• Clinical Research •

Goniosynechialysis under a microscope alone and under direct gonioscopy for chronic angle-closure glaucoma patients coexisted with cataract

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Received: 2025-03-25 Accepted: 2025-09-22

Abstract

● **AIM:** To compare the efficacy of goniosynechialysis (GSL) under a microscope alone (GM) and under direct gonioscopy (GG) for chronic angle-closure glaucoma (CACG) coexisted with cataract.

● **METHODS:** A prospective, single-center, and randomized controlled trial was conducted. Patients diagnosed as CACG and cataract were randomly allocated into either GM group or GG group. In GM group, the range of peripheral anterior synechiae (PAS) was confirmed through gonio-lens after phacoemulsification with intraocular lens implantation (PEI). PAS was separated only under a microscope. After separating the closed angle of 360° by this method, we used a surgical gonioscope to confirm the PAS range. If any remaining PAS was present, we would separate them with an iris repositor under the direct gonio-lens until angle of 360° was reopened. In GG group, PAS was separated under direct gonioscopy after PEI until angle of 360° was reopened. The range of residual PAS after GSLs was the primary outcome. Intraoperative complications (hyphema), intraocular pressure (IOP) and anti-glaucoma medication usage after operation were the secondary outcomes.

● **RESULTS:** Sixty eyes were included, each group comprising 30 eyes. The average age [GM group: 66.3±6.8y (12 males), GG group: 67.6±8.9y (7 males), P=0.550], the baseline IOP (GM group: 29.6±11.5 mm Hg, GG group: 32.4±12.2 mm Hg, P=0.366) and the average initial PAS extent (GM group: 8.9±2.6h, GG group: 9.4±2.5h, P=0.425) were similar in the two groups. In GM group, the PAS range reduced from 8.9±2.6h before operation to 7.2±2.9h after PEI and 3.3±2.2h after GSL. In GG group, the PAS range reduced from 9.4±2.5h before operation to 7.5±2.9h after PEI and 0.1±0.3h after GSL. The PAS after PEI was significantly reduced compared to the pre-operative PAS in both groups (all P<0.001). The extent of residual PAS after GSL in GM group was larger than that in GG group with significant statistical difference (P<0.001). Patients who underwent GSL without a gonioscope were more likely to develop hyphema than those who underwent GSL under direct gonioscopy. The difference of hyphema grade between the two groups was statistically significant (P=0.019).

● **CONCLUSION:** PEI alone can not open 360° of angle completely. PEI+GSL significantly reduced PAS range. But for patients with CACG, GSL under a microscope alone is more difficult to separate stable PAS completely and adequately than GSL under direct gonioscopy.

● **KEYWORDS:** goniosynechialysis; phacoemulsification; chronic angle-closure glaucoma; peripheral anterior synechiae; cataract

DOI:10.18240/ijo.2026.03.09

Citation: Du J, Li YY, Chen DF, Li JQ, Huang QJ, Zhu SQ, Ye WQ, Zhu S, Xu SX, Li GX, Liang YB. Goniosynechialysis under a microscope alone and under direct gonioscopy for chronic angle-closure glaucoma patients coexisted with cataract. *Int J Ophthalmol* 2026;19(3):490-497

INTRODUCTION

Chronic angle-closure glaucoma (CACG) is a leading global cause of blindness, particularly prevalent in Asia[1]. This condition is characterized by the appositional or synechial closure of the anterior chamber angle[2]. CACG's multifaceted etiology highlights the importance of permanent peripheral anterior synechiae (PAS) in its pathogenesis.

Prolonged narrow angles or appositional closure can lead to PAS, causing pupillary blockage and increased intraocular pressure (IOP). CACG, a long-standing condition, typically exhibits elevated IOP when the angle is closed by more than 180 degrees due to PAS[3]. The treatment of CACG focuses on reopening the anterior chamber angle, deepening the anterior chamber and reducing IOP, with a crucial emphasis on addressing PAS. However, PAS stability in many cases renders phacoemulsification with intraocular lens implantation (PEI), with or without viscoelastic injection into the peripheral angle, ineffective in fully reopening extensive PAS, necessitating mechanical separation[4].

