BMC Ophthalmology

RESEARCH

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Comparative evaluation of phacoemulsification combined with goniosynechi-alysis with goniotomy versus trabeculectomy in patients with angle-closure glaucoma and cataract

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Abstract

Purpose This study aims to evaluate the effectiveness and safety of phacoemulsification cataract extraction with intraocular lens implantation (PEI) combined with Goniosynechialysis (GSL), Goni-otomy (GT), and PEI combined with Trabeculectomy (TRAB), in managing mid to late-stage Primary Angle-Closure Glaucoma (PACG) combined with cataract.

Methods A retrospective analysis was conducted on 42 patients (54 eyes) with mid to late-stage PACG combined with cataracts, who were previously treated at Dongyang People's Hospital from December 3, 2020, to November 30, 2023. Among them, 16 (24 eyes) underwent PEI-GSL-GT, and 26 (30 eyes) underwent PEI-TRAB. After minimum of 6 months of postoperative follow-up, observations were made on intraocular pressure (IOP), best-corrected visual acuity (BCVA), use of antiglaucoma medications, and complications for both surgical procedures.

Results Postoperative BCVA improved significantly in both groups. In the PEI-GSL-GT group, IOP decreased by 26% (from 17.75 to 13.13 mmHg); in the PEI-TRAB group, it decreased by 14.5% (from 17.87 to 15.27 mmHg). At the 6-month follow-up, IOP was significantly lower in the PEI-GSL-GT group compared to the PEI-TRAB group. The number of patients using antiglaucoma medications decreased significantly in both groups. By the 6-month follow-up, no patients in the PEI-GSL-GT group were using antiglaucoma medications.

Conclusions PEI-GSL-GT is more effective than PEI-TRAB in lowering IOP in patients with mid to late-stage PACG, potentially reducing or discontinuing postoperative antiglaucoma medications, decreasing postoperative complications, and improving visual acuity.

Keywords Goniotomy, Goniosynechialysis, Trabeculectomy, Phacoemulsification cataract extraction with intraocular lens implantation, Primary angle-closure glaucoma

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Introduction

Glaucoma is a condition marked by permanent harm to the optic nerve due to high IOP which cannot be reversed. By 2040, the global prevalence of glaucoma is projected to rise to 111.8 million, with PACG being most common in Asia [1].

In China, PACG accounts for a significant proportion, leading to a higher probability of irreversible blindness [2]. With China's aging population there is an expected surge in demand for glaucoma treatment. The primary pathogenesis of PACG involves closure of the anterior chamber angle, leading to obstruction of aqueous humor outflow, resulting in elevated IOP and damage to the visual field and the optic nerve. As optic nerve damage caused by glaucoma is currently irreversible, reducing IOP is crucial for preventing or slowing disease progression. At present, the primary approaches to reducing IOP comprise of medication, laser therapy, and surgical intervention [3]. For patients with advanced glaucoma who do not respond well to conservative treatment for controlling IOP, surgery is often the primary method for IOP control.

Currently, PEI-GSL has become a common surgical treatment for PACG with cataract [4]. This procedure is mainly suitable for patients with anterior chamber angle adhesions involving less than 180° [5]. Persistent adhesions between the trabecular meshwork and iris hinder aqueous humor outflow, leading to mitochondrial dysfunction and trabecular meshwork fusion, resulting in irreversible damage to trabecular meshwork cells [6–7]. Therefore, for most patients with adhesions involving more than 180°, simple GSL may still leave residual glaucoma, necessitating TRAB [5, 8]. However, as TRAB is dependent on the functioning of the filtration bleb, postoperative care of the bleb is demanding and complications are common, including bleb scarring, excessive filtration, choroidal detachment, malignant glaucoma, endophthalmitis, etc [9]. Some patients often experience surgical failure due to postoperative bleb scarring. This aligns with findings from Clement Tham et al., emphasizing the necessity of combining Phaco with GSL or TRAB in advanced PACG cases due to extensive synechial closure [10, 11].

