The Progression of Peripheral Anterior Synechia after Combined Phacoemulsification with Goniosynechialysis Under an Ophthalmic Endoscope: A Three-Year Study

Xinyi Liu

Wenzhou Medical University

Yau Kei Chan

the University of Hong Kong

Lin Fu

Wenzhou Medical University

Yunhe Song

Sun Yat-Sen University

Junhua Li

Wenzhou Medical University

Li Nie

Wenzhou Medical University

Xiulan Zhang

Sun Yat-Sen University

Weihoa Pan (✉ pan_weihua@163.com)

Wenzhou Medical University

Research Article

Keywords: primary angle-closure glaucoma, phacoemulsification combined with goniosynechialysis, peripheral anterior synechia, intraocular pressure, viscoelastics, iris repositior

Posted Date: October 14th, 2021

DOI: <https://doi.org/10.21203/rs.3.rs-962744/v1>

License: © ⓘ This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Abstract

Aim To investigate the long-term changes of peripheral anterior synechia (PAS) after phacoemulsification with goniosynechialysis under an ophthalmic endoscope (Phaco-OE-GSL) in primary angle-closure glaucoma (PACG) assisted with viscoelastics alone or viscoelastics combined with iris repositor (viscoelastics-repositor).

Method A retrospective study was conducted. Thirty-nine eyes of 31 PACG patients were included. The follow-up period was 36 months. The main outcomes of the study included the changes of PAS, intraocular pressure (IOP), and the success rate.

Results Phaco-OE-GSL was performed assisted with viscoelastics-alone on 20 eyes, and viscoelastics-repositor on 19 eyes. The total recurrence rates of PAS were 62.5% in viscoelastics-alone group and 87.5% in viscoelastics-repositor group. In particular, the recurrence rate of PAS at the same location at which were separated intraoperatively were 37.3% and 75.0% respectively ($P=0.033$). The recurrence of PAS was observed in 2 eyes in viscoelastics-alone group and 12 eyes in viscoelastics-repositor group within 1-month follow-up ($P<0.001$). In addition, comparing any two follow-ups 6 months after surgery, there are not significant differences in the extent of re-PAS in total eyes ($P>0.05$). The extent of postoperative PAS at final follow-up was positively correlated with the range of PAS preoperatively ($P=0.036$, $r=0.356$). The complete success rates were 85.0% and 89.5% of viscoelastics-alone group and viscoelastics-repositor group at 36-month follow-up respectively. Both the preoperative and postoperative distribution of PAS are mainly concentrated on the upper (84.6% and 95.8%) and nasal side (74.4% and 62.5%), followed by the inferior side, and the least on the temporal side.

Conclusion In summary, although the recurrence rate of PAS was high in early postoperative period, the progression of PAS was rapidly resolved after 6 months postoperatively, and Phaco-OE-GSL is an effective treatment for the long-term control of IOP of PACG patients especially with large range of PAS ($>180^\circ$). Both preoperative and postoperative PAS are mainly concentrated on the upper and nasal side. Besides, our results suggested that mechanical separation may be easier to promote the progression of postoperative PAS than viscoelastics-alone separation.

Key Message

The range of PAS has rapidly progressed within 6 months postoperatively. There was higher rate of re-PAS at the same location at which were separated intraoperatively, and intraoperative complications in viscoelastic-repositor group than viscoelastics-alone group.

Introduction

Primary angle-closure glaucoma (PACG) is the leading cause of irreversible blindness which affects around 11.7 million people worldwide[1], and the patients are mostly from East Asia[2, 3]. Its pathogenesis is mainly due to the elevated intraocular pressure (IOP) and its further progression lead to

irreversible optic nerve injury. In comparison, PACG causes five times as much blindness as primary angle-open glaucoma[4, 5].

Phacoemulsification with goniosynechialysis (Phaco-GSL) has been one of the popular surgical procedures for patients with PACG nowadays [6–8]. GSL was firstly described in 1984[9], and was performed along with phacoemulsification in 1999 [10], GSL is a surgical method to treat peripheral anterior synechiae (PAS) by separating the adhered iris from the trabecular meshwork, thereby opening the angle of the anterior chamber and restoring the outflow function of aqueous humor of the trabecular meshwork. GSL is performed by using viscoelastics alone or viscoelastics combined with mechanical separation to separate the iris from the trabecular meshwork. Previous studies have shown that viscoelastics alone is an effective and safe way to restore the outflow pathway and avoid tissue damage[11, 12]. Mechanical separation may be required when PAS could not be completely resolved by viscoelastics alone. However, the mechanical separation using the repositor may damage the iris tissue and cause inflammation postoperatively. The complication may lead to the reattachment of the iris on the trabecular meshwork and block the aqueous outflow pathway again.