Goniosynechialysis (GSL) involves using specialized techniques to remove PAS from the angle wall, in an attempt to restore trabecular function[5]. GSL falls into two categories based on the surgical field: GSL under a microscope alone and GSL under direct gonioscopy. Each approach has its own set of inherent advantages and limitations. In the process of using instruments to separate the PAS under a microscope alone, the situation of anterior chamber angle cannot be seen in real time so that the PAS cannot be accurately separated[6]. This may lead to unnecessary destruction of the angle structure, resulting in intraoperative anterior chamber bleeding, postoperative inflammatory reaction and other complications[7-8]. In many previous studies[9-12], such as GSL using viscoelastic or GSL under a microscope, GSL was performed without the use of gonio-lens to confirm the angle closure range. The control of IOP in the short term was satisfactory, but the long-term effect and the situation of PAS were reported with different results. On the other hand, we believe that it is necessary to confirm the PAS range with gonio-lens repeatedly before separation during GSL under a microscope alone. But even if this is done, there will still be some of the angle that cannot be separated by instruments only under a microscope.

In contrast, GSL under direct gonioscopy can offer direct observation of the angle, providing clarity in assessing angle separation effectiveness. The surgeon can see the specific situation of the separation of the angle in real time when separating the angle, and perform the separation operation more accurately. Study[13] had also evaluated the effect of GSL under the guidance of gonio-lens but the gonioscope they used is a direct gonio-lens. Although the gonio-lens can also realize the direct visualization of the angle at the same time to guide the separation, the light from the angel is refracted through the lens to form the image. The angle of the microscope and the patient's head position need to be adjusted. And the superior section is technically difficult to see so that the superior angle may often be separated without the guidance of a gonio-lens[14-15]. This performance is troublesome, prolongs the operation time and reduces the operation efficiency. Therefore, in our study, a gonio-lens which has a double-mirror and reflects light to form image was used in GSL under direct gonioscopy, without the need to adjust the microscope angle and the patient's head position.

In theory, GSL under a microscope alone, as opposed to GSL under direct gonioscopy, has some defects in the accuracy of separating anterior chamber angle. Therefore, the study aims to assess and contrast the efficacy of PAS separation between GSL under a microscope alone and GSL under direct gonioscopy in patients with CACG and cataracts.

PARTICIPANTS AND METHODS

Ethical Approval This study complied with the principles outlined in the Declaration of Helsinki and received ethics approval (2021-073-K-62-01). This study was registered at Chinese Clinical Tiral Registry (https://www.chictr.org.cn). Trial registration number is ChiCTR2100049721. Written informed consent was obtained from each patient.

Participants Participants were individuals diagnosed with CACG at the Eye Hospital, Wenzhou Medical University, between June 2021 and March 2023. Diagnostic criteria for CACG included chronically elevated IOP resulting from primary angle closure, with or without glaucomatous optic disc changes and visual field abnormalities. Surgical indications were met if either of the following criteria was fulfilled: 1) PAS extent ≥6h (per Chinese Guidelines for Glaucoma Diagnosis and Treatment, which recommends surgical intervention for eyes with more than two quadrants of synechia angle closure)[16]. 2) The presence of cataracts necessitating surgical intervention.

Exclusion criteria included the following: 1) Prior intraocular surgery (except for allowed procedures: laser peripheral iridotomy, laser iridoplasty, and anterior chamber paracentesis). 2) Ocular conditions affecting anterior segment anatomy, such as ciliary body or iris cysts, ocular trauma, or the use of topical medications altering iris configuration. 3) A history of uveitis. 4) Extended use of topical or systemic glucocorticoids.

Participants were randomly assigned to two groups, GSL under a microscope alone (GM group) and GSL under direct gonioscopy (GG group), using a random number table. GM group underwent PEI-GSL under a microscope alone, while GG group underwent PEI-GSL under direct gonioscopy. Surgeries were performed by two experienced surgeons (Liang YB and Li GX).