Over the past few years, there has been a gradual emergence of minimally invasive glaucoma surgery (MIGS), which provides benefits like minimal trauma, reduced complications, and enhanced safety. Currently, domestically, clinical practice in MIGS mainly includes gonioscopy-assisted transluminal trabeculotomy (GATT), canaloplasty (CP), and trabeculotome tunnelling trabeculoplasty (3T) surgeries, among others. One of the surgical methods within MIGS that focuses on the trabecular meshwork-Schlemm's canal pathway is Schlemm's canal incision surgery. The surgery involves incising the inner wall of the trabecular meshwork and Schlemm's canal to reduce resistance to aqueous humor outflow, thereby lowering IOP [12]. Literature has reported that GSL and GT can effectively reduce IOP in angle closure glaucoma and decrease the use of antiglaucoma medications [13, 14]. However, based on our search, there are currently no reports comparing the efficacy and safety of Goniosynechialysis and goniotomy versus trabeculectomy. Therefore, we conducted a retrospective analysis of the postoperative outcomes of patients who underwent these two surgical methods at our hospital from December 2020 to November 2023.

This study aims to observe and analyze the efficacy of PEI-GSL-GT compared to PEI-TRAB in the treatment of mid to late stage PACG with cataract, and to evaluate its safety.

Materials and methods

General information

The patients' clinical record data were retrospectively collected analyzed anonymously. The enrolled cases were diagnosed as mid to late-stage PACG combined with cataract from December 3,2020, to November 30, 2023.

Due to the retrospective nature of this study, the exact duration of glaucoma progression for each patient was not consistently available. However, all included patients were diagnosed with mid-to-late stage primary angle-closure glaucoma based on predefined inclusion criteria. The inclusion criteria are as follows: (1) Best-Corrected Visual Acuity (BCVA) lower than 0.5 LogMAR was measured using a logarithm of the minimum angle of resolution (logMAR) chart at a distance of 5 m. (2) Gonioscopy demonstrated angle closure characterized by peripheral anterior synechiae (PAS) over a range exceeding 180°, covering specific regions such as the nasal side, nasal inferior, and nasal superior angles. Gonioscopy was used to evaluate the anterior chamber angle, and the degree of angle closure was graded using the Shaffer grading system. The inclusion criterion of more than 180° of angle closure refers specifically to PAS and does not include appositional angle closure. (3) IOP > 21 mmHg regardless of the use of antiglaucoma medications, (4) presence of glaucomatous optic neuropathy (cup-to-disc ratio ≥ 0.7 or inter-eye cup-to-disc ratio difference > 0.2). (5) Glaucomatous visual field defects diagnosed by Humphrey visual field examination using the SITA-standard 24 – 2 or 30 – 2 protocols, such as paracentral scotoma, nasal step, arcuate defect, and tunnel vision, with mean deviation (MD) ≤ -6dB [15–16]. Patients meeting criteria (2), (3), and (4), or (2), (3), and (5), are diagnosed as having mid to late-stage PACG.

The study excludes participants who have: (1) secondary PACG, (2) a history of previous ocular surgery or trauma, (3) severe systemic diseases that are not conducive to surgery, (4) diabetes, or (5) other ocular diseases necessitating surgical treatment.

Primary and Secondary Outcome Measures. The primary outcome measure was the reduction in IOP at 6 months postoperatively. Secondary outcome measures included changes in BCVA, the number of antiglaucoma medications required, and the incidence of postoperative complications.

Ocular examinations

All participants underwent comprehensive ophthalmic examinations preoperatively and postoperatively, including anterior and posterior segment examination using slit-lamp biomicroscopy with a slit-lamp lens (Volk 90 D Slit-Lamp Lenses, VOLK), and IOP measurement using non-contact intraocular pressure examination (NT-530P; NIDEK). Anterior chamber angle examination was conducted with a gonioscopy (OSMGA, OCULAR). Visual acuity and best corrected visual acuity examinations (BCVA) were performed using Standard logarithmic acuity chart at a distance of 5 m. The visual field test was performed using the 24 – 2 Swedish Interactive Thresholding Algorithm standard by a Humphrey field analyzer (Humphrey; Carl Zeiss Meditec). All examinations were conducted by experienced examiners and ophthalmologists following standard procedures. Data on BCVA, IOP, use of antiglaucoma medications, and surgical-related complications were documented. Data on BCVA (logMAR), IOP, use of antiglaucoma medications, and surgical-related complications were meticulously recorded at each follow-up appointment.

Surgical procedures

Experienced surgeons skilled in both cataract and glaucoma procedures conducted all surgeries. For all surgeries, sub-Tenon's anesthesia with lidocaine was used during the surgical procedure. Some patients undergoing TRB also received subconjunctival anesthesia.

