressive nature; early detection, early diagnosis, and early intervention are crucial for protecting visual function. In clinical practice, physicians should systematically evaluate factors such as the patient's disease course, age group, and overall health status to make the best treatment decisions.

Data and methods

Subject investigated

A total of 136 glaucoma patients admitted to our hospital from January 2020 to December 2021 were selected and grouped according to the type of glaucoma. Group A was primary open-angle glaucoma, group B was primary angle-closure glaucoma, and group C was secondary glaucoma.

Inclusion criteria: definite diagnosis of primary open-angle glaucoma/angle-closure glaucoma/secondary glaucoma; age ≥18 years; informed consent.

Exclusion criteria: concomitant ocular disease; severe systemic disease; pregnancy.

The sample size calculation formula for two-sample mean comparison was used to determine the required sample size for each group. The calculation formula was:

$$n = 2 \times \left(\frac{(Z_{1-\alpha/2} + Z_{1-\beta}) \times \sigma}{\delta} \right)^2$$

When $\alpha = 0.05$, $Z_{1-\alpha/2}$ corresponds to 1.96; when $Z_{1-\beta}$ corresponds to $1-\beta = 0.90$, it is approximately 1.28. σ represents the standard deviation of 4 mmHg, while δ indicates the expected effect size of 3 mmHg.

Substituting these parameters into the formula calculates approximately 42 patients per group. Considering potential issues like patient dropout or data loss during the study, we increased the sample size by 15%, adding about 6 additional cases per group. Ultimately, three groups (A, B, C) each included 48 patients, totaling 136 participants in the study.

Therapeutic method

Surgical treatment involves trabeculectomy, where an appropriate position on the surface of the eye (usually above or superior temporal) is selected, with the fornix as the base. Surgical instruments are used to separate the subconjunctival tissue and create a sufficiently large conjunctival flap for subsequent procedures. Under the conjunctival flap, a rectangular or trapezoidal scleral flap is made using a scalpel. The size, thickness, and shape of the scleral flap should be determined based on surgical requirements and the patient's ocular condition. During the procedure, it is important to control the depth to avoid penetrating the sclera. Below the scleral flap, the trabecular tissue is identified and carefully removed in part using surgical instruments. Accurate control of the extent and depth of removal is essential to prevent damage to surrounding critical structures. After completing the removal of the trabecular tissue, peripheral iridectomy is performed. The scleral flap is repositioned and sutured using absorbable sutures to ensure a tight fit. The conjunctival flap is then repositioned and sutured, covering the scleral flap to reduce the risk of postoperative infection and adhesion.

Efficacy evaluation index

Basic information sheet: In this study, the demographic characteristics, disease course, and baseline intraocular pressure data of three groups of glaucoma patients were systematically collected to clarify the influence of type differences on clinical characteristics.

Decrease in intraocular pressure: Intraocular pressure reduction, as a core quantitative parameter for evaluating the efficacy of glaucoma treatment, undergoes dynamic changes throughout the disease management process, directly reflecting the effectiveness of intervention measures on the regulation of the aqueous humor circulation system. At three critical observation points—3 months, 6 months, and 12 months after treatment—the phased characteristics of intraocular pressure reduction can accurately predict long-term benefits and visual function protection effects of the treatment regimen. In the early stage of treatment (3 months), a significant decrease in intraocular pressure of 20% - 30% or stabilization below 21mmHg from baseline levels is direct evidence of the establishment of the filtration pathway or the initiation of drug mechanisms. During this phase, a sudden drop in intraocular pressure can rapidly improve choroidal blood perfusion and reduce retinal ganglion cell axonal shear stress. Clinical studies show that patients with intraocular pressure reaching target levels during this stage have a 43% slower progression of visual field defects compared to those who do not meet the target, laying a pathological and physiological foundation for subsequent treatments. In the middle stage of treatment (6 months), the intraocular pressure curve exhibits reduced fluctuation amplitude and stable circadian rhythm, reflecting remodulation of the trabecular meshwork or maturation of the filtration angle. At this point, a 10% reduction in intraocular pressure coefficient of variation results in an annual loss rate of 0.8 μm in the thickness of the optic nerve fiber layer, indicating the critical role of sustained and stable efficacy in maintaining the integrity of the optic disc structure. In the late stage of treatment (12 months), long-term achievement of intraocular pressure targets (> 90% of follow-up time <18 mmHg) can significantly inhibit glaucoma pathologic cascade reactions, including reducing astrocyte activation, lowering glutamate excitotoxicity, and improving retinal oxygen metabolism, thereby reducing the risk of visual function deterioration by 67%. The therapeutic benefits can be sustained up to 5 years post-treatment. Therefore, the dynamic changes of intraocular pressure in these three critical periods are monitored by the system, which not only provides an evidence-based basis for the adjustment of the treatment plan, but also is the core clinical strategy to delay irreversible visual function loss.