Gonio-lens

Ahmed DVX, USA Ocular Company This gonio-lens is a double-mirror design and the light is reflected through the two mirrors inside the gonio-lens. So it is imaged indirectly and the image is positive. It redirects the tilted anterior chamber angle image to the coaxial position of the operating microscope. The image magnification is 1.3×. The static field of view is 120°. The contact surface diameter is 10 mm. The ring diameter is

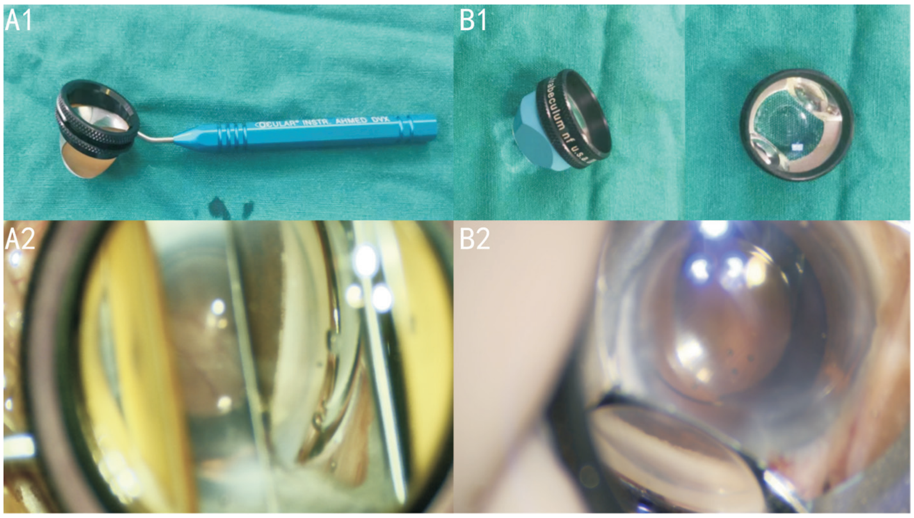

Figure 1 Appearance and intraoperative observation of surgical gonio-lens A: Direct gonio-lens (Ahmed DVX, USA Ocular company). A1: Appearance of Ahmed DVX; A2: The Ahmed DVX was placed on the cornea to confirm the range of PAS. B: Gonio-lens (VG2, USA Volk company). B1: Appearance of VG2; B2: The VG2 was placed on the cornea to confirm the range of PAS. PAS: Peripheral anterior synechiae.

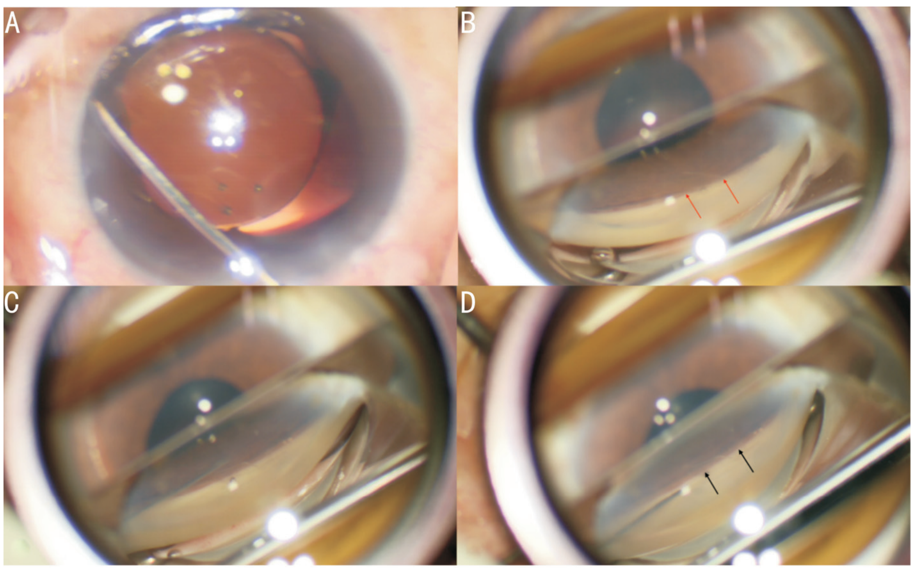

Figure 2 Separate the closed angle and separate the residual PAS with an iris repositor under the direct gonio-lens (Ahmed DVX, USA Ocular Company) until the scleral spur became visible A: Only under the operating microscope and without gonioscope; B: The PAS between the red arrows; C: Separate the PAS with an iris repositor; D: The angle (between the black arrows) was reopen after separation. PAS: Peripheral anterior synechiae.