PEI-GSL-GT

In the left eye, the corneal side incision was made at the 2–3 o'clock position, while in the right eye, the main corneal incision was located at the 9–10 o'clock position. This was followed by phacoemulsification of the cataract and subsequent implantation of an intraocular lens. After implantation, viscoelastic material was injected into the anterior chamber.

The microscope was tilted nasally at an angle of approximately 30–40 degrees. During the surgery, a nuclear hook was used under direct visualization with a gonioscopy lens to gently apply pressure to the iris root, thereby separating the adherent anterior chamber angle until the trabecular meshwork was exposed. Using Zeng's Trabeculotomy knife, the tip of the knife was gently maneuvered to incise the nasal side of Schlemm's canal, over a range of approximately 90° to 150°, where the white outer wall of Schlemm's canal was visible, accompanied by a small amount of red reflux. The GSL procedure was performed only at the site of the goniotomy to ensure precise removal of PAS within the incision range. The surgery was concluded with the sealing of the corneal incision after the removal of the viscoelastic material.

PEI-TRAB

Corneal traction sutures were applied, and a conjunctival flap with its base at the limbus was created. The sclera was cauterized for hemostasis. A scleral flap, approximately 4×4 mm in size with its base at the limbus and about half the thickness of the cornea, was created. The corneal side incision was made at the 2–3 o'clock position, and the main corneal incision was located at the 9–10 o'clock position. After phacoemulsification of the cataract and implantation of an intraocular lens, a 1×3 mm strip of trabecular tissue was excised, along with a peripheral iridectomy. Two 10 – 0 nylon sutures were positioned at the top edges of the scleral flap, along with two adjustable sutures. The conjunctival wound was closed with 10 – 0 nylon sutures. After the removal of the viscoelastic material, the corneal incision was sealed, and the filtering bleb was observed to disperse, completing the surgery.

Three days prior to surgery, both patient groups administered levofloxacin eye drops in the operated eye four times daily to prevent infection. At the conclusion of the surgery, tobramycin-dexamethasone eye ointment was applied within the conjunctival sac. Postoperatively, the regimen included levofloxacin, tobramycin-dexamethasone, and pranoprofen eye drops, each administered four times a day to prevent infections. Pilocarpine was not used in any of the patients. Adjustable sutures were typically removed 2–4 weeks postoperatively, depending on IOP stability or elevation. Local steroids and anti-glaucoma medications were adjusted according to changes in IOP.

Continuous data were presented as means and standard deviations, while categorical data were described using counts, fractions, or percentages. Qualitative variables in the two groups were analyzed using either Chi-square tests or Fisher's exact tests. Quantitative variables between groups were compared using t-tests or Mann-Whitney U tests. For analyzing data distribution patterns within groups, paired sample t-tests, repeated measures ANOVA, or Friedman tests were used. All tests were two-tailed by default unless specified otherwise. The Type I error rate was set at 5%, and a p-value of less than 0.05 was considered statistically significant. Statistical analyses were performed using SAS JMP software (JMP 14 Pro).

Table 1 Demographic characteristics and baseline clinical status

		PEI-GSL-GT (16 subjects)	PEI-TRAB (26 subjects)	*P* value
N of eyes (%)		24 (44.4)	30 (55.6)	-
Age, yr (mean ± SD)		71.25 ± 7.97	74.58 ± 9.65	0.2338
Gender	Male (%)	11 (68.75)	10 (38.46)	0.1109
	Female (%)	5 (31.25)	16 (61.54)	
Pre-op BCVA (logMAR)		0.73 ± 0.35	0.89 ± 0.39	0.1376
Pre-op cup-to-disc ratio		0.75 ± 0.17	0.61 ± 0.20	0.011
Pre-op closed angle range(degree)		255 ± 55.25	250 ± 61.19	0.45
Pre-op visual field defects(MD)		-20.41 ± 8.35	-17.64 ± 7.75	0.19
Pre-op glaucoma medication (n(%))	0	0	1	0.7595
	1	8	7	
	2	12	15	
	3	4	7	

Table 2 IOP at each time point after operation

IOP(mmHg)	PEI-GSL-GT(mean ± SD) (24eyes)	PEI-TRAB(mean ± SD) (30eyes)	*P***
Pre-op	17.75 ± 4.54	17.87 ± 3.13	0.569
1 day	12.96 ± 3.79	16.73 ± 7.15	0.027
1 week	14.21 ± 5.00 †	14.23 ± 4.22	0.581
1 month	13.54 ± 2.25	15.8 ± 3.92	0.029
3 months	12.91 ± 2.39	14.13 ± 3.13	0.164
6 months	13.13 ± 2.79	15.27 ± 3.68	0.035
P*	0.0091	0.0008	