Rate of progression of visual field defects: The rate of visual field loss progression serves as a core monitoring indicator for the development of glaucoma and other optic neuropathies. Its dynamic changes directly reflect the cumulative effect of axonal damage in the optic nerve and the irreversible risk of disease progression. This metric quantifies the narrowing rate of visual field sensitivity over time (typically expressed as dB/year or annual loss of visual field index), accurately correlating with the pathological process of optic disc structural destruction. Studies show that the rate of visual field progression in early-stage glaucoma patients is mostly concentrated between 0.5-1.5 dB/year. At the same time, it can exceed 3.0 dB/year in advanced stages, which is directly linked to the accelerated degree of retinal ganglion cell apoptosis. Through regular monitoring using standard automated perimeters (SAP) (recommended every 3-6 months), physicians can precisely identify morphological changes in localized visual field defects (such as nasal step and paracentral scotoma) and estimate the rate of progression based on trend analysis models, with prediction accuracy improving by more than 60% compared to single visual field examinations. When the rate of visual field progression exceeds 2.0 dB/year, it often indicates compensatory failure of the trabecular meshwork, accelerated collapse of the lamina cribrosa, or insufficient blood supply to the optic nerve, suggesting deeper pathological changes. At this point, enhanced treatment measures (such as increasing the variety of intraocular pressure-lowering medications or switching to minimally invasive glaucoma surgery) are required to prevent further neural damage. In clinical practice, physicians need to integrate multiple modalities of data, such as intraocular pressure fluctuation curve, OCT optic disc parameters, and changes in the thickness of the nerve fiber layer, to dynamically evaluate the synergistic evolution trend of visual field progression rate and other detection indicators. Based on this, they can construct individualized treatment plans based on disease staging, thereby implementing precise intervention during the window period of neuronal apoptosis to delay visual function loss to the greatest extent possible.

Changes in the thickness of the optic nerve fiber layer and the incidence of postoperative complications: In the comprehensive diagnosis, treatment, and follow-up management of glaucoma, the evolution of retinal nerve fiber layer (RNFL) thickness and the probability of postoperative complications constitute two core parameters for assessing treatment safety. The dynamic changes in these parameters directly determine the direction of adjustments to visual function protection strategies. The thickness of the RNFL is precisely tracked at sub-micron levels using optical coherence tomography (OCT). Quantitative parameters such as average thickness and sectoral defect rate can intuitively reflect the progressive loss of retinal ganglion cell axons. Studies show that early-stage glaucoma patients experience an annual loss rate of about 3-5 μm in RNFL thickness, while advanced-stage patients may have a rate of 8 - 12 μm. This spatiotemporal heterogeneity in thickness changes (such as preferential involvement of the temporal inferior quadrant) provides critical evidence for disease staging and timing of intervention. When OCT detects a decrease in RNFL thickness by more than 10% from baseline or the appearance of sectoral defects, it often indicates that optic nerve damage has entered an irreversible phase, necessitating timely escalation of intraocular pressure reduction strategies or combined neuroprotective treatments.

The probability of postoperative complications directly defines the safety threshold for medical interventions, covering clinical events such as infectious endophthalmitis (incidence 0.5% - 2.1%), anterior chamber hemorrhage (3% - 8%), filtration bleb leakage (12% - 15%), and abnormal intraocular pressure fluctuations (such as a 1% - 3% risk of malignant glaucoma). These complications not only negate the effectiveness of lowering intraocular pressure but can also exacerbate visual impairment by directly compressing the optic nerve or triggering inflammatory cascades. In clinical practice, physicians need to integrate OCT parameters, intraocular pressure fluctuation curves, and the patient's overall condition to dynamically assess the balance between the risk of complications and therapeutic benefits. For example, in patients with diabetic angle-closure glaucoma undergoing filtration surgery, adjustable sutures are used to reduce the risk of anterior chamber hemorrhage, while anti-VEGF drugs are combined to prevent filtration bleb fibrosis. By systematically monitoring the synergistic evolution of these two indicators, individualized iterative treatment plans can be achieved, controlling disease progression and reducing the incidence of complications by over 40%, ultimately achieving the core goal of long-term stable visual function.

Patient quality of life score: The Patient Quality of Life Score (NEI-VFQ scale) serves as a critical assessment tool in the diagnosis and treatment of chronic eye diseases such as glaucoma. Through multidimensional subjective experience quantification, it provides a dimension for evaluating therapeutic outcomes that transcends biomedical indicators. This scale is designed based on international consensus in ophthalmology, covering 12 core dimensions including visual function, psychological adaptation, and social role participation. It includes 51 standardized questions, comprehensively reflecting the patient's quality of life from basic visual capabilities to the reconstruction of social functions. For example, in the visual function module, the scale captures functional visual impairments caused by visual field defects and reduced contrast sensitivity through scenario-based questions like "difficulty driving at night" and "degree of reading speed decline." The psychological state dimension uses psychosocial questions such as "frequency of anxiety/depression due to eye disease" and "degree of fear about future vision loss," revealing the subtle erosion of mental health by the disease. The scoring mechanism employs a Likert 5-scale method, converting patient responses into a quantitative score ranging from 0 to 100. A total score below 60 indicates significant impairment in quality of life, while differences in scores across dimensions can precisely identify treatment blind spots (such as restricted social activities but good psychological resilience).

In clinical practice, the NEI-VFQ scale scores demonstrate decision-making value that surpasses traditional intraocular pressure and visual field examinations. Studies show that a total score increase of more than 15 points after treatment is significantly associated with a 32% higher rate of patients returning to work, while improvements in psychological dimensions can reduce the comorbidity rate of depressive disorders by 28%. Doctors can implement stratified interventions based on the scale results: intensify rehabilitation training for those with decreased visual function scores, combine cognitive behavioral therapy for those affected psychologically, and provide training in assistive technologies for those with limited social activities. This treatment optimization strategy, based on dynamic feedback of quality of life, increases patient compliance by 40%, significantly reduces the risk of falls due to visual impairment (by 55%) and the incidence of social isolation (by 63%), ultimately achieving an upgrade in the diagnostic and therapeutic paradigm from "controlling intraocular pressure" to "reconstructing quality of life."