23.5 mm and the handle length is 82 mm. When it is used, the surgeon does not need to adjust the microscope and position, and the patient's head position does not need to be adjusted.

VG2, USA Volk Company This gonio-lens has a 2-mirror, all-glass design to view anterior chamber. It has high magnification (1.50×) combined with dual mirror angles (60°/64°) allows for both a detailed and a broad view of the anterior chamber and it requires rotation to view all quadrants of the angle.

Surgical Procedures In GM group, the surgical procedure began with a clear corneal incision phacoemulsification and intraocular lens (IOL) implantation within the capsular bag. Subsequently, viscoelastic was injected into the anterior chamber, particularly focusing on the anterior angles to significantly deepen the peripheral anterior chamber. The surgical gonio-lens (VG2, USA Volk company or Ahmed DVX, USA Ocular company) was placed on the cornea to confirm the range of PAS (Figure 1). The surgeon then gently pushed the peripheral iris downward using an iris repositor only under the operating microscope (Figure 2A). When it was determined that the angle was separated 360 degrees by this method, the angle was visualized, and any remaining PAS was confirmed using a direct gonio-lens (Ahmed DVX, USA Ocular company). If any remaining PAS was present, we would meticulously separate them with an iris repositor until the scleral spur became visible under the direct gonio-lens (Figure 2B-2D). To conclude the procedure, the viscoelastic material was replaced with balanced salt solution, and incisions were hydrostatically sealed.

In GG group, the procedure was similar to GM group until viscoelastic material was injected into the anterior chamber. To assess the range of PAS after PEI, a direct gonio-lens (Ahmed DVX, USA Ocular company) was placed on the cornea under the operating microscope (Figure 1B). Concurrently, an iris repositor was employed to gently press down on the root of the iris synechia, thereby opening the anterior chamber angle. In this procedure, the angle was directly observable, and angle separation was performed simultaneously. The angle structure was reestablished by confirming the re-exposed pigment trabecular network as the standard. Similar to the previous group, the viscoelastic material was replaced with balanced salt solution, and incisions were hydrostatically sealed.

Examination and Follow-up All patients underwent a comprehensive pre-operative examination. This included the evaluation of several key parameters, including the range of PAS determined through dynamic gonioscopy, IOP, and the number of prescribed anti-glaucoma medications. The range of PAS was recorded in 12 clock-hour segments and it was observed at several points: 1) The surgeon conducted gonioscopy immediately after completing the PEI procedure to record observed PAS, which was recorded as PAS after PEI. 2) After performing GSL under a microscope alone in GM group and GSL under direct gonioscopy in GG group, the surgeon confirmed and recorded PAS extent using a gonioscope, which was recorded as PAS after GSLs. 3) For those patients who underwent the following GSL under direct gonioscopy, the surgeon used a gonioscope to determine and record PAS extent, which was recorded as PAS at the end of surgery.

Follow-up examinations were scheduled at 1wk, 1mo post-surgery. Each follow-up visit included a routine ophthalmic examination, assessing IOP and the number of prescribed anti-glaucoma medications.

Statistical Analysis The difference between groups, such as eye and gender, was analyzed by χ^2-test. Intraoperative complication was analyzed by rank sum test. Independent t-tests, using Student's *t*-test, were applied to analyze age, preoperative and postoperative IOP and anti-glaucoma medication count. Within-group pre- and post-surgical comparisons were conducted using paired *t*-tests. Statistical significance was set at $P<0.05$. Statistical analyses were performed using the SPSS software (version 29.0).

RESULTS

A total of 60 patients (60 eyes) with CACG and cataract were included in this study, and 30 eyes of 30 subjects were divided into GM group and GG group respectively. The average age of the 60 patients was 67.0±7.9y, including 19 males and 41 females.