P*: result of repeated measurement test; P**: result of t-test or Mann–Whitney U test

† 1 data was excluded at 1 week after operation in PEI-GSL-GT group for Steroid-induced ocular hypertension

Results

Baseline data

The study sample consisted of 42 patients with a total of 54 eyes. Of these, 26 patients (30 eyes) underwent PEI-TRAB surgery, while 16 patients (24 eyes) underwent PEI-GSL-GT surgery. In terms of gender distribution, males predominated in the PEI-GSL-GT group. No statistically significant differences were observed in terms of age or other demographic factors ($P > 0.05$), as shown in Table 1.

Vision

The preoperative BCVA for the PEI-GSL-GT group was 0.73 ± 0.35, improving to 0.38 ± 0.30 at 3 months postoperatively. In the PEI-TRAB group, the preoperative BCVA was 0.89 ± 0.39, improving to 0.55 ± 0.07 at 3 months. Both groups demonstrated significant improvements in BCVA at 3 months post-surgery compared to their preoperative values, with statistically significant differences ($p < 0.001$). However, no statistically significant differences were found in BCVA between the groups either preoperatively or at 3months postoperatively ($p = 0.1376$, $p = 0.0904$).

IOP

Table 2 displays the IOP measurements for patients in both groups at various follow-up time intervals. According to repeated measures analysis of variance, the IOP values in both groups significantly decreased over the treatment period ($P < 0.05$). In the PEI-GSL-GT group, IOP decreased by 26%, from 17.75 mmHg to 13.13 mmHg, whereas in the PEI-TRAB group, it reduced by 14.5%, from 17.87 mmHg to 15.27 mmHg. The preoperative IOP in the PEI-GSL-GT group was 17.75 ± 4.54 mmHg, and the IOP at each subsequent time point postoperatively was significantly lower than preoperatively. Furthermore, significant differences in IOP values between the two groups were identified at specific postoperative time points: day 1, month 1, and month 6. At these time points, the IOP values in the PEI-GSL-GT group were lower than those in the PEI-TRAB group.

Antiglaucoma medication usage

In terms of the number of antiglaucoma medications used, both groups of patients demonstrated a significant reduction postoperatively compared to preoperative levels, with statistically significant differences observed. Before surgery, the PEI-GSL-GT group used an average of 2 (1, 2) types of antiglaucoma medications, whereas the PEI-TRAB group used an average of 2 (1, 2.25) types. At the 6-month follow-up, none of the patients in the PEI-GSL-GT group were using any antiglaucoma medications, while in the PEI-TRAB group, 5 patients were still using 1 to 2 types of antiglaucoma medications.

Complications

Surgical complications were reported in both groups（Table 3). In the PEI-GSL-GT group, intraoperative complications included one case of anterior chamber hemorrhage and one case of steroid-induced elevated IOP. Additionally, one patient developed cystoid macular edema approximately two months postoperatively. In the PEI-TRAB group, complications were primarily related

Table 3 Surgical complications associated with PEI-GSL-GT and PEI-TRAB

Complications	PEI-GSL-GT *n*	PEI-TRAB *n*	*P* value
Hyphema	1	1	
Choroidal detachment		1	
Bleb scarring		7	
Steroid-induced ocular hypertension	1		
Capsular contraction	1		
Filtration bleb leakage		1	
Excessive filtration		1	
Malignant glaucoma		1	
Macular Edema	1		
Total	4	12	0.0661

Hyphema was classified into five grades based on the proportion of the anterior chamber filled with blood: Grade 0 (microscopic hyphema), Grade I (≤ 1/3), Grade II (> 1/3 to ≤ 1/2), Grade III (> 1/2), and Grade IV (total hyphema)

to postoperative bleb issues, including one instance of anterior chamber hemorrhage, one case of malignant glaucoma, and seven instances of bleb fibrosis. There were no significant differences in the frequency of intraoperative complications between the two groups. However, the overall incidence of complications was notably lower in the PEI-GSL-GT group compared to the PEI-TRAB group.