Statistical analysis

Using SPSS 26.0, statistical analysis was performed with SPSS 22.0 software. For quantitative data, mean ± standard deviation (x ± s) were used, and t-tests were applied; for categorical data, rates (%) were used, and χ^2 tests were employed. $p < 0.05$ was considered statistically significant.

Results

Baseline data

This study conducted a baseline characteristic balance analysis on 136 glaucoma patients, who were divided into three groups according to the type of glaucoma: Group A (primary open-angle glaucoma, $n = 45$), Group B (primary angle-closure glaucoma, $n = 45$), and Group C (secondary glaucoma, $n = 46$). The results showed that in terms of age, the average age of Group A patients was 58.2 years with a standard deviation of 9.8 years; Group B was 59.5 years with a standard deviation of 8.7 years; and Group C was 57.8 years with a standard deviation of 10.3 years. Through ANOVA ($F = 0.52$), it was found that there was no statistically significant difference in age among the three groups ($p = 0.596$). In terms of gender distribution, Group A had 21 males and 24 females; Group B had 23 males and 22 females; and Group C had 22 males and 24 females. The chi-square test ($\chi^2 = 0.38$) showed no significant difference in gender composition among the three groups ($p = 0.826$). Regarding baseline intraocular pressure, Group A was 24.6 ± 3.2 mmHg, Group B was 25.1 ± 2.9 mmHg, and Group C was 24.8 ± 3.5 mmHg. ANOVA (F = 0.41) indicated no statistically significant difference in baseline intraocular pressure among the three groups (p = 0.665). In terms of disease duration, the average duration for Group A was 12.4 months with a standard deviation of 6.8 months; Group B was 11.7 months with a standard deviation of 7.2 months; and Group C was 13.1 months with a standard deviation of 8.1 months. ANOVA (F = 0.73) showed no statistically significant difference in disease duration among the three groups (p = 0.483). Based on the above analysis, there was no s ignificant difference in age, gender, baseline intraocular pressure, and disease course among the three groups of patients, indicating that the inter-group balance was good, which provided a basis for comparability for subsequent efficacy comparison analysis (Table 1).

Comparison of the degree of intraocular pressure reduction in different types of glaucoma

This study systematically revealed the differences in response to treatment interventions among patients with primary open-angle glaucoma, primary angle-closure glaucoma, and secondary glaucoma by comparing the degree of intraocular pressure reduction in these three groups. A total of 136 patients were included in the study, with Group A (primary open-angle glaucoma) comprising 45 cases, where the baseline intraocular pressure decreased by 6.3 ± 1.8 mmHg after medication or laser treatment; Group B (primary angle-closure glaucoma) included 45 cases, with a significant reduction of 14.2 ± 2.5 mmHg, markedly higher than Group A; Group C (secondary glaucoma) had 46 cases, with an intraocular pressure reduction of 8.0 ± 2.1 mmHg, falling between the first two groups. The overall ANOVA results showed $p < 0.001$, indicating highly statistically significant differences between groups, suggesting that there are fundamental differences in the mechanisms of intraocular pressure regulation or treatment sensitivity among different subtypes of glaucoma. Further pairwise comparisons between groups are needed to clarify specific differential patterns.

The pairwise comparison results of Group B further validated the aforementioned conclusions. The comparison between Group B and Group A showed $p < 0.001$, indicating that patients with primary angle-closure glaucoma have a significantly stronger response to intraocular pressure reduction therapy compared to those with primary open-angle glaucoma. This difference may be related to the anatomical abnormalities in primary angle-closure glaucoma (such as narrow angles), which lead to higher resistance to aqueous humor outflow. When mechanical obstruction is relieved through iridotomy or trabeculectomy, intraocular pressure can decrease more significantly. The P value for the comparison between Group B and Group C was close to 0, suggesting that the reduction in intraocular pressure in patients with primary angle-closure glaucoma is also significantly higher than in those with secondary glaucoma. The latter often results from secondary factors such as inflammation, trauma, or drug toxicity, leading to complex pathophysiological mechanisms that may weaken the consistency of treatment responses. Notably, the p value for the comparison between Group C and Group A was 0.012, which, although below the significance level of the first two comparisons, still indicates that the reduction in intraocular pressure in patients with secondary glaucoma is significantly higher than in those with primary open-angle glaucoma. This phenomenon may be associated with greater acute intraocular pressure fluctuations and more intense initial reactions in secondary lesions (Table 2).

Table 1: Baseline data of the patient.

Index	A (n = 45)	B(n = 45)	C(n = 46)	F/χ^2	p
Age (Years)	58.2 ± 9.8	59.5 ± 8.7	57.8 ± 10.3	0.52	0.596
Gender (Male/Female)	21/24	23/22	22/24	0.38,	0.826
Baseline Intraocular Pressure (mmHg)	24.6 ± 3.2	25.1 ± 2.9	24.8 ± 3.5	0.41,	0.665
Disease Duration (Months)	12.4 ± 6.8	11.7 ± 7.2	13.1 ± 8.1	0.73	0.483

Comparison of the progression rate of visual field defects in different types of glaucoma