Previous studies have shown that Phaco-GSL is more effective in lowering IOP than other surgical approaches like phacoemulsification alone, phaco-trabeculectomy and trabeculectomy[13, 14]. In particular, Phaco-GSL is effective in releasing the closure of synechial angle and lowering the IOP on eyes with chronic primary angle-closure glaucoma or with extensive PAS[15]. However, some studies suggested that stand-alone effect of GSL on lowering the IOP may not be significant[16, 17].

To the best of our knowledge, most previous studies on Phaco-GSL extensively reported the effects of the postoperative IOP control. However, the progression of the postoperative PAS, which is the pathological basis of PACG and frequent complication of GSL, has not been widely studied. The monitoring of the peripheral anterior angle is important because an adequately open angle is crucial for controlling IOP in PACG patients. The recurrence of PAS (re-PAS) is common, and therefore the regular check-up is essential to ensure that the anterior angle remains open after surgery. If re-PAS is being identified it can be treated in a timely manner.

Therefore, to evaluate the long-term characteristic progression of PAS of phacoemulsification with goniosynechialysis under an ophthalmic endoscope (Phaco-OE-GSL) assisted with viscoelastics alone or viscoelastics combined with mechanical separation approach, a retrospective study was conducted to review the medical records of **39** eyes of 31 patients with PACG in our clinical centre. Besides the effect of lowering IOP, the incidence of re-PAS and its progression have also been investigated.

Methods

Patient

The medical records of Chinese patients with PACG who underwent Phaco-OE-GSL between March 2013 and September 2015 at the Affiliated Eye Hospital of Wenzhou Medical University were retrospectively

reviewed. The diagnoses of PACG were based on the diagnostic criteria of the International Society of Geographic and Epidemiologic Ophthalmology (ISGEO)[18]. The inclusion criteria were (1) the preoperative range of synechial angle closure to be greater than 90°, (2) the preoperative IOP greater than 21 mmHg, with or without anti-glaucoma medication, and (3) the lens opacity was deemed to cause significant decrease of vision based on the opinion of the primary investigator. Exclusion criteria included (1) patients with ocular disease known to affect the anatomy of anterior segment, such as uveitis, ciliary body or iris cysts, trauma and the use of topical drugs, and (2) patients with a history of the long-term use of topical or systemic glucocorticoid. The study followed the tenants of the Declaration of Helsinki and was approved by the Ethics Committee of School of Ophthalmology and Optometry, Eye Hospital, Wenzhou Medical University.

Outcome Measures

The main outcome measurements were the range of synechial angle closure of re-PAS, the recurrence rate of PAS, IOP values, and the treatment success rate within 3-year follow-up period. The secondary outcomes included the change of number of anti-glaucoma medications and complications. The complete success was defined as IOP of 21 mmHg or lower and without the use of anti-glaucoma medications. The qualified success was defined as an IOP of 21 mmHg or lower and with the use of topical medications.

Surgical Procedure

All surgeries were performed under topical anesthesia by the same surgeon (Dr. Weihua Pan). Phacoemulsification was performed through a 2.2 mm main incision and 1 mm lateral incision, and an IOL was implanted within the capsular bag afterwards. GSL was performed by injecting viscoelastics into the anterior chamber to resolve PAS. The ophthalmic endoscopic probe was then used to investigate the anterior angle. If the PAS could not be completely resolved by viscoelastics, a modified iris reposer was used to detach the remained adhered iris from the trabecular meshwork. In all cases, a 23G endoscopic probe with a diameter of 0.6 mm was used to enter the anterior chamber through main incision. After the GSL procedure, viscoelastics was replaced by Ringer's solution and the incisions were sealed by corneal stromal hydration or closed using a 10-0 nylon suture.

All patients were prescribed with tobramycin and dexamethasone eye drops for 4 weeks (4×/d), nonsteroidal anti-inflammatory eye drops for 4 weeks (4×/d), and 0.5% pilocarpine eye drops for 4 weeks (2×/d) postoperatively.

Statistical analyses

All statistics were performed using SPSS (version 22; IBM Corp, Armonk, NY). The One-way ANOVA followed by Bonferroni Post-hoc Test was used to analyse the range of synechial angle closure, changes of the IOP, anti-glaucoma medications for continuous variables before and after surgery. Independent sample *t*-test was used to compare preoperative basic characteristics, and the range of synechial angle closure, IOP between viscoelastics-alone group and viscoelastics combine with iris-repositor

(viscoelastics-repositor) group. The Chi-square test (Fisher's Exact Test) was used to analyse the comparison of the rate of re-PAS and complications. Kaplan–Meier survival curve analysis and the log-rank test were used to evaluate the cumulative rate of treatment success. P-values of less than 0.05 were considered statistically significant.