Discussion

For patients with mid to late stage PACG and an extensive treatment history, PEI-GSL may not adequately address the underlying impaired trabecular meshwork function. This insufficiency can result in inadequate aqueous outflow or recurrent anterior chamber angle adhesions, often leading to suboptimal control of IOP or subsequent increases in IOP [17]. As a result, the standard surgical approach for mid to late stage PACG, particularly when combined with cataracts, has historically been a combined procedure of phacoemulsification and TRAB [18].

Traditional TRAB remains the mainstream surgical option for glaucoma treatment due to its effective reduction of IOP. However, this procedure involves a lengthy surgery, significant tissue damage, and relies on creating a filtration bleb, which can lead to unavoidable complications such as bleb leaks, bleb encapsulation, and bleb scarring.

In the past decade, various MIGS have continued to emerge, overcoming the drawbacks of surgeries reliant on filtration blebs [19]. The outflow of aqueous humor mainly occurs through the trabecular meshwork, Schlemm's canal, and distal outflow tissues [20]. In MIGS, procedures such as Schlemm's canal viscodilation and Schlemm's canal incision are primarily aimed at the trabecular meshwork and Schlemm's canal.

In PACG the main pathological feature is the gradual formation of peripheral iris adhesions, which ultimately lead to the closure of the anterior chamber angle. Prolonged elevated IOP and peripheral iris adhesions can induce a series of morphological and functional changes in the trabecular meshwork and Schlemm's canal [21]. Theoretically, IOP can be reduced by either removing or incising the affected trabecular meshwork, or by increasing its tension to enhance the drainage of aqueous humor into the collector channels [22].

In the PEI-GSL-GT group, we used Zeng's trabecular microbypass blade to incise the Schlemm's canal during surgery. The Zeng's trabecular microbypass blade was invented by Dr. Zeng Liuzhi, a prominent ophthalmologist in China. Its blade is triangular in shape with three edges, with a cutting angle of 30°. The blade is perpendicular to the working arm, forming a 90° angle, which enables precise incision of the inner wall tissue of the trabecular meshwork and Schlemm's canal simultaneously, facilitating easier expansion of the incision. This technique allows for easier opening of collapsed or narrowed Schlemm's canal without damaging the outer wall of the canal.

Research has shown that aqueous humor outflow in the eye is not uniformly consistent but rather exhibits segmental variation, with corresponding segmental activity and opening of Schlemm's canal [23]. In normal individuals, the cross-sectional area of the collector channels in the nasal quadrant is larger than that in the temporal quadrant [24]. Therefore, during surgery, we chose to incise the nasal quadrant of Schlemm's canal within a range of 90–120 degrees. It has indeed been demonstrated that incising within this range is sufficient to effectively control IOP.

The incision of Schlemm's canal, which targets the eye's natural drainage pathways, typically involves lower risks of severe complications due to the absence of a filtration bleb [25]. The primary complication associated with this procedure is anterior chamber hemorrhage; following the incision of the inner wall of Schlemm's canal, bleeding may occur, but it generally resolves within 3–5 days post-surgery. However, improper surgical techniques, such as damaging the outer wall of Schlemm's canal or the iris ciliary body, can lead to serious complications, including significant bleeding, detachment of the iris root, or dislocation of the ciliary body.

In this study, within the PEI-GSL-GT group, except for one case where intraoperative bleeding led to hyphema entering the vitreous cavity, which was absorbed within two weeks post-operatively, a small amount of Schlemm's canal hyphema in other patients was absorbed within 3–5 days. One patient experienced steroid-induced IOP elevation on the fourth day after surgery, which normalized after discontinuation of steroid eye drops. Another patient developed capsular phimosis syndrome about one month postoperatively, which resolved after laser capsulotomy with restored visual acuity. Additionally, around two months post-surgery, one patient developed cystoid macular edema, which subsided within a week after the application of topical non-steroidal anti-inflammatory eye drops.

In contrast, the most common postoperative complications in the PEI-TRAB group were related to filtering blebs. In this group, all patients developed filtering blebs immediately after surgery. Over time, 7 cases experienced bleb scarring, 1 case had bleb leakage, 1 case had excessive filtration, 1 case had choroidal detachment, 1 case had anterior chamber hyphema, and 1 case developed malignant glaucoma. The patient with bleb leakage achieved anterior chamber reformation with conservative treatment using a pressure bandage. The hemorrhage in the patient with anterior chamber hyphema resolved with conservative management. The patient with malignant glaucoma had their IOP controlled using mydriatics and pressure-lowering medications. The scarring and loss of the 7 filtering blebs occurred within 1–3 months postoperatively. Among these, 2 cases experienced recurrence of scarring after bleb revision surgery. Ultimately, at 3 months postoperatively, all 7 patients with bleb scarring lost their filtering blebs and required ongoing use of IOP-lowering medications.

