• Clinical Research •

# Assessing microcatheter-assisted 360-degree trabeculotomy combined with trabeculectomy for refractory glaucoma: 1-year results

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## Abstract

● **AIM:** To evaluate the efficacy and safety of microcatheter-assisted 360-degree trabeculotomy combined with trabeculectomy (MATT-Trab) for treating refractory glaucoma.

● **METHODS:** Patients with refractory glaucoma who underwent MATT-Trab were retrospectively examined. Efficacy indicators for research statistics included the intraocular pressure (IOP) level, degree of decrease, changes in medication dosage, and success rate. Safety indicators included the best-corrected visual acuity and incidence of complications.

● **RESULTS:** This study comprised 31 patients, including 11 males and 20 females, with ages ranging from 8mo to 67y (mean age: 29.40±22.10y). The average postoperative IOP at 1d, 1wk, 1mo, 3mo, 6mo, 1y, and the last follow-up was significantly lower than the average preoperative IOP (31.33±9.24 mm Hg, $P$<0.05). The average number of postoperative medications at 1y was 0.48±1.51, which was significantly reduced compared to that used preoperatively (3.77±0.99, $P$=0.00). The absolute and qualified success rates were 45.16% and 83.87%, respectively. Visual acuity exhibited no statistically significant difference between the postoperative and preoperative follow-up time points, except for the first day after surgery. The most common postoperative complications were anterior chamber hemorrhage (25 cases, 86.21%) and high IOP (10 cases, 34.48%).

● **CONCLUSION:** Our results indicate that MATT-Trab is effective and safe for treating refractory glaucoma.

● **KEYWORDS:** glaucoma; refractory glaucoma; trabeculotomy; trabeculectomy; microcatheter

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## INTRODUCTION

Glaucoma is a progressive optic neuropathy characterized by optic nerve damage and visual field defects caused by increased intraocular pressure (IOP)[1]. It is the main cause of irreversible blindness worldwide, affecting over 70 million people, with 10% experiencing blindness in both eyes[2]. Refractory glaucoma is diagnosed when conventional interventions, such as anti-glaucoma drugs, anti-glaucoma surgery, or laser treatment, prove ineffective, leading to the progression of visual field and optic nerve defects[3]. Clinically, it mainly includes neovascular glaucoma, pediatric glaucoma, secondary glaucoma caused by inflammation, and secondary glaucoma caused by trauma. Current glaucoma treatment focuses on reducing IOP, which remains the only proven method to effectively halt the progression of visual field damage[4-5]. Among the numerous glaucoma surgeries, trabeculectomy is the most traditional and widely applicable surgical method. It effectively reduces IOP in the short-term post-surgery. However, due to the body's inherent capacity for post-traumatic repair, postoperative scarring of the filter vesicles can occur, leading to blockage of filtration channels and surgical failure[6]. This situation is more pronounced in refractory glaucoma due to the complex etiology, which can promote the proliferation of fibroblasts and the synthesis of extracellular matrix components, ultimately leading to the failure of filtration surgery[7].

According to a survey conducted by the American Glaucoma Association, minimally invasive glaucoma surgery has emerged as a recent alternative for treating glaucoma[8-10].

In illumination microcatheter-assisted trabeculotomy, the microcatheter facilitates direct and continuous observation of Schlemm's canal, enabling the safe and complete execution of circumferential trabeculotomy while reducing conjunctival damage without reliance on filter blebs[11-13]. In primary open angle glaucoma, the area with the highest resistance to aqueous humor outflow is the tissue adjacent to the inner wall of Schlemm's canal[14]. The pathogenesis of trabecular meshwork degeneration is also observed in certain secondary glaucoma, such as steroid-induced glaucoma and Posner-Schlossman syndrome, making them suitable for trabeculotomy. However, Rosenquist *et al*[15] showed that even after trabeculotomy in laboratory models, 50% of outflow resistance persists. Therefore, for patients with refractory glaucoma, combining trabeculectomy to enhance the external filtering function with trabeculotomy to enhance the internal filtering function has become the preferred surgical method to compensate for each individual method's shortcomings. This study aimed to evaluate the efficacy and safety of microcatheter-assisted 360-degree trabeculotomy combined with trabeculectomy (MATT-Trab) for the treatment of refractory glaucoma.

## PARTICIPANTS AND METHODS

**Ethical Approval** The data review was performed in compliance with the Declaration of Helsinki, and each patient provided written informed consent. This study was approved by the Ethics Committee of Beijing Tongren Hospital (No. TREC2015-XJS04).