Table 1 provided a summary of the demographic information of all subjects in both groups prior to surgery. Comparing the baseline characteristics in both the groups, the average age (P=0.550) and baseline IOP (P=0.366) values in GM group and GG group are similar, respectively. The average initial PAS extent (P=0.425) was also similar in the two groups. The only statistically significant difference between the two groups was the laterality of the eyes (P=0.037). However, the laterality of the eyes is not an influencing factor for the primary outcome in this study and it will not affect the results of the study. These ensured that intraoperative and postoperative data could be compared across the two groups effectively.

Table 1 Demographics information of all subjects

Parameters	GM group (*n*=30)	GG group (*n*=30)	*P*
Gender, *n* (%)			0.165
Male	12 (40.0)	7 (23.3)	
Female	18 (60.0)	23 (76.7)	
Eye, *n* (%)			0.037[a]
Right	13 (43.3)	21 (70.0)	
Left	17 (56.7)	9 (30.0)	
Age (y)	66.3±6.8	67.6±8.9	0.550
Pre-operative PAS (h)	8.9±2.6	9.4±2.5	0.425
Pre-operative IOP (mm Hg)	29.6±11.5	32.4±12.2	0.366

GM: Goniosynechialysis under a microscope alone; GG: Goniosynechialysis under direct gonioscopy; PAS: Peripheral anterior synechiae; IOP: Intraocular pressure. [a]Statistical significance.

After PEI, the PAS extent in GM group decreased to 7.2±2.9h and that in GG group changed to 7.5±2.9h. The PAS after PEI was significantly reduced compared to the pre-operative PAS in both groups (all P<0.001; Table 2). The extent of residual PAS after GSL in GM group was 3.3±2.2h and that in GG group was 0.1±0.3h. The residual PAS after GSL has significant statistical difference between two groups (P=0.000; Table 2). Measurements of PAS post-GSL were notably lower than measurements of PAS post-PEI in both groups (all P<0.001; Table 2). Subgroup analysis, based on the type of operation, revealed no statistically significant difference in PAS reduction after PEI between GM group and GG group (P=0.800; Figure 3) but significant difference in PAS reduction after GSLs (P<0.001; Figure 3).

In GM group, out of 30 eyes, 4 eyes (13.3%) achieved complete anterior chamber angle reopening, while the remaining 26 eyes (86.7%) presented with residual PAS after GM (Table 3). The average range of residual PAS was 3.3±2.2h, requiring accurate and comprehensive separation through GSL under direct gonioscopy. In GM group, the residual PAS further decreased to 0.1±0.6h after GSL under direct gonioscopy (P<0.001; Table 2). There was no significant difference in PAS at the end of surgery between the two groups (P=0.561). While the PAS of 28 eyes (93.3%) have been reopened completely in GG group. The specific situation of the range of PAS after GSLs is shown in Table 3.

Table 2 Comparisons of intraoperative data (*n*=60)

Parameters	GM Group (*n*=30)	P^a	GG Group (*n*=30)	P^a	P^b
Pre-operative PAS (h)	8.9±2.6		9.4±2.5		0.425
PAS after PEI (h)	7.2±2.9	0.001[c]	7.5±2.9	0.001[c]	0.642
PAS after GSLs (h)	3.3±2.2	0.000[c]	0.1±0.3	0.000[c]	0.000[c]
PAS at the end of surgery (h)	0.1±0.6	0.000[c]	0.1±0.3	0.000[c]	0.561

GM: Goniosynechialysis under a microscope alone; GG: Goniosynechialysis under direct gonioscopy; GSL: Goniosynechialysis; PAS: Peripheral anterior synechiae; PEI: Phacoemulsification combined with intraocular lens implantation. [a]Student's *t*-test (paired *t* test), compared with pre-operative PAS; [b]Student's *t*-test (independent samples *t* test), compared between GM Group and GG Group. [c]Statistical significance.