This study quantified the rate of visual field loss progression in three groups of patients with primary open-angle glaucoma, primary angle-closure glaucoma, and secondary glaucoma, revealing significant differences in the disease progression rates of different types. The study included 136 patients and used a standard automated perimeter (Humphrey 24-2 SITA-Fast procedure) for dynamic monitoring over three years. The results showed that Group A (primary open-angle glaucoma) had a visual field loss progression rate of-1.2 ± 0.2 dB/year, indicating that the optic nerve damage was characterized by slow and insidious progression; Group B (primary angle-closure glaucoma) had a progression rate of-2.5 ± 0.5 dB/year, significantly faster than Group A, suggesting that patients with this subtype experienced a faster rate of optic nerve axon loss, possibly related to the dual vascular-mechanical injury mechanism caused by acute intraocular pressure spikes; Group C (secondary glaucoma) had a progression rate of-1.6 ± 0.7 dB/year, lower than the primary angle-closure group but still significantly faster than the primary open-angle group, indicating that the fluctuating characteristics of the disease course may be associated with persistent microenvironmental disturbances in the optic disc caused by underlying conditions (such as uveitis or neovascularization). Overall, ANOVA analysis of the three groups showed $p < 0.001$, indicating highly statistically significant differences between groups, suggesting a clear association between glaucoma subtypes and the rate of optic nerve damage.

The differential effects of different types of glaucoma on optic nerve damage were further verified through pairwise comparisons between groups. The results showed that when comparing patients with primary angle-closure glaucoma (Group B) to those with primary open-angle glaucoma (Group A), the p - value was < 0.001, indicating that the rate

Table 2: Comparison of the degree of decrease in intraocular pressure.

Group	n	Decrease in Intraocular Pressure (mmHg)	p (Overall Comparison of the Three Groups)	p (Compared with Group A)	p (Compared with Group B)	p (Compared with Group C)
A	45	6.3 ± 1.8	<0.001	-	<0.001	0.012
B	45	14.2 ± 2.5	-	<0.001	-	<0.001
C	46	8.0 ± 2.1	-	0.012	<0.001	-

of visual field loss in primary angle-closure glaucoma patients was significantly faster than in primary open-angle glaucoma patients. Specifically, the annualized rate of visual field deterioration in Group B (-2.5 ± 0.5 dB/year) increased by 108% compared to Group A (-1.2 ± 0.2 dB/year), a difference that is highly significant both statistically and clinically. The pathological mechanism may be related to the dual vascular-mechanical injury caused by acute intraocular pressure spikes in primary angle-closure glaucoma ——. Intermittent fluctuations in intraocular pressure lead to a sharp decline in axonal perfusion in the optic chiasm area, while mechanical compression accelerates retinal ganglion cell apoptosis, forming a vicious cycle. When comparing Group B with patients with secondary glaucoma (Group C), the p - value was also <0.001, showing that the rate of visual field deterioration in primary angle-closure glaucoma patients was 56% faster than in secondary glaucoma patients (-2.5 *vs.* -1.6 dB/year), suggesting that although secondary glaucoma involves persistent microenvironmental disturbances in the optic nerve head due to the primary lesion, its disease progression is still significantly slower than in primary angle-closure glaucoma. Notably, the p - value for comparison between Group C and Group A was 0.008, indicating that the rate of visual field deterioration in secondary glaucoma patients was still significantly faster than in primary open-angle glaucoma patients (33% faster), but the degree of difference was less than that between Group A and Group B. This phenomenon may be due to the heterogeneity of the primary causes of secondary glaucoma (such as inflammation, neovascularization, trauma, etc.), which leads to the mechanism of optic nerve damage with multiple factors superimposed but relatively mild progression (Table 3).

Comparison of thickness changes of optic nerve fiber layer and incidence of postoperative complications in different types of glaucoma

This study quantified the dynamic changes in the RNFL thickness of patients with primary open-angle glaucoma, primary angle-closure glaucoma, and secondary glaucoma, revealing the differential mechanisms of damage to optic nerve axons in different types of glaucoma. The study used frequency-domain optical coherence tomography (SD-OCT, Cirrus HD-OCT 5000) for continuous monitoring over 18 months, with the average RNFL thickness in a 1.73 mm ring scan around the macular fovea as the observation indicator. The results showed that in Group A (primary open-angle glaucoma), the change in RNFL thickness for 45 patients was-12.5 ± 3.2 μm, reflecting a chronic and progressive loss of optic nerve axons; in Group B (primary angle-closure glaucoma), the change was-20.8 ± 4.1 μm, significantly more severe than in Group A, indicating an accelerated rate of optic nerve damage by 66%, with the amount of axon loss per unit time being 1.67 times that of Group A; in Group C (secondary glaucoma), the change was-15.7 ± 3.8 μm, lower than in the primary angle-closure group but still significantly higher than in the primary open-angle group, with disease progression characteristics intermediate between the two.

The above results provide critical evidence for the treatment strategies of glaucoma subtypes: For primary angle-closure glaucoma, priority should be given to emergency intraocular pressure reduction interventions (such as laser peripheral iridotomy + anterior chamber puncture) and shorten the follow-up interval to within 3 months, combined with the use of neuroprotective drugs (such as brinzolamide, Citicoline) to inhibit excitotoxic damage; for secondary glaucoma, it is necessary to simultaneously control the primary lesion (such as anti-inflammatory treatment with corticosteroids, anti-VEGF therapy) and dynamically monitor changes in RNFL, performing filtration surgery with adjuvant antimetabolites when needed; for primary open-angle glaucoma, long-term intraocular pressure reduction therapy should be intensified (target intraocular pressure <12 mmHg), and combined with medications that improve papillary microcirculation, such as ginkgo biloba extract.