**Participants** We retrospectively examined patients with refractory glaucoma who underwent MATT-Trab performed by an experienced doctor at Beijing Tongren Hospital from November 2020 to July 2022. In cases where only one eye underwent surgery, that eye was selected for grouping. If both eyes underwent surgery, one eye was randomly selected for grouping by flipping a coin.

**Inclusion Criteria** The inclusion criteria were as follows: 1) MATT-Trab in our hospital; 2) diagnosis consistent with refractory glaucoma, including congenital glaucoma, secondary glaucoma, primary open angle glaucoma, and primary angle-closure glaucoma, with uncontrolled IOP after anti-glaucoma surgery[16]; 3) complete follow-up data.

**Exclusion Criteria** The exclusion criteria were as follows: angle closure due to adhesions, neovascular glaucoma, active uveitis, history of eye surgery or trauma other than anti-glaucoma surgery, history of severe heart and lung disease, advanced cancer, mental illness, treatment with anticoagulants, renal dialysis, use of oral medication that affects IOP, and pregnant women.

**Surgical Procedure** General anesthesia or subconjunctival injection (0.2 mL) of 2% lidocaine for local anesthesia was administered. A conjunctival flap was created based on the fornix above the superior nasal or supratemporal area. Subsequently, a trapezoidal superficial scleral flap, measuring approximately 5 mm×4 mm and covering half of the sclera, was prepared. A sponge soaked in 0.4 mg/mL mitomycin C was placed under the conjunctival and scleral flaps for 3–4min, followed by thorough rinsing with a large amount of physiological saline. A 3 mm×3 mm triangular deep scleral flap was then created and dissected until the uveal tissue became visible. The anterior edge of the deep scleral flap crossed the outer wall of the Schlemm's canal, exposing its broken ends on both sides. An appropriate amount of viscoelastic agent was injected into the anterior chamber, and a microcatheter (iTrackTM 250A, iScience International, USA) was inserted through one side of the Schlemm's canal, running along its length. In some cases, a microcatheter protruded from the other end of the Schlemm's canal, allowing both ends to be pulled, completing a full-circumference trabeculectomy. A radial scleral incision was made at the obstructed area under the guidance of a flashing light at the tip of the microcatheter in cases where the microcatheter encountered resistance in scarred areas or other parts of previous surgeries, thereby preventing it from moving forward or causing it to be lost and enter the choroid or anterior chamber. The tip of the microcatheter was exposed and removed, and both ends were pulled to complete the subtotal incision of the trabecular meshwork. The deep scleral flap was sutured with 10-0 nylon thread. A 1.5 mm ×3 mm section of the trabecular tissue at the corneoscleral edge was removed, followed by peripheral iridectomy. The base of the iridectomy was made as wide as possible, ensuring full-layer penetration, with three ciliary processes visible. The two corners of the superficial sclera flap and both sides of the waist were fixed with 10-0 nylon sutures. After rinsing the anterior chamber to remove the viscoelastic agent and controlling bleeding from the lateral incision, the anterior chamber was reconstructed, and filtration function was evaluated. The conjunctiva was subsequently sutured with 10-0 nylon suture, and it was ensured that the IOP returned to normal levels. All surgeries were performed by the same experienced glaucoma surgeon (Wang T).

**Observation Indicators** Basic preoperative examinations, including the best-corrected visual acuity (logMAR), IOP (i-Care), visual field (Humphrey 750i Field Analyzer, Carl Zeiss Meditec, Oberkochen, Germany), cup-to-disc ratio, preoperative medication, and details of the surgical process, were recorded. Best corrected visual acuity (logMAR), IOP (i-Care), complications, medication, and success rates were recorded at 1d, 1wk, 1, 3, 6, 12mo, and the last follow-up after surgery. All assessments were carried out by experienced technicians. The efficacy indicators for research statistics included the IOP level and degree of decrease, changes in medication dosage, and success rate. Safety indicators included the best-corrected visual acuity and incidence of complications.

**Success Rate** The Advanced Glaucoma Intervention Study demonstrated that minimal progression occurs when IOP is maintained below 18 mm Hg[17]. Therefore, we defined surgical success as a postoperative IOP less than or equal to 18 mm Hg, coupled with a decrease in IOP from baseline greater than or equal to 30%. If this criterion was met without the need for medication, it was considered as absolute success. If medication was needed, it was considered as qualified success. Similarly, if the postoperative IOP was less than or equal to 18 mm Hg but the reduction was less than 30%, it was considered qualified success. Surgical failure was identified in cases where there was no light perception after surgery and another surgery was needed to reduce the IOP or if there was postoperative low IOP (below 6 mm Hg). Patients lost to follow-up were excluded from the success or failure rate calculations.