Results

The baseline characteristics of the study group was summarized in Table 1. The PAS of 20 eyes (51.3%) could be fully resolved by using viscoelastics alone during surgery, and the remaining 19 eyes (48.7%) required the use of the iris repositor to mechanically separate the adhered iris from the trabecular meshwork. The residual range of synechial angle closure of that 19 eyes, right after the use of viscoelastics but before the use of iris repositor, was $85.3^{\circ} \pm 64.4^{\circ}$. The preoperative angle of synechial angle closure was significant higher in viscoelastics-repositor group than in viscoelastics-alone group ($P = 0.012$).

Table 1
Preoperative basic characteristics of 39 eyes

	Viscoelastics-alone group	viscoelastics-repositor group	<i>P</i> -value ^a
Number of eyes	20 eyes	19 eyes	-
age (years)	62.7 ± 11.3	63.2 ± 7.1	0.867
Male - female ratio	7/13	6/13	0.826
CPACG - APAC ratio	20/0	16/3	0.083
OD - OS ratio	11/9	7/11	0.632
IOP (mmHg)	24.7 ± 8.6	20.7 ± 7.4	0.135
Number of anti-glaucoma medications	1.9 ± 1.0	1.6 ± 1.0	0.403
Range of synechial angle closure (°)	157.6 ± 85.9	222.6 ± 61.9	0.012*
Axial length (mm)	22.68 ± 0.83	22.36 ± 0.951	0.313
Visual acuity (logMAR)	0.19 ± 0.21	0.34 ± 0.66	0.314
Vertical cup disc ratio (C/D)	0.6 ± 0.2	0.6 ± 0.2	0.943
IOP, intraocular pressure, all Data are given as mean ± SD ^a , independent sample <i>t</i> -test *, <i>p</i> -values < 0.05. (which test you have used) logMAR, logarithmic minimal angle resolution. CPACG, chronic primary angle-closure glaucoma APAC, acute primary angle-closure			

The postoperative progression of PAS in the viscoelastics-alone group and viscoelastics-repositor group are summarized in Table 3 and Figure 1. The range of synechial angle closure within 3-year follow-up was significantly smaller than that at baseline (**P<0.05**) in both the groups. However, 23 eyes (69.7%, n = 33) suffered re-PAS (range, 15° -270°) postoperatively within 3-year follow-up, where 62.5% (9 eyes) in Viscoelastics-alone group and 87.5% (14 eyes) in Viscoelastics-repositor group, and the recurrence of PAS occurred in early postoperative period (Table 3). An important to note is that the recurrence rate of PAS at the same location at which were separated intraoperatively were significantly higher in viscoelastics-repositor group than viscoelastics-alone group (75.0% vs 37.3%, **P = 0.033**). Also, the re-PAS cases was

significantly more in viscoelastics-repositor group than in viscoelastics-alone group at 1-month follow-up group ($P < 0.001$, Figure 1). In addition, the range of re-PAS was significantly larger in viscoelastics-repositor group than in viscoelastics-alone group throughout the whole follow-up period within 36 months follow-up ($P < 0.05$, Figure 1). As shown in Figure 2, the extent of postoperative PAS at final follow-up was positively correlated with the range of PAS preoperatively ($P = 0.036$, $r = 0.356$).

In total eyes, the distribution of PAS before operation is mainly concentrated on the upper and nasal side, followed by the inferior side, and the least on the temporal side (respectively, 84.6%, 74.4%, 35.9%, and 25.6%). after surgery, The distribution of PAS after surgery is the same as before surgery, the frequency of PAS in each position is 95.8%, 62.5%, 29.2%, 12.5%. The comparison of PAS distribution between the two groups is shown in Table 2. No significant difference between the two groups ($P > 0.05$). Therefore, both preoperative and postoperative PAS distributions are mainly located from the upper part to the nasal side, and the frequency of PAS decreases as it approaches the temporal side.

Table 2
Distribution of PAS in 39 eyes with primary angle-closure glaucoma

Distribution	Preoperative		Postoperative	
	Viscoelastics-alone group	viscoelastics-repositor group	Viscoelastics-alone group	viscoelastics-repositor group
upper	70% (14/20)	100% (19/19)	100% (10/10)	92.9% (13/14)
inferior	15% (3/20)	57.9% (11/19)	10% (1/10)	42.9% (6/14)
Nasal	65% (13/20)	84.21% (16/19)	50% (5/10)	71.4% (10/14)
temporal	20% (4/20)	31.6% (6/19)	20% (2/10)	7.1% (1/14)

The progression of IOP from the baseline to 3-year follow-up is shown in Figure 3. The mean baseline IOP was statistically higher than that in all the postoperative follow-up time points in the two groups ($P < 0.05$). Results of Kaplan–Meier survival analysis for success rate in two groups are shown in Figure 4. At the end of the follow-up, the complete success rate and qualified success rate were 85% and 90% respectively in viscoelastics-alone group. In comparison, the completes success rate and qualified success rate were 89.5% and 100% respectively in viscoelastics-repositor group. No statistically significant differences of the IOP and success rates at final examination were found between the two groups ($P = 0.163$ and $P = 0.686$). Nevertheless, the mean number of anti-glaucoma medication at the 36-month follow-up, was statistically lower than that at baseline ($P < 0.001$) (Table 3).