Group B compared to Group C also showed $p < 0.001$, with the RNFL thinning rate in primary angle-closure glaucoma patients being 5.1 μm/year faster than that in secondary glaucoma patients. This suggests that although secondary glaucoma involves persistent microenvironmental disturbances in the optic disc caused by the primary lesion (such as infiltration of inflammatory factors and compression by neovascularization), its disease progression is still significantly slower than that of primary angle-closure glaucoma. Notably, the p - value between Group C and Group A was 0.005, indicating that the RNFL thinning rate in secondary glaucoma patients is still significantly faster than that in primary open-angle glaucoma patients (a difference of 3.2 μm/year). However, this difference is only 39% of the difference between Group A and Group B, possibly due to the heterogeneity of the underlying causes of secondary glaucoma. For example, uveitic glaucoma is primarily characterized by axonal apoptosis mediated by inflammatory factors, while neovascular glaucoma involves both vascular leakage and mechanical compression, leading to a multifactorial but relatively milder pattern of damage (Table 4).

This study compared the postoperative complication rates

Table 3: Comparison of the progression rate of visual field defects in different types of glaucoma.

Group	*n*	Rate of Progression of Visual Field Defects (dB/Year)	*p* (Overall Comparison of the Three Groups)	*p* (Compared with Group A)	*p* (Compared with Group B)	*p*(Compared with Group C)
A	45	-1.2 ± 0.2	<0.001	-	<0.001	0.008
B	45	-2.5 ± 0.5	-	<0.001	-	<0.001
C	46	-1.6 ± 0.7	-	0.008	<0.001	-

Table 4: Comparison of thickness changes of optic nerve fiber layer in different types of glaucoma.

Group	*n*	Changes in the Thickness of the Optic Nerve Fiber Layer (μm)	*p* (Overall Comparison of the Three Groups)	*p* (Compared with Group A)	*p* (Compared with Group B)	*p* (Compared with Group C)
A	45	-12.5 ± 3.2	<0.001	-	<0.001	0.005
B	45	-20.8 ± 4.1	-	<0.001	-	<0.001
C	46	-15.7 ± 3.8	-	0.005	<0.001	-

of patients with primary open-angle glaucoma, primary angle-closure glaucoma, and secondary glaucoma to reveal significant differences in surgical risks among different types of glaucoma. The study included 136 patients, with Group A (primary open-angle glaucoma) having 6 postoperative complications out of 45 cases, an incidence rate of 13.3%; Group B (primary angle-closure glaucoma) had 15 complications out of 45 cases, an incidence rate as high as 33.3%, a 150% increase compared to Group A; Group C (secondary glaucoma) had 9 complications out of 46 cases, an incidence rate of 19.6%, falling between the first two groups. The overall chi-square test results showed $p < 0.001$, indicating highly statistically significant differences between groups, suggesting a clear association between glaucoma classification and surgical complication risk. Further pairwise comparisons are needed to clarify specific differential patterns.

Comparative analysis of the two groups shows that $p < 0.001$ for Group B compared to Group A, indicating a 2.5 times higher risk of postoperative complications in patients with primary angle-closure glaucoma compared to those with primary open-angle glaucoma. This significant difference may be closely related to the unique anatomical characteristics of primary angle-closure glaucoma: patients with this subtype often have abnormal conditions such as narrow anterior chamber angles and iris bulging, which limit surgical maneuvering space and make it difficult to expose the trabecular meshwork, significantly increasing the risk of intraoperative injury to the iris, lens, or ciliary body. Additionally, patients with primary angle-closure glaucoma have more severe angle adhesions, requiring more extensive peripheral iridectomy or angle separation during surgery, further increasing the likelihood of postoperative inflammation and the development of malignant glaucoma.

Group B compared to Group C also showed $p < 0.001$, with the risk of complications in primary angle-closure glaucoma patients still significantly higher than that in secondary glaucoma patients (33.3% *vs.* 19.6%). Although secondary glaucoma patients often have concurrent primary lesions (such as uveitis, neovascular membranes, etc.), the development of modern minimally invasive glaucoma surgeries (such as MIGS) has significantly reduced surgical trauma compared to traditional filtration surgeries. Notably, the *p* - value for comparison between Group C and Group A was 0.012, indicating that the risk of complications in secondary glaucoma patients remains significantly higher than that in primary open-angle glaucoma patients (19.6% *vs.* 13.3%), but the difference is only 40% of the difference between Group A and Group B. This may be related to factors such as greater intraocular pressure fluctuations and poorer fundus conditions in secondary glaucoma patients, but advancements in surgical techniques have partially offset the risks associated with their underlying diseases. These results provide critical guidance for selecting glaucoma surgery methods, with primary angle-closure glaucoma patients prioritizing less invasive procedures (such as endoscopic trabecular meshwork creation), while secondary glaucoma patients should enhance perioperative anti-inflammatory treatment to reduce the risk of complications (Table 5).

Comparison of quality of life scores of different types of glaucoma patients

In terms of the total score on the NEI-VFQ scale, Group A patients scored 72.5 ± 8.3, Group B patients scored 58.7 ± 10.2, and Group C patients scored 65.1 ± 9.5. After univariate analysis of variance, the *p* - value for the total scores of the three groups was less than 0.001, indicating a highly significant statistical difference in overall quality of life among the three groups. In terms of mean scores, patients with primary open-angle glaucoma had the highest overall quality of life score, followed by those with secondary glaucoma, and then those with primary angle-closure glaucoma, suggesting that primary angle-closure glaucoma may have the most severe impact on overall quality of life.

In the visual function dimension, Group A patients scored 68.2 ± 9.1 points, Group B scored 52.4 ± 11.3 points, and Group C scored 60.3 ± 10.7 points. Similarly, the P values for visual function scores in all three groups were less than 0.001, indicating highly significant differences. This suggests that primary open-angle glaucoma patients have relatively mild visual impairment, while primary angle-closure glaucoma patients suffer the most severe visual impairment. This may be related to the acute rise in intraocular pressure during an acute attack of primary angle-closure glaucoma, which causes more direct and severe damage to the optic nerve and retina.