Table 3 The range of residual PAS

Range of PAS	GM group after GM (*n*=30)	GM group at the end of surgery (*n*=30)	GG group at the end of surgery (*n*=30)
0h	4 (13.3%)	28 (93.3%)	28 (93.3%)
1h	1 (3.3%)	1 (3.3%)	2 (6.7%)
1.5h	1 (3.3%)	0	0
2h	6 (20%)	0	0
2.5h	2 (6.7%)	0	0
3h	2 (6.7%)	1 (3.3%)	0
4h	4 (13.3%)	0	0
5h	4 (13.3%)	0	0
6h	3 (10.0%)	0	0
6.5h	1 (3.3%)	0	0
7h	2 (6.7%)	0	0

GM: Goniosynechialysis under a microscope alone; GG: Goniosynechialysis under direct gonioscopy; PAS: Peripheral anterior synechiae.

Among the 60 patients, one patient in GM group and two patients in GG group exhibited one hour of PAS after GSLs. In their cases, the angle at 12 o'clock was unobservable due to the absence of corneal edema at the corresponding location. Additionally, one patient in GM group had 3h of PAS remaining after GSL, primarily due to persistent hyphema in the 9-12 o'clock region, which could not be entirely resolved, resulting in a blurred angle. Although the range of PAS varied post-PEI compared to pre-operation, it remained incomplete, indicating that PEI, while effective to some extent, cannot fully resolve complete angle closure of 360-degree.

Table 4 displayed the comparison of intraoperative hyphema between the two groups. Patients in GM group had a higher likelihood of experiencing hyphema compared to those in GG group (*P*=0.019).

The comparisons of preoperative and postoperative IOP between the two groups are presented in Table 5. In GM group, there was a statistically significant reduction in postoperative IOP compared to per-operative IOP at all follow-up time points (all *P*<0.05). In GG group, postoperatively, there was also a significant reduction in IOP compared to the per-operative IOP (all *P*<0.05). However, when comparing the two groups, there was no significant difference in IOP at the same follow-up time points (all *P*>0.05), except at week 1 (*P*=0.025). This suggests that both operations effectively reduced IOP, with no significant difference in their efficacy for IOP reduction.

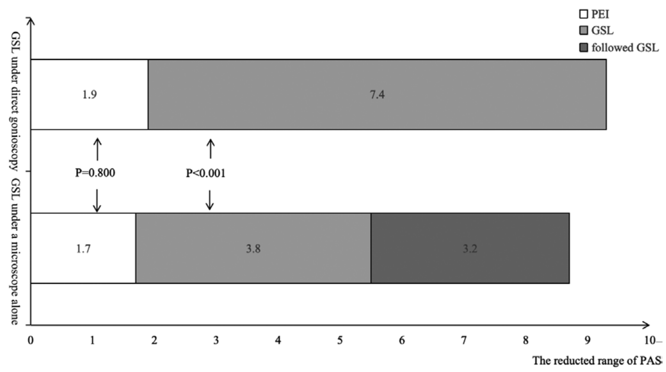

Figure 3 Column stacking diagram of the reducted range of PAS during different procedures GSL: Goniosynechialysis; PAS: Peripheral anterior synechiae; PEI: Phacoemulsification with intraocular lens implantation.

Table 4 Comparisons of intraoperative hyphema Eye number

Grade of hyphema	GM group (*n*=30)	GG group (*n*=30)
0	16	24
1	8	5
2	5	1
3	1	0

GM: Goniosynechialysis under a microscope alone; GG: Goniosynechialysis under direct gonioscopy. 0: No hyphema; 1: Spot hyphema; 2: Less than the pupil area; 3: More than the pupil area.

The comparison of the number of anti-glaucoma medications before and after surgery was shown in Table 6. In GM group,

Table 5 Comparisons of preoperative and postoperative IOP

Parameters	No. of eyes	GM Group	P^a	No. of eyes	GG Group	P^a	P^b
Pre-operative IOP (mm Hg)	30	29.6±11.5		30	32.4±12.2		0.366
1wk IOP (mm Hg)	29	16.6±5.7	0.000[c]	30	13.7±3.6	0.000[c]	0.025[c]
1mo IOP (mm Hg)	28	15.9±6.2	0.000[c]	24	13.4±4.9	0.000[c]	0.117

GM: Goniosynechialysis under a microscope alone; GG: Goniosynechialysis under direct gonioscopy; IOP: Intraocular pressure. [a]Student's *t*-test (paired *t* test), compared with pre-operative IOP; [b]Student's *t*-test (independent samples *t* test), compared between GM Group and GG Group. [c]Statistical significance.