**Statistical Analysis** The data for measured parameters in this study showed a normal distribution in the *W*-test and are presented as mean±standard deviation. The success rate and incidence of complications are expressed as a percentage. Paired *t*-tests were used to compare the best corrected visual acuity, IOP, and medication dosage before and after surgery. A *P*-value <0.05 was considered to indicate a statistically significant difference. IBM SPSS 24 software (Chicago, IL, USA) was used for all statistical analyses, and Prism 9.4.0 software (GraphPad Software, USA) was used to create the statistical charts.

## RESULTS

**Patient Demographic and Preoperative Data** In total, 31 patients, including 11 males and 20 females, were included in this study. The age range of the patients was from 8mo to 67y (mean age: 29.40±22.10y). Among them, there were 13 cases diagnosed with primary open angle glaucoma, three cases with juvenile open angle glaucoma, 10 cases with primary congenital glaucoma, two cases with primary chronic angle-closure glaucoma, one case with pigmentary glaucoma, one case with Axenfeld-Rieger syndrome, and one case with Posner-Schlossman syndrome. The duration of illness ranged from 1mo to 24y (mean duration: 4.36±5.30y). After surgery, all the patients were followed up for more than 1y, with a maximum follow-up period of 26mo (mean follow-up period: 14.67±4.63mo). There were 14 initial surgeries and 17 multiple surgeries, with 13 patients undergoing trabeculectomy. Among them, three had undergone more than one needling surgery, one had undergone trabeculectomy combined with traditional trabeculotomy, one had undergone selective laser trabeculoplasty. Two patients with a diagnosis of primary angle-closure glaucoma, one of whom had undergone cataract phacoemulsification combined with intraocular lens implantation, goniosynechialysis, the other had undergone trabeculectomy combined with cataract phacoemulsification and intraocular lens implantation, goniosynechialysis. The complete trabecular meshwork can be seen under gonioscopy. The patient with Posner-Schlossman syndrome included in our study had a history of 5y and had trabeculectomy 4 years ago. Although there is still a history of several attacks after surgery, the IOP could be maintained normal through drugs and eyeball massage. Reoperation was performed during the inactive period since IOP was poorly controlled due to the scarring of the filtering bleb. The average preoperative medication number was 3.77±0.99. Before surgery, 13 cases had a visual acuity check, with a visual acuity of 0.66±0.44 (logMAR). In 14 cases, visual acuity was no higher than fingers at a distance of 10 cm. For four cases, a visual acuity check was not conducted. One patient diagnosed with juvenile open angle glaucoma was found to have no light perception in his left eye 2 years ago. The patient baseline data are shown in Table 1.

**Table 1 Demographic and preoperative data of patients**

| Variable | Number |
|---|---|
| Sex | |
| Male | 11 |
| Female | 20 |
| Age | 8mo–67y (29.40±22.10y) |
| Eye | |
| Right | 13 |
| Left | 18 |
| Diagnosis | |
| Primary open angle glaucoma | 13 |
| Juvenile open angle glaucoma | 3 |
| Primary congenital glaucoma | 10 |
| Primary angle-closure glaucoma | 2 |
| Pigmentary glaucoma | 1 |
| Axenfeld-Rieger syndrome | 1 |
| Posner-Schlossman syndrome | 1 |
| Duration | 4.36±5.30y (1mo–24y) |
| Follow-up time (mo) | 14.67±4.63 (6–26) |
| No. of operations | |
| First | 14 |
| Several | 17 |
| Number of medications | 3.77±0.99 (2–6) |
| Best-corrected visual acuity (logMAR) | |
| ≤2.0 | 13 (0.66±0.44) |
| Counting finger | 2 |
| Hand movement | 7 |
| Light perception | 4 |
| No light perception | 1 |
| Unable to cooperate | 4 |
| Highest IOP (mm Hg) | 43.55±10.39 (27–60) |
| Preop. IOP (mm Hg) | 31.33±9.24 (16–50) |
| Cup-to-disc ratio | 0.92±0.14 (0.5–1.0) |

IOP: Intraocular pressure.