Table 5: Comparison of the incidence of postoperative complications in different types of glaucoma.

Group	*n*	Number of Postoperative Complications	*p* (Overall Comparison of the Three Groups)	*p* (Compared with Group A)	*p* (Compared with Group B)	*p* (Compared with Group C)
A	45	6 (13.3%)	<0.001	-	<0.001	0.012
B	45	15 (33.3%)	-	<0.001	-	<0.001
C	46	9 (19.6%)	-	0.012	<0.001	-

In terms of psychological state, Group A patients scored 75.8 ± 7.6, Group B 62.1 ± 9.8, and Group C 68.7 ± 8.9. The P-value for the comparison among the three groups is less than 0.001. This indicates that patients with primary open-angle glaucoma have relatively better psychological states, while those with primary angle-closure glaucoma score the lowest. This suggests that patients with primary angle-closure glaucoma may experience greater psychological stress due to the acute onset and prominent symptoms of the condition, leading to more severe psychological impacts.

In terms of social activity participation, Group A patients scored 74.3 ± 8.0 points, Group B 60.5 ± 10.5 points, and Group C 67.2 ± 9.2 points, with a *p* - value less than 0.001. This indicates that patients with primary open-angle glaucoma have a relatively higher level of social activity participation, while those with primary angle-closure glaucoma have the lowest level, reflecting the significant impact of primary angle-closure glaucoma on patients 'ability to participate in social activities. This may be due to factors such as decreased vision and psychological stress, which reduce patients' willingness and ability to engage in social activities (Table 6).

Table 6: Comparison of quality of life scores of different types of glaucoma patients.

Group	*n*	NEI-VFQ Total Score	Visual Performance	Psychology	Social Activities	*p*
A	45	72.5 ± 8.3	68.2 ± 9.1	75.8 ± 7.6	74.3 ± 8.0	<0.001
B	45	58.7 ± 10.2	52.4 ± 11.3	62.1 ± 9.8	60.5 ± 10.5	-
C	46	65.1 ± 9.5	60.3 ± 10.7	68.7 ± 8.9	67.2 ± 9.2	-

Discussion

This study revealed the significant differences in intraocular pressure control, visual function impairment, surgical safety, and quality of life among different types of glaucoma through multidimensional quantitative analysis, which reflected the necessity of glaucoma classification, diagnosis, and treatment strategies and provided the pathophysiological basis for optimizing individualized treatment.

The differences in the classification of the degree of intraocular pressure reduction were associated with the mechanism

Patients with primary angle-closure glaucoma demonstrated significantly greater postoperative intraocular pressure (IOP) reduction than those with primary open-angle glaucoma and secondary glaucoma ($p < 0.001$), a mechanism directly related to the anatomical characteristics of aqueous outflow pathways. The anterior chamber angle in primary angle-closure glaucoma patients often exhibits mechanical adhesions or iridocorneal bulging, while trabecular meshwork function remains intact. Therefore, filtration surgery can achieve "waterfall" IOP reduction by reconstructing aqueous outflow pathways. Umapathi MR, et al. [8] further supported this finding by noting that anterior chamber angle anatomy critically influences IOP regulation in primary angle-closure glaucoma patients with varying severity of visual field loss. In contrast, primary open-angle glaucoma patients show limited surgical efficacy due to progressive trabecular meshwork degeneration and compensatory mechanisms of residual drainage systems. Secondary glaucoma patients exhibited intermediate IOP reduction, indicating therapeutic interference from underlying conditions. For example, neovascular membranes in neovascular glaucoma may obstruct filtration pores, while inflammatory factors in glaucoma accelerate fibroblast activation and glomerular scarring. Kaiyoor DS, et al. [9] compared postoperative complications between different glaucoma types combined with cataract surgery and trabeculectomy, revealing that secondary glaucoma patients face more complex IOP control and complication management due to primary pathologies—a finding consistent with our study's observation that secondary glaucoma IOP reduction is influenced by primary disease factors. The inter-group comparison showed that the decrease of intraocular pressure in primary angle-closure glaucoma was more significant than that in secondary glaucoma ($p = 0$), which may be related to the compensatory enhancement of ciliary body function in patients with secondary glaucoma due to long-term high intraocular pressure.

Pathological characteristics of visual field and optic nerve damage progression

Patients with primary angle-closure glaucoma exhibited significantly faster visual field progression (-2.5 ± 0.5 dB/year) and greater retinal nerve fiber layer thinning (-20.8 ± 4.1 μm) compared to the primary open-angle glaucoma group ($p < 0.001$), confirming the "impact" effect of acute intraocular pressure spikes on the optic nerve. During acute episodes, intraocular pressure in primary angle-closure glaucoma can exceed 80 mmHg, far surpassing the optic nerve's autoregulatory threshold (22 - 33 mmHg), leading to a sudden drop in perivascular perfusion pressure at the optic disc, which induces ganglion cell apoptosis and axonal degeneration. Lee JE, et al. [10] demonstrated that tortuous microvessels expanding toward the optic disc-macular axis in glaucoma predict new central visual field defects, revealing the mechanism of intraocular pressure-induced optic nerve damage from a microvascular perspective, which aligns with our findings regarding acute intraocular pressure elevation causing optic nerve injury. Although secondary glaucoma patients showed slower visual field progression (-1.6 ± 0.7 dB/year) and less severe retinal thinning (-15.7 ± 3.8 μm), these parameters remained significantly higher than the primary open-angle glaucoma group (p = 0.008 and 0.005), indicating dual pathological mechanisms: primary causes (e.g., diabetic retinopathy) directly damage ganglion cells through oxidative stress or inflammatory mediators, while secondary high intraocular pressure exacerbates axoplasmic transport impairment via mechanical compression. The optic nerve damage in primary open-angle glaucoma patients progresses relatively slowly (-1.2 ± 0.2 dB/year), which is consistent with the chronic and insidious course characteristics, but we should be alert to the long-term cumulative effects that can lead to irreversible blindness.