Table 6 Comparison of number of anti-glaucoma medications between pre- and post-operation

Parameters	No. of eyes	GM Group	P^a	No. of eyes	GG Group	P^a	P^b
Pre-operative	30	2.1±1.3		30	2.2±1.2		0.839
1wk	29	0.4±0.7	0.000[c]	30	0.2±0.5	0.000[c]	0.166
1mo	28	0.4±0.8	0.000[c]	24	0.1±0.3	0.000[c]	0.048

GM: Goniosynechialysis under a microscope alone; GG: Goniosynechialysis under direct gonioscopy. [a]Student's *t*-test (paired *t* test), compared with pre-operative PAS; [b]Student's *t*-test (independent samples *t* test), compared between GM Group and GG Group. [c]Statistical significance.

the use of anti-glaucoma medications significantly decreased from 2.1±1.3 before the surgery to 0.4±0.7 at 1wk and 0.4±0.8 at 1mo post-surgery (all $P<0.001$). In GG group, a similar reduction was observed, with anti-glaucoma medications decreasing from 2.2±1.2 before the surgery to 0.2±0.5 at 1wk and 0.1±0.3 at 1mo post-surgery (all $P<0.001$). There was no statistically significant difference between the two groups at any of the follow-up points (all $P>0.05$) expect 1mo ($P=0.048$).

DISCUSSION

We observed that PEI alone can open approximately 2 to 3h worth of PAS in CACG patients, which aligns with findings in prior research (Lee *et al*[11]: preoperative *vs* postoperative 181.33±90.62 *vs* 62.67±69.23 degrees; Tham *et al*[17]: preoperative *vs* postoperative 266.4±59.6 *vs* 198.9±99.1 degrees). However, the average range of PAS after PEI in both groups in our study was slightly larger than the report by Tun *et al*[18] (4.73±2.83h), likely due to the initial extensive PAS in our patients. Therefore, the effect of PEI to remove PAS is insufficient.

As previously mentioned, there are two primary GSL procedure types. Currently, many surgeons opt for GSL under a microscope in their clinical practice[19]. This study further compared the efficacy of separating PAS by two types of GSLs after PEI. Our study included 30 eyes that underwent GSL under a microscope, followed by GSL under direct gonioscopy performed if residual PAS remained. Out of the 30 eyes, four eyes (13.3%) achieved complete anterior chamber angle reopening, while the remaining 26 eyes (86.7%) still had 3.3±2.2h of residual PAS after GSL under a microscope alone. This result was statistically different from the residual PAS after GSL under direct gonioscopy. These findings indicate that GSL under a microscope alone cannot fully open the entire angle comparing with GSL under direct gonioscopy. For ethical reasons, we performed GSL under direct gonioscopy if any residual PAS remained. Following GSL under direct gonioscopy, the extent of residual PAS significantly decreased compared to GSL under a microscope. This underscores the necessity of direct visualization during the procedure to accurately and efficiently address the remaining PAS. This approach is beneficial for achieving a broader angle opening, which is crucial for postoperative IOP control. Moreover, GSL under direct gonioscopy has simple operation steps. Although we do not have specific statistics, empirically, the number of the procedure of GSL under direct gonioscopy is less compared to GSL under a microscope alone. And it can save some surgical time.

In our study, as in Lin *et al*[20], GSL under direct gonioscopy employed a flat instrument to physically displace the peripheral iris away from the angle, ensuring full exposure of the scleral spur - the technique's endpoint. Therefore, the extent of remaining PAS at the end of operation in our study was minimal, with only 0.1±0.6 and 0.1±0.3h remaining, a notably lower residual PAS than in other reports[4,11].