One limitation of the trabeculectomy procedure in this study was the absence of mitomycin C (MMC), which is widely used to reduce scarring and improve the success rate of filtering blebs. Due to the discontinuation of MMC production in China, it was unavailable for clinical use during the study period. This factor may have influenced the surgical outcomes in the PEI-TRAB group. To optimize postoperative outcomes, adjustable sutures were used during the surgery, allowing for postoperative modification based on IOP levels. However, the lack of postoperative use of subconjunctival antifibrotic agents, which can mitigate fibrosis and enhance bleb function, may have further contributed to the lower-than-expected IOP reduction observed in this group. These limitations highlight the need for alternative antifibrotic strategies when MMC is unavailable.

Despite these complications, the IOP in all cases of bleb scarring was ultimately controlled within the normal range with medication. Notably, such complications were almost entirely absent in the PEI-GSL-GT group. At the final follow-up, the mean IOP in eyes with functioning filtering blebs was 13.91 ± 2.45 mmHg, while in eyes where filtering blebs were lost due to scarring, the mean IOP was 19.71 ± 3.64 mmHg with the use of IOP-lowering medications. These findings highlight the importance of maintaining functioning filtering blebs in achieving optimal IOP control.

This study conducted a 6-month postoperative follow-up for both patient groups. The results showed that in the PEI-GSL-GT group, the IOP decreased from 17.75 to 13.13 mmHg. In contrast, the PEI-TRAB group experienced a decrease in IOP from 17.87 to 15.27 mmHg. At the 6-month follow-up, the IOP was significantly lower in the PEI-GSL-GT group compared to the PEI-TRAB group. Additionally, due to the inclusion of cataract surgery, patients in both groups experienced varying degrees of improvement in visual acuity postoperatively. Notably, at the last follow-up, none of the patients in the PEI-GSL-GT group were using antiglaucoma medications, which highlights a significant advantage over the PEI-TRAB group.

Since PEI-GSL-GT does not rely on filtering blebs, it effectively addresses issues such as excessive early postoperative filtration, shallow anterior chamber, bleb leakage, and late-stage bleb scarring that lead to increased IOP. Therefore, for patients with coexisting cataracts and mid to late-stage PACG, the PEI-GSL-GT group shows significant advantages in postoperative complications and IOP control compared to the PEI-TRB group. We recommend PEI-GSL-GT as the preferred option, with PEI-TRB as an alternative if the initial surgery does not succeed.

Throughout the study, PEI-GSL-GT has demonstrated several advantages over the traditional PEI-TRAB. By removing cataracts, it not only widens the anterior chamber angle and improves the outflow of aqueous humor but also opens adhesions in the angle through goniosynechialysis. Additionally, it reduces IOP by incising the inner wall of Schlemm's canal and removing diseased trabecular tissue, thereby decreasing resistance to aqueous humor outflow. PEI-GSL-GT surpasses PEI-TRB in reducing the use of antiglaucoma medications postoperatively, controlling IOP, and lowering the incidence of complications. For patients with mid to late-stage PACG and coexisting cataracts, PEI-GSL-GT can be considered an effective alternative to the conventional PEI-TRB approach.

In summary, PEI-GSL-GT surgery effectively reduces IOP in patients with mid-to-late stage PACG and coexisting cataracts, and further improves vision. Moreover,