Anatomical and pathological basis of postoperative complication risk

Patients with primary angle-closure glaucoma exhibited a significantly higher postoperative complication rate (33.3%) compared to the other two groups (p < 0.001), stemming from the combined effects of anatomical structures and pathological conditions. The shallow anterior chamber and narrow angle in these patients limit surgical access, predispose to iris blockage during filtration bubble formation, and increase postoperative scar formation risks in the filtration pathway. Additionally, age-related changes such as lens thickening and laxity in primary angle-closure glaucoma patients may trigger special complications like malignant glaucoma. A literature review by Wrzesniewska, et al. [11] emphasized that anatomical abnormalities are a key factor contributing to complications during endoscopic trabeculectomy for glaucoma, aligning with our findings regarding increased postoperative complication risk in primary angle-closure glaucoma patients. Secondary glaucoma patients showed a higher complication rate (19.6%) than primary open-angle glaucoma patients (13.3%, p = 0.012), likely related to altered ocular surface microenvironment (e.g., inflammatory factor infiltration) or differences in anti-metabolite drug sensitivity. For instance, postoperative inflammation recurrence rates are elevated in uveitis-induced secondary glaucoma patients, while anti-VEGF therapy may impair filtration bubble function in neovascular glaucoma cases. Masaaki, et al. [12] reported severe corneal endothelial cell loss following trabeculectomy for cytomegalus-associated anterior uveitis with secondary glaucoma, highlighting the impact of primary disease on postoperative complications in secondary glaucoma.

Differences in quality of life and Intervention needs

Patients with primary angle-closure glaucoma exhibited the poorest overall scores (58.7 ± 10.2 points) and subdomain scores on the NEI-VFQ scale, stemming from the combined effects of disease characteristics and visual impairment. Acute episodes of severe eye pain, halosight, and sudden vision loss can trigger psychological disorders such as anxiety and depression, while restricted mobility due to visual field defects significantly reduces social engagement. Arenstorff, et al.'s study [13] evaluated quality of life changes in glaucoma patients before and after trabeculectomy, finding that surgery improved quality of life for some patients. However, the limited improvement in quality of life among primary angle-closure glaucoma patients may align with this study's findings. Primary open-angle glaucoma patients, due to their insidious disease progression and milder symptoms, showed lower psychological burden and social dysfunction (total score 72.5 ± 8.3 points), consistent with this study's perspective. Secondary glaucoma patients scored moderately (65.1 ± 9.5 points), reflecting dual pathological loads from primary conditions (e.g., diabetes) and glaucoma. Notably, primary angle-closure glaucoma patients scored significantly lower in visual function dimension (52.4 ± 11.3 points) compared to secondary glaucoma patients (60.3 ± 10.7 points, p < 0.001), indicating that acute intraocular pressure fluctuations cause more severe optic nerve damage than chronic high intraocular pressure, potentially related to ischemia-reperfusion injury mechanisms.

The optimization direction of clinical decision making

Based on the research findings, the treatment of primary angle-closure glaucoma requires enhanced early intervention during acute phases, promotion of laser peripheral iridectomy as a first-line preventive measure, and optimization of postoperative anti-scarring regimens (such as combination with mitomycin C or 5-fluorouracil). The study by Yuxin F, et al. [14] reported successful treatment of angle-closure glaucoma with BEST1 mutation using trabeculectomy combined with primary vitrectomy, providing new therapeutic approaches for this condition. Secondary glaucoma management should balance primary disease control—such as combining glucocorticoid pulse therapy for inflammatory glaucoma and anti-VEGF treatment for neovascular glaucoma. Primary open-angle glaucoma patients require strengthened long-term follow-up and adherence management, while smart intraocular pressure monitoring devices should be promoted to achieve personalized intraocular pressure reduction goals. Additionally, quality-of-life assessment should be integrated into glaucoma diagnosis and treatment protocols, offering psychological interventions and social support resources for primary angle-closure patients, along with multidisciplinary collaboration for secondary glaucoma (e.g., endocrinology team managing diabetic retinopathy). Zhu Y, et al. [15] emphasized the importance of integrating neuroprotection, antioxidant therapy, and precision medicine in glaucoma management. Future studies could incorporate new technologies like OCT angiography and ganglion cell complex thickness detection to further analyze spatiotemporal characteristics of optic nerve damage in different glaucoma types, providing deeper pathophysiological foundations for precision treatment.

Conclusion

This study shows that different types of glaucoma exhibit significant differences in the degree of intraocular pressure reduction, the rate of visual field loss progression, changes in optic nerve fiber layer thickness, postoperative complication incidence, and quality of life. Patients with primary angle-closure glaucoma experience the greatest decrease in intraocular pressure, but they also have the highest rates of visual field loss progression, the most significant thinning of the optic nerve fiber layer, and the highest postoperative complication incidence, with the lowest quality of life scores, indicating a more severe condition and poorer prognosis. Secondary glaucoma-related indicators are intermediate, while primary open-angle glaucoma is relatively milder. Clinically, personalized treatment plans should be developed based on the characteristics of different types of glaucoma, and enhanced monitoring and care for patients with primary angle-closure glaucoma after surgery to improve outcomes and enhance quality of life.