There were 4 eyes with the range of synechial angle closure in re-PAS larger than 180° . Moreover, the range of re-PAS kept increasing throughout the follow-up period after surgery. The 3 eyes (range of synechial angle closure, $180^\circ - 210^\circ$) in viscoelastics-repositor group, the mean IOP was 18.1 mmHg (range, 16 -20 mmHg) at final follow-up. The range of re-PAS was 270° in the eye at 10-month follow-up

in the viscoelastics alone group, and the IOP was still unable to be controlled even with conjunct of four anti-glaucoma medications. Ahmed-Valve implantation was performed to resolve the evaluation of IOP.

The comparison of complications between the two groups are shown in Table 3. The viscoelastics-repositor group (8 eyes) has a statistically significant higher rate of intraoperative hemorrhage ($P = 0.024$) than the viscoelastics-alone group (2 eyes). The hemorrhage was completely absorbed in few days after surgery, with no obvious symptoms of discomfort. There are no significant differences of the postoperative complications in between the two groups ($P > 0.05$). The postoperative complications included ciliary body detachment in one eye in Viscoelastics-alone group on the first day after surgery, with eye drops of tobramycin and dexamethasone administered. The IOP of that eye resumed normal, and the ciliary body was roughly repositioned at 1 week postoperatively. Two eyes suffered postoperative Transient elevated IOP in Viscoelastics-alone group.

Table 3
Postoperative changes of PAS, medication and the rate of complications in the two groups

	Visco-alone group	viscoelastics-repositor group	<i>P</i> -value
The range of synechial angle closure of re-PAS at final follow-up (°)	53.8 ± 69.4	97.5 ± 70.6	0.074 ^a
Percentage of eyes with re-PAS within 3-year follow-up (%)	62.5 (10 eyes)	87.5 (14 eyes)	0.102*
Percentage of eyes with re-PAS at same location within 3-year follow-up (%)	37.3 (6 eyes)	75.0 (12 eyes)	0.033*
The time at which re-PAS occurred postoperatively (months)	3.9 ± 3.3	3.0 ± 2.6	-
The number of anti-glaucoma medication	0.2 ± 0.4	0.3 ± 0.5	0.583 ^a
Complication – Intraoperative Hemorrhage (%)	10 (2/20)	42 (8/19)	0.022*
Complication – postoperative ciliary body detachment (%)	5 (1/20)	0	0.323*
Complication – postoperative Transient elevated IOP (%)	10 (2/20)	0	0.157*
^a , independent <i>t</i> -test *, Chi-square test (Fisher's Exact Test). <i>P</i> -values in bold signify <i>p</i> values <0.05. re-PAS, Recurrence of peripheral anterior synechia			

Discussion

In the study, the results showed that the rate of recurrence of PAS postoperatively was high in both the viscoelastics-alone group and viscoelastics-iris repositor group, the location of both preoperative and postoperative PAS is mostly concentrated from the upper part to the nasal side. Cases with the use of iris repositor had higher rates of re-PAS and intraoperative haemorrhage than cases with the use of viscoelastics alone ($P<0.05$). However, there was no significant difference between the two groups in terms of the surgical success rate and IOP management.