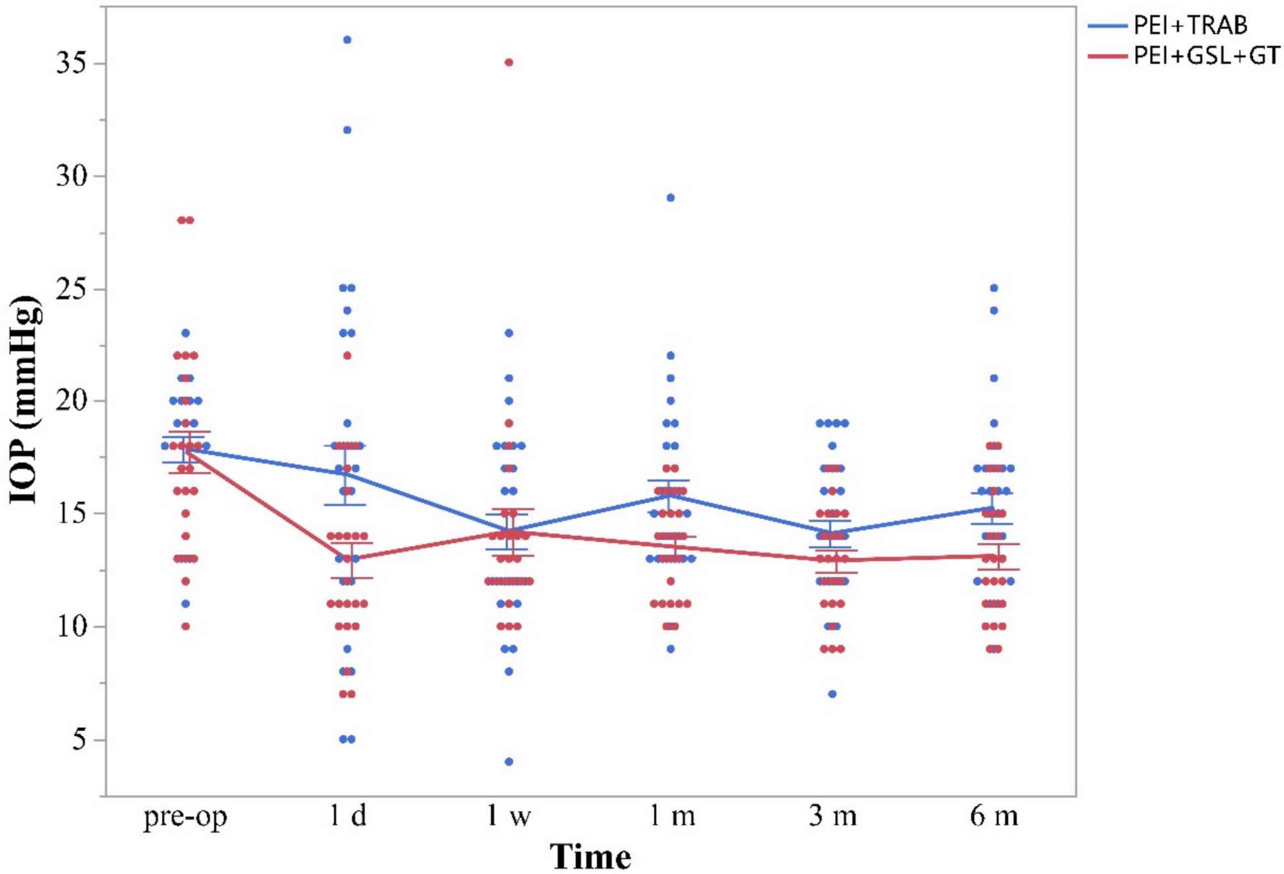

Fig. 1 Mean IOP at each time point (Each error bar is constructed using one standard error from the mean)

it avoids many postoperative complications such as encapsulation, leakage, and scarring of the filtering bleb, making it a safe and effective surgical option for treating patients with mid-to-late stage PACG and coexisting cataracts.

This study, however, has several limitations. First, the use of air puff tonometry for IOP measurement, although non-invasive and commonly used in clinical practice, may have lower accuracy compared to Goldmann applanation tonometry, potentially affecting the precision of IOP data. Future studies should consider adopting Goldmann tonometry for more reliable measurements. Second, as a retrospective study with a limited sample size and relatively short follow-up period, the long-term efficacy of the surgery remains to be validated. Further multicenter prospective studies are warranted to address these limitations.

Acknowledgements
We thank Professor Xiulan Zhang for her guidance and support during this study.

Author contributions
ML conceived the idea, statistical data, data analysis and prepared the manuscript. YJ data analysis, prepared Fig. 1, revision of manuscript. JH statistical data.

Funding
The study was supported by the Jinhua Municipal Bureau of Science and Technology (Grant/Award Number: 2023-4-269).

Data availability
The data that support the findings of this study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate
The written consent was waived by the Medical Ethics Committee of Dongyang People's Hospital due to its retrospective nature. The study was approved by the Medical Ethics Committee of Dongyang People's Hospital on April 29, 2024 (ID: 2024-YX-132) and adhered to the tenets of the Declaration of Helsinki.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Received: 27 June 2024 / Accepted: 17 February 2025
Published online: 27 February 2025

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