Although PEI has been reported as effective in reducing IOP in PACG patients[21-23]. However, for patients with advanced PACG and long-term angle closure, the efficacy of PEI alone may be less favorable compared to that in patients with early-stage PACG[24]. And it may not suffice for controlling high IOP in some cases. Nonetheless, both surgical approaches in this study significantly lowered postoperative IOP compared to the baseline, aligning with previous studies on the effectiveness of PEI-GSL in IOP reduction[4,10,25]. Moreover, IOP did not significantly differ between the two groups at the same follow-up time points, except for at 1wk.

Our study assessed and minimized residual PAS, not only following PEI but also during GSL, utilizing a surgical gonio-lens for comprehensive evaluation. This approach contributed to the reduced extent of PAS in both groups compared to previous studies[11,18,26]. Our primary aim was to mechanically open the angle, restore the normal anterior chamber angle structure, and expose the natural channels of the trabecular meshwork. This promotes aqueous humor outflow and, consequently, IOP reduction. Crucially, continuous gonioscopy was pivotal during the entire surgical procedure, significantly contributing to our significant IOP reduction. Direct visualization ensured clear observation of the angle, facilitating precise separation of stable PAS areas while minimizing instrument-related angle damage and preventing extensive hyphema[8]. Our results (Table 3) support the hypothesis that direct gonioscopy enhances angle separation efficiency and precision in determining the separation site. Further comparative studies may be necessary to clarify this association more comprehensively in the future.

The advantages of this study should be recognized. Prospective randomized controlled trials are known for their resistance to bias and lack of recall requirements, and are considered the gold standard in clinical research. Furthermore, this is the first global study to compare the efficacy of these two GSLs. We used the gonio-lens to confirm the range of PAS during the surgery. The results strongly indicated that the efficacy of PEI alone in separating PAS was limited and PEI-GSL could attach better effect in separating PAS. The accuracy of GSL under direct gonioscopy for CACG patients was proved for the first time. While no significant differences emerged in the effect of operation, this research lays the groundwork for future GSL surgical method investigations.

Our study also exhibits limitations, including a small sample size, a lack of measurement of PAS at 1mo post-operation and a relatively brief follow-up period. The limited sample size may not fully capture potential differences between the two groups. And we can observe anti-glaucoma medication usage at 1mo and IOP at 1wk are statistically different between the two groups. Due to the limitation of small samples, the stability of secondary outcomes was affected and that means there is not enough reliable basis for extrapolation of conclusions. Due to the Corona Virus Disease-19 pandemic, the results of PAS at 1mo after surgery were missing. The situation of postoperative re-PAS could not be observed and reported. For the missing postoperative PAS data, this resulted from pandemic-related restrictions where out-of-town patients could only visit local hospitals that lacked gonioscopy-capable ophthalmologists. So we were unable to collect postoperative re-PAS data. Furthermore, the short follow-up duration may hinder long-term efficacy assessment of GSL. However, long-term management of CACG is crucial for prognosis. Therefore, our results can only demonstrate the short-term efficacy of the surgery and cannot be used to infer the long-term efficacy. However, the focus of our study is to compare the efficacy of PAS separation, rather than to evaluate long-term outcomes. The long-term efficacy should still be proven through future long-term follow-up studies. Future research endeavors will aim to increase the sample size for more comprehensive verification of intergroup disparities.

Overall, PEI alone couldn't open 360° of anterior chamber angle completely. PEI+GSL significantly reduced PAS range, IOP and number of anti-glaucoma medications. But for patients with CACG, GSL under a microscope alone is more difficult to separate stable PAS completely and adequately than GSL under direct gonioscopy.

ACKNOWLEDGEMENTS

Foundations: Supported by the Program for Zhejiang Leading Talent of S&T Innovation (No.2021R52012); Key Research and Development Projects of Zhejiang Province (No.2022C03112).

Conflicts of Interest: Du J, None; **Li YY,** None; **Chen DF,** None; **Li JQ,** None; **Huang QJ,** None; **Zhu SQ,** None; **Ye WQ,** None; **Zhu S,** None; **Xu SX,** None; **Li GX,** None; **Liang YB,** None.

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