The recurrence of PAS is quite common after Phaco-GSL according to previous studies and the results in the present study. However, the result showed that Phaco-GSL is still being considered to be effective in controlling IOP for patients with PACG[19, 20], and the progression of PAS was rapidly resolved after 6 months postoperatively. A study has shown that 83.3% of patients with CPACG suffered from re-PAS, but the success rates was 100% at 6 months follow-up postoperatively[21]. Another study showed that the success rate after Phaco-GSL at 5-year follow-up was 85.9% (IOP<21 mmHg)[22]. Our previous study also found that 68.4% of eyes suffered from different degrees of synechial angle closure, but the complete success rate was 97.4% at the 18-month follow-up[8]. Besides, In the present study, re-PAS happened in 10 eyes (62.5%) in viscoelastics-alone group and 14 eyes (87.5%) in viscoelastics-repositor group throughout the whole follow-up period. Although the rate of re-PAS was high, the range of synechial angle closure at final follow-up was significantly much smaller than the baseline in both the groups ($P<0.05$). Moreover, most of the cases with re-PAS had a good control of IOP, and the complete success rates were 85.0% and respectively 89.5% at 3-year follow-up. In addition, our results also showed that the rate of re-PAS was already quite significant at 1-month postoperatively, especially in the viscoelastics-repositor group (71%, 12/17). And the range of synechial angle closure in the viscoelastics-repositor group rapidly progress within 6 months postoperatively, but such progression was rapidly resolved beyond the 6-month postoperative period. The results is in agreement with a recent study, which showed that PAS recurred very early postoperatively and all large-scale re-PAS ($\geq 90^\circ$) occurred within 1 week after surgery[23]. These results suggested that PAS recurred very early postoperatively. But even when PAS recurred, the subsequent situation of most cases tended to be stable without significant progression. And it also indicated that it is important to identify when will PAS recur as if the problem is severe the patient can be receiving a timely treatment to avoid the progression of glaucoma.

For the formation of adhesive angle closure, the "inflammatory response" at the root of the iris might be a quite important reason especially after surgery. Some studies quantitatively assessed the intraocular infammation in eyes with CPACG, APAC, and normal eyes, and found that the mean fare value and mean cell counts were highest in APAC eyes, followed by PACG and normal eyes respectively[24, 25]. It noted that the influence of inflammation may be critical for the progression of the PAS. In addition, the result in our study showed that the viscoelastics-repositor group had a larger range of re-PAS ($P<0.05$) and higher rates of re-PAS ($P=0.033$) at the same location which were separated intraoperatively, and a significantly

higher rate of recurrence of PAS happened within 1-month follow-up than cases with the use of viscoelastics alone ($P<0.001$). This suggested that even if the PAS is fully resolved using iris reposer, the chance of re-PAS is still high at early stage postoperatively. Moreover, a significantly higher rate of intraoperative haemorrhage was found in the viscoelastics-repositor group than the viscoelastics-alone group (42% vs 10%, $P=0.022$). These differences in the surgical outcomes between two groups may be accounted for the difference in the severity of the PAS preoperatively. The cases in the viscoelastics-repositor group had a significantly larger range of synechial angle closure preoperatively than those in viscoelastics-alone group ($222.6^{\circ} \pm 61.9^{\circ}$ vs $157.6^{\circ} \pm 85.9^{\circ}$, $P=0.012$), and the extent of postoperative PAS is positively significant correlation with that of the preoperative PAS. Besides, the possible reason that accounts for the higher rate of re-PAS in viscoelastic-repositor group may as well be the mechanical damage on both iris and trabecular meshwork induced by the iris reposer. This may especially be true for eyes with long-term elevated IOP that leads to a widespread atrophy of the iris and therefore become more vulnerable to damage. Such damage may lead to the aggravation of postoperative inflammatory response, and then the iris tissue may prone to adhere onto the trabecular meshwork again. Therefore, it also suggested that the progression of PAS is most likely related to the degree of inflammatory response. To improve the surgical outcome based on the results in this study: Firstly, the use of viscoelastics alone to separate PAS is suggested, or Patients with $PAS \leq 180^{\circ}$ may be able to be operated cataract surgery alone. Our recent study found that for patients with preoperative $PAS \leq 180^{\circ}$, the complete success rate was 76.0%(57/75) in Phaco-alone group. This is similar to a result of the complete success rate which is 73.68% (28/38) in Phaco-GSL group, it indirectly indicated that the effect of GSL addition in patients with $PAS \leq 180^{\circ}$ is not obvious, and the decrease of IOP was mainly due to that the cataract surgery deepens anterior chamber and releases the Peripheral anterior closure. Secondly, when the residual PAS range is still larger after viscoelastical separation, surgeons may adopt another method of mechanical separation, such as distal separation and traction separation, instead of detaching the adhered iris from the trabecular meshwork. This can avoid directly damaging the peripheral iris tissue as much as possible. Thirdly, it may be of great significance to develop a viscoelastics with greater viscosity and stronger aggregation to separate PAS with less damage.

In addition, The results of this study found that PAS in PACG patients is mostly concentrated from the upper part to the nasal side, and less PAS occurs in the temporal and lower parts according to the examination of the gonioscope, which is consistent with previous studies[23, 26, 27]. These studies have evaluated the topographic distribution of PAS, and reported that PAS tends to occur superiorly in angle. Why do most PAS start from the superior side and nasal side first? Some studies suggested that the weight of the aqueous column in the anterior chamber play a essential role, the superior part has a relatively narrower angle than other parts of a normal eye. Besides, the dominant segment of aqueous humor outflow may affect the location where PAS first forms. Some studies[28, 29] confirmed that there is a segmental advantage in aqueous humor outflow, that is in nasal aqueous outflow. The outflow of aqueous humor in the dominant stage may make the iris roots easily inhale into the trabecular meshwork, and then cause adhesion of the anterior chamber angle.