**Table 2 Mean IOP at baseline and follow-up** mean±SD

| Time | IOP (mm Hg) | Amplitude reduction in IOP | Percentage reduction in pressure (%) | *t* | *P* |
|---|---|---|---|---|---|
| Pre | 31.33±9.24 | - | - | - | - |
| 1d post | 21.67±12.67 | 9.66±18.13 | 30.83 | 2.967 | 0.006 |
| 1wk post | 12.45±4.19 | 18.88±10.86 | 60.26 | 9.677 | 0.000 |
| 1mo post | 14.29±4.00 | 17.04±10.34 | 54.39 | 9.178 | 0.000 |
| 3mo post | 14.90±3.99 | 16.48±11.28 | 52.44 | 8.004 | 0.000 |
| 6mo post | 15.91±4.12 | 15.47±10.09 | 49.22 | 8.397 | 0.000 |
| 12mo post | 17.17±5.51 | 13.73±10.59 | 45.20 | 6.736 | 0.000 |
| Last follow-up | 16.78±4.54 | 14.59±10.18 | 46.44 | 7.855 | 0.000 |

IOP: Intraocular pressure; SD: Standard deviation.

**Table 3 Changes in the postoperative success rate**

| Parameters | 1d | 1wk | 1mo | 3mo | 6mo | 12mo | Last follow-up |
|---|---|---|---|---|---|---|---|
| Absolute success number | 16 | 24 | 23 | 21 | 19 | 14 | 13 |
| Absolute success rate (%) | 51.61 | 77.42 | 74.19 | 67.74 | 61.29 | 45.16 | 41.94 |
| Qualified success number | 20 | 27 | 28 | 27 | 28 | 26 | 26 |
| Qualified success rate (%) | 64.52 | 87.1 | 90.32 | 87.1 | 90.32 | 83.87 | 83.87 |
| Failed number | 11 | 4 | 3 | 4 | 3 | 5 | 5 |
| Failed rate (%) | 35.48 | 12.9 | 9.68 | 12.9 | 9.68 | 16.13 | 16.13 |

**Changes in Intraocular Pressure** The average preoperative IOP was 31.33±9.24 mm Hg. The average postoperative IOP at 1d, 1wk, 1, 3, 6mo, 1y, and the last follow-up was significantly lower than the preoperative IOP, and the difference was statistically significant ($P$<0.05). However, on the first day after surgery, 10 cases (32.26%) had an IOP higher than 30 mm Hg due to anterior chamber hemorrhage. Seven cases had their IOP reduced to normal levels after anterior chamber puncture, use of local and systemic IOP-lowering drugs, and laser suture lysis (Table 2, Figures 1 and 2).

**Changes in Medication Dosage** The average number of medications used postoperatively was 0.48±1.51, which was significantly reduced compared to that used preoperatively (3.77±0.99, $P$=0.00). Twenty-six cases (83.87%) did not require IOP-lowering drugs, whereas five cases (16.13%) required pressure-lowering drugs. Among them, three cases diagnosed with primary congenital glaucoma required a local IOP-lowering drug 3mo after surgery, which maintained normal IOP thereafter. A patient diagnosed with juvenile open angle glaucoma was treated with two types of IOP-lowering drugs 1y after surgery, with the IOP remaining within the normal range. A patient diagnosed with Posner-Schlossman syndrome had normal IOP after 3mo of postoperative use of three local IOP-lowering drugs. A patient diagnosed with primary open angle glaucoma started medication 1mo after surgery, but despite using four local IOP-lowering drugs and consuming oral acetazolamide, the IOP was not well-controlled. This patient was scheduled for another surgical procedure (Figure 3).