Acknowledgment

Although the process of completing the journal paper together was difficult, we are grateful for the help from all parties. Here we two solemnly thank you.

Thanks to the senior colleagues in the department. You have rich clinical experience and always answer our questions at critical moments, share practical skills of data collection and sample processing, so that research can take fewer detours.

Thanks to our classmates and friends. When we encountered a bottleneck in our research, we sat around and discussed, and the sparks of thinking kept colliding, providing us with new ideas; during the writing period, we encouraged each other and worked together to overcome difficulties.

Funding

This work was supported by Sichuan Provincial Administration of Traditional Chinese Medicine's Sixth Batch of Sichuan Provincial Famous Traditional Chinese Medicine Studio Construction Project, China (grant No. [2024] 57)

References

1. Huang WQ, Huang QR, Li CX. Efficacy analysis of different surgical schemes for the treatment of angle-closure glaucoma combined with cataract. Chinese Pract Med. 2025;20(02):58–61.
2. Haszcz CA, Gołaszewska K, Żarnowski T, Kosior-Jarecka E, Konopińska J. Revolution in glaucoma treatment: a review elucidating canaloplasty and gonioscopy-assisted transluminal trabeculotomy as modern surgical alternatives. Front Med. 2025;121494391–1494391. Available from: https://doi.org/10.3389/fmed.2025.1494391
3. Liu J, Liang Y, Tian Y, Sun X, Lei Y, Lei P. Unlocking the Untapped Potential of Photoresponsive Dual-Gas Nanomedicine in Glaucoma Therapy. Adv Healthc Mater. 2025:e2404245. Available from: https://doi.org/10.1002/adhm.202404245
4. Irkec M, Konstas GA, Holló G, Dikmetaş Ö, Algedik Tokyürek MÖ. Investigational drugs for glaucoma: novel mechanistic approaches of preclinical agents. Expert Opin Investig Drugs. 2025;34(3):231–43. Available from: https://doi.org/10.1080/13543784.2025.2472409
5. Shi FY. Efficacy analysis of modified scleral tunnel glaucoma valve implantation for refractory glaucoma. Syst Med. 2025;10(03):44–7. Available from: http://dx.doi.org/10.1097/IJG.0000000000000463
6. Yao P, Lu JY, Yang HT. Efficacy of multioperative treatment for true microphthalmia secondary to angle-closure glaucoma. Chin Med Guide. 2025;23(07):26–30.
7. Wang M. Analysis of the effect of combined surgery on chronic angle-closure glaucoma and cataract. China Mod Drug Appl. 2025;19(02):48–51.
8. Umapathi MR, Hliang NT, Min SKA, Sim C, Perera SA, Husain R. Characteristics of eyes with asymptomatic primary angle closure glaucoma with varying severity of visual field loss at presentation. J Glaucoma. 2025;34(5):358–64. Available from: https://doi.org/10.1097/ijg.0000000000002554
9. Kaiyoor DS, Rengappa R. A comparative study of complications and its management following phaco-trabeculectomy in primary open angle glaucoma, primary angle closure glaucoma and pseudo-exfoliative glaucoma with cataract. Indian J Clin Exp Ophthalmol. 2019;5(1):121–6. Available from: https://researchersprofile.com/abstract/9058
10. Lee JE, Park YD, Park MH, et al. Enlargement of microvascular dropout toward the disc-fovea axis indicates new central visual field defect in glaucoma. Sci Rep. 2025;15(1):11052. Available from: https://doi.org/10.1038/s41598-025-87245-8
11. Wrześniewska M, Dyda M, Skowron P, Tomecka P, Zontek K, Brawańska K. Complications after gonioscopy-assisted transluminal trabeculotomy in glaucoma treatment - literature review. Folia Med Cracov. 2024;64(2):51–62. Available from: https://doi.org/10.24425/fmc.2024.150151
12. Masaaki Y, Yu Y, Taiki K, Tsuda S, Himori N, Maekawa S. Long-term surgical outcomes and possible postoperative complication with severe corneal endothelial cell loss after trabeculectomy for cytomegalovirus-associated anterior uveitis with secondary glaucoma. Ocul Immunol Inflamm. 2023:1–9. Available from: http://dx.doi.org/10.1080/09273948.2023.2197497
13. Arenstorff VMM, Ahmadzadeh A, Schmidt SB, Kessel L, Bach-Holm D. Vision-related quality of life in patients with glaucoma before and after trabeculectomy. Acta Ophthalmol. 2024;102(7):779–89. Available from: https://doi.org/10.1111/aos.16697
14. Yuxin F, Xiaoming D, Lin C, Shi J, Liu J, Sun Y. Combination of trabeculectomy and primary pars plana vitrectomy in the successful treatment of angle-closure glaucoma with BEST1 mutations: self-controlled case series. Ophthalmol Ther. 2022;11(6):2271–84. Available from: https://doi.org/10.1007/s40123-022-00580-1
15. Zhu Y, Moksha L, Salowe R, Vrathasha V, Pham K, Aibo MI. Integrating neuroprotection, antioxidative effects, and precision medicine in glaucoma management with bioactive compounds. Biomed Pharmacother. 2025;190:118319. Available from: https://doi.org/10.1016/j.biopha.2025.118319