However, there still is a certain controversy over whether it is necessary to combine GSL with Phaco to treat PACG patients. Some studies found that stand-alone effect of GSL on lowering the IOP may not be significant, and GSL may have some potential limitations[16, 17]. It suggested that long-term PAS will damage the filtering function of the trabecular meshwork, so mechanical relief of PAS may not result in lowering of the IOP, and the lowering of the IOP may not last long owing to reformation of PAS. On contrary, a study demonstrated that compared to traditional surgery, Phaco-GSL was as successful as phaco-trabeculectomy at lowering IOP[30]. In addition, the extent of preoperative PAS might play an essential part to evaluate the stand-alone effect of GSL. A study found that for the eyes with PAS > 180°, the complete success rate is 50% in Phaco-alone, which is lower than the complete success rate of 74.41% in the Phaco-GSL group, thus indicating that patients with large range of PAS (> 180°) requires Phaco combined with GSL to achieve better operative outcomes.

In this study, three eyes had a synechial angle closure larger than 180° under re-PAS. but they had normal range of IOP and did not require the use of any anti-glaucoma medications. The possible reasons may be twofold. First, the function of the trabecular meshwork with open angle less than 180° may still be able to maintain adequate aqueous outflow. Second, it may be related to the region of peripheral anterior angle that is not being blocked by the iris. A study found that nasal and superior outflow channels have a better drainage ability than the temporal and inferior channels[31]. Two out of the three eyes mentioned had the upper outflow channels unblocked. In contrast, another eye has a synechial angle closure of 270° under re-PAS at 10-month follow-up postoperatively. The IOP was abnormally high and could not be controlled by anti-glaucoma medications. The case was later being treated by Ahmed valve implantation, and the IOP resumed to normal.

Our study has two limitations. First, this is a retrospective study with a relatively small sample size and the follow-up checking has a high drop-off rate, which may both lead to a less conclusive result. Second, a previous study has shown that the both the re-PAS and success rate were different in between chronic and acute cases of PACG after Phaco-GSL. Since most of the subjects in this study were patients with chronic PACG, the results may not be fully translatable to the acute cases.

In summary, although the recurrence rate of PAS was high in early postoperative period, the progression of PAS was rapidly resolved after 6 months postoperatively, and Phaco-OE-GSL is an effective treatment for the long-term control of IOP of PACG patients especially with large range of PAS (> 180°). Both preoperative and postoperative PAS are mainly concentrated on the upper and nasal side. Besides, our results suggested that mechanical separation may be easier to promote the progression of postoperative PAS than viscoelastics-alone separation.

Abbreviations

Primary angle-closure glaucoma

PACG

Chronic Primary angle-closure glaucoma

PACG
Acute Primary angle-closure
APAC
intraocular pressure
IOP
phacoemulsification with goniosynechialysis
Phaco-GSL
phacoemulsification with goniosynechialysis under an ophthalmic endoscope
Phaco-OE-GSL
peripheral anterior synechiae
PAS
The recurrence of PAS
re-PAS
International Society of Geographic and Epidemiologic Ophthalmology
ISGEO
Viscoelastics alone
visco-alone
viscoelastics combine with iris-repositor
visco-repositor
Vertical cup disc ratio
C/D

Declarations

Ethics approval and consent to participate

The study followed the tenants of the Declaration of Helsinki and was approved by the Ethics Committee of School of Ophthalmology and Optometry, Eye Hospital, Wenzhou Medical University. The written informed consent was obtained from all study participants.

Consent for publication

I, Weihua Pan, give my consent for information about my manuscript to be published in [BMC Ophthalmology](#).

I understand that the information will be published without my/my child or ward's/my relative's (circle as appropriate) name attached, but that full anonymity cannot be guaranteed.

I understand that the text and any pictures or videos published in the article will be freely available on the internet and may be seen by the general public. The pictures, videos and text may also appear on other websites or in print, may be translated into other languages or used for commercial purposes. I have been offered the opportunity to read the manuscript.

Written informed consent for publication of their clinical details and/or clinical images was obtained from patients and relative of patients.

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

Funding

This study was supported by the Nature and Science Foundation of Zhejiang Province, China (Grant No. LY17H120008). It supported in the data collection, interpretation and writing the manuscript.

Authors' contributions

L-XY designed and performed the study, collected and analysed the data, and drafted and revised the paper. C-YK and F-L designed the study, and analysed the data, and drafted and revised the paper. S-YH, L-JH and N-L drafted and revised the paper. P-WH and Z-XL designed and performed the study, collected and analysed the data, and drafted and revised the paper.

Acknowledgements

We would like to thank the Nature and Science Foundation of Zhejiang Province and the Start-up funding grant from Wenzhou Medical University, for their support on our study performance.

References

1. Tham YC, Li X, Wong TY, Quigley HA, Aung T, Cheng CY. Global Prevalence of Glaucoma and Projections of Glaucoma Burden through 2040 A Systematic Review and Meta-Analysis. *Ophthalmology*, 2014. **121**(11): p. 2081-2090.
2. Congdon N, Wang F and Tielsch JM. Issues in the epidemiology and population-based screening of primary angle-closure glaucoma. *Survey of Ophthalmology*, 1992. **36**(6): p. 411-423.
3. Foster PJ, Oen FT, Machin D, Ng TP, Devereux JG, Johnson GJ, et al. The prevalence of glaucoma in Chinese residents of Singapore: a cross-sectional population survey of the Tanjong Pagar district. *Archives of Ophthalmology*, 2000. **118**(8): p. 1105-11.
4. Raychaudhuri A, Lahiri S K, Bandyopadhyay M, Foster PJ, Reeves BC, Johnson GJ. A population based survey of the prevalence and types of glaucoma in rural West Bengal: The West Bengal Glaucoma Study. *British Journal of Ophthalmology*, 2005. **89**(12): p. 1559-1564.

5. Jacob A, Thomas R, Koshi SP, Braganza A, Muliyl J. Prevalence of primary glaucoma in an urban south Indian population. *Indian Journal of Ophthalmology*, 1998. **46**(2): p. 81.
6. Liu Y, Li WJ, Jiu XD, Lei X, Liu L, Yan C, et al. Systematic Review and Meta-Analysis of Comparing Phacoemulsification Combined with goniosynechialysis to other mainstream procedures in treating patients with angle-closure glaucoma. *Medicine*, 2019. **98**(42): p. e17654.
7. A. Rodrigues, P. Alaghband, L. Beltran Agullo et al., "Aqueous outflow facility after phacoemulsification with or without goniosynechialysis in primary angle closure: a randomised controlled study," *British Journal of Ophthalmology*, vol. 101, no. 7, pp. 879–885, 2017.
8. Nie L, Pan W, Fang A, Li Z, Qian Z, Fu L. Combined Phacoemulsification and Goniosynechialysis under an Endoscope for Chronic Primary Angle-Closure Glaucoma. *Journal of Ophthalmology*. **2018**: p. 1-7.
9. Campbell DG, Vela A. Modern goniosynechialysis for the treatment of synechial angle-closure glaucoma. *Ophthalmology*. 1984 Sep;91(9):1052-60. doi: 10.1016/s0161-6420(84)34195-1.
10. Teekhasaene C, Ritch R. Combined phacoemulsification and goniosynechialysis for uncontrolled chronic angle-closure glaucoma after acute angle-closure glaucoma. *Ophthalmology*. 1999 Apr;106(4):669-74; discussion 674-5. doi: 10.1016/S0161-6420(99)90149-5.
11. Zhang J X, Wang Y, Chen L, Hao LJ. Principle and advantages of using viscoelastic agent undergo goniosynechialysis during glaucoma and cataract combined surgery. *International Eye Science*, 2014.
12. Zhang XY. Clinical Study on the Treatment of Closed Angle Glaucoma with the Blunt Angle of the Viscoelastic Agent. *China & Foreign Medical Treatment*, 2016.
13. Tun TA, Baskaran M, Perera SA, Htoon HM, Aung T, Husain R. Swept-source optical coherence tomography assessment of iris–trabecular contact after phacoemulsification with or without goniosynechialysis in eyes with primary angle closure glaucoma. *Br J Ophthalmol*, 2015. **99**(7): p. 927-931.
14. Shao T, Hong J, Xu J, Le QH, Wang JJ, Qian SH. Anterior Chamber Angle Assessment by Anterior-segment Optical Coherence Tomography After Phacoemulsification With or Without Goniosynechialysis in Patients With Primary Angle Closure Glaucoma. *Journal of Glaucoma*, 2015. **24**(9): p. 647-55.
15. Zhang H, Tang G, Liu J. Effects of Phacoemulsification Combined With Goniosynechialysis on Primary Angle-closure Glaucoma. *Journal of Glaucoma*, 2016. **25**(5): p. e499.
16. Wang N and Jia SB. Phacoemulsification with or without goniosynechialysis for angle-closure glaucoma: a global Meta-analysis based on randomized controlled trials. *international journal of ophthalmology*, 2019(5): p. 826-833.
17. Husain R, Do T, Lai J. Efficacy of Phacoemulsification Alone vs Phacoemulsification With Goniosynechialysis in Patients With Primary Angle-Closure Disease A Randomized Clinical Trial. *JAMA Ophthalmology*, 2019. **137**(10): p. 1107-1113.

18. Foster PJ, Buhrmann R, Quigley HA, Johnson GJ. The definition and classification of glaucoma in prevalence surveys. *The British journal of ophthalmology*, 2002. **86**(2): p. 238-42.
19. Harasymowycz PJ, Papamatheakis DG, Ahmed I, Assalian A, Lesk M, Al-Zafiri Y, et al. Phacoemulsification and goniosynechialysis in the management of unresponsive primary angle closure. *Journal of Glaucoma*, 2005. **14**(3): p. 186-9.
20. Lai JS, Tham CC, Lam DS. The Efficacy and Safety of Combined Phacoemulsification, Intraocular Lens Implantation, and Limited Goniosynechialysis, Followed by Diode Laser Peripheral Iridoplasty, in the Treatment of Cataract and Chronic Angle-closure Glaucoma. *Journal of Glaucoma*, 2001. **10**(4): p. 309-315.
21. Tian T, Li M, Pan Y, Cai Y, Fang Y. The effect of phacoemulsification plus goniosynechialysis in acute and chronic angle closure patients with extensive goniosynechia. *BMC ophthalmology*, 2019. **19**(1): p. 65.
22. Kameda T, Inoue T, Inatani M, Tanihara H. Long-term efficacy of goniosynechialysis combined with phacoemulsification for primary angle closure. *Graefes Arch Clin Exp Ophthalmol*, 2013. **251**(3): p. 825-30.
23. Lee JY, Kim YY, Jung HR. Distribution and characteristics of peripheral anterior synechiae in primary angle-closure glaucoma. *Korean J Ophthalmol*. 2006 Jun;20(2):104-8. doi: 10.3341/kjo.2006.20.2.104.
24. Gazzard G, Foster PJ, Devereux JG, Oen F, Chew P, Khaw PT, Seah S. Intraocular pressure and visual field loss in primary angle closure and primary open angle glaucomas. *Br J Ophthalmol*. 2003 Jun;87(6):720-5. doi: 10.1136/bjo.87.6.720.
25. Kong X, Liu X, Huang X, Mao Z, Zhong Y, Chi W. Damage to the blood-aqueous barrier in eyes with primary angle closure glaucoma. *Mol Vis*. 2010 Oct 8;16:2026-32.
26. Inoue T, Yamamoto T, Kitazawa Y. Distribution and morphology of peripheral anterior synechiae in primary angle-closure glaucoma.[J]. *Journal of Glaucoma*, 1993, 2(3):171.
27. Mok KH, Lee VW. Synechial angle closure pattern in Chinese chronic primary angle-closure glaucoma patients. *J Glaucoma* 2001;10:427-8.
28. Kagemann L, Wollstein G, Ishikawa H, et al. Identification and assessment of Schlemm's canal by spectral-domain optical coherence tomography[J]. *Invest Ophthalmol Vis Sci*, 2010, 51(8):4054-4059. DOI:10.1167/iovs.09-4559.
29. Cha E, Xu J, Gong L, et al. Variations in active out flow along the trabecular out flow pathway [J]. *Exp Eye Res*, 2016, 146:354-360. DOI:10.1016/j.exer.2016.01.008.
30. *Nguyen Xuan, H, Nguyen D, Ngan, Nguyen T, Huong, et al., Comparing the Safety and Efficacy of Phacogoniosynechialysis With Phacotrabeculectomy in the Management of Refractory Acute Primary Closure Angle Glaucoma With Cataract: A Multicenter Randomized Trial. 2021. 30.*
31. Huang AS, Penteadó RC, Saha SK, Do JL, Ngai P, Hu Z, et al. Fluorescein Aqueous Angiography in Live Normal Human Eyes. *Journal of Glaucoma*, 2018. **27**(11): p. 957-964.

Figures

Figure 1

A The number of eyes with re-PAS within the study period. B The range of synechial angle closure of the re-PAS within the study period. The symbol* indicates a statistically significant difference between the two groups ($P < 0.05$). n, number of eyes in the group at the corresponding time point. Intra-op, indicates the time right after performing GSL.

Figure 2

The extent of postoperative PAS at final follow-up was positively correlated with the range of PAS preoperatively.

Figure 3

The IOP profiles of the two groups along the 3-yr follow-up period. The value presented is in mean + S.D.
n, number of eyes in the group at the corresponding time point.

Figure 4

Kaplan-Meier cumulative probability curve of success for viscoelastics alone group vs viscoelastics-repositor group over time (months).