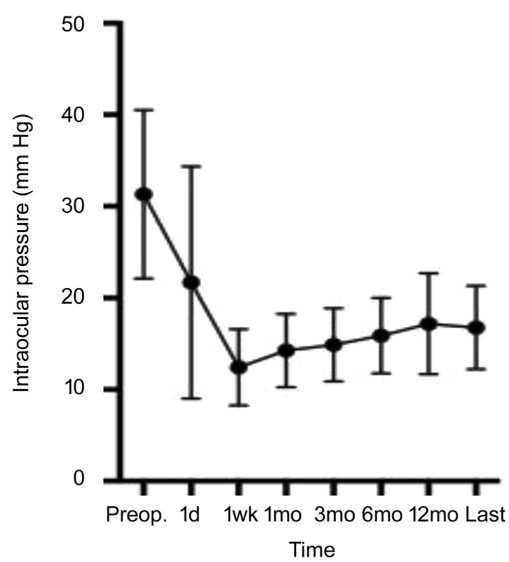

**Figure 1 Mean intraocular pressure at baseline and follow-up.**

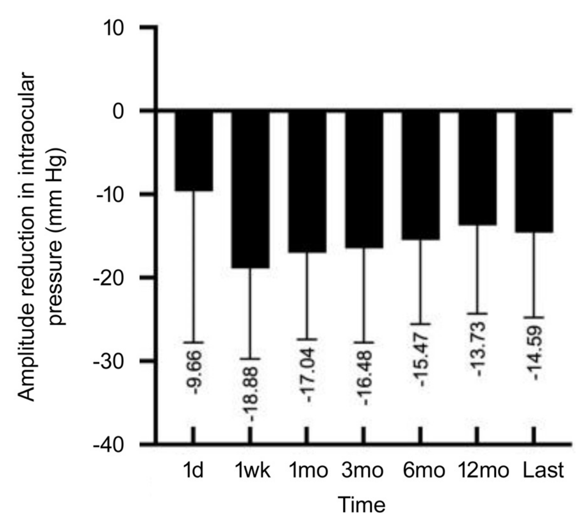

**Figure 2 Mean amplitude reduction in intraocular pressure at follow-up.**

**Success Rate** At 1y after surgery, the absolute success rate and qualified success rate were 45.16% and 83.87%, respectively. At the last follow-up, the absolute success rate and qualified success rate were 41.94% and 83.87%, respectively. The changes in postoperative success rate are shown in Table 3 and Figure 4.

**Visual Changes** The number of cases with improved, unchanged, and decreased visual acuity at 1d, 1wk, 1, 3, 6, and 12mo after surgery, as well as at the last follow-up, is recorded in Table 4. During the 1-year follow-up after surgery, with the exception of four cases where vision checks were not performed, 11 cases (40.74%) experienced improved vision, 10 cases (37.04%) had unchanged vision, and six cases (22.22%) had decreased vision. Among the 13 patients with visual acuity better than 2.0 (logMAR visual acuity chart), there was no statistically significant difference in visual acuity between postoperative and preoperative follow-up time points, except for the first day after surgery. The highest number of cases with decreased vision was observed on the first day after surgery (Table 4 and Figure 5).

**Complications** The most common postoperative complication was anterior chamber hemorrhage. On the first day after surgery, 25 cases (86.21%) experienced varying degrees of anterior chamber hemorrhage, all of which resolved within 3d to 2wk. Postoperative high IOP was observed in 10 cases (34.48%), all occurring on the first day after surgery due to anterior chamber hemorrhage. Among them, seven cases (24.13%) had stable IOP after early anterior chamber puncture, systemic IOP-lowering drugs, and laser suture lysis. The remaining three cases had persistently high IOP, requiring reoperation. Five cases (17.24%) presented with strong filtration and a shallow anterior chamber, which improved after compression bandaging and enhanced pupil dilation. Severe postoperative inflammatory reactions occurred in two cases (6.90%), and these were relieved with oral and local administration of glucocorticoids. No serious complications, such as low IOP macular degeneration or choroidal detachment, were reported.

## DISCUSSION

The effectiveness of filtration surgery in reducing IOP has been widely established, with success rates ranging from 70% to 90% in most cases. However, managing refractory glaucoma remains a challenge in clinical practice. The establishment of effective filtration channels is hindered by fibrous proliferation in the filtering bleb area, leading to an increased risk of surgical failure. All patients included in our study had refractory glaucoma, and most had experienced one or more surgical failures. We used MATT-Trab to treat refractory glaucoma. The transient increase in IOP observed on the first day after surgery was alleviated, and at the 1-year follow-up, the average IOP

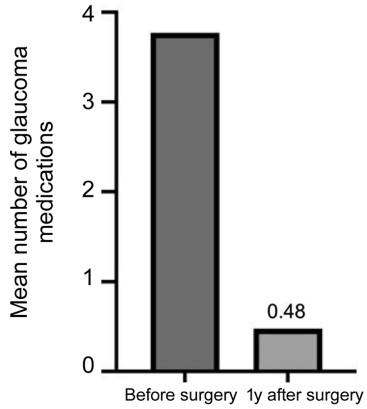


Figure 3 Number of medications before and after surgery.

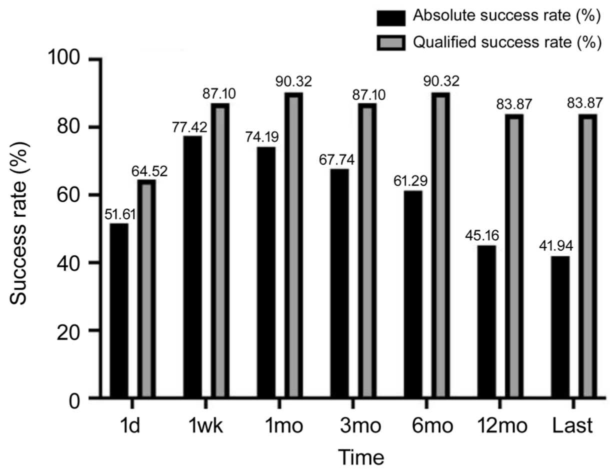


Figure 4 Success rates at follow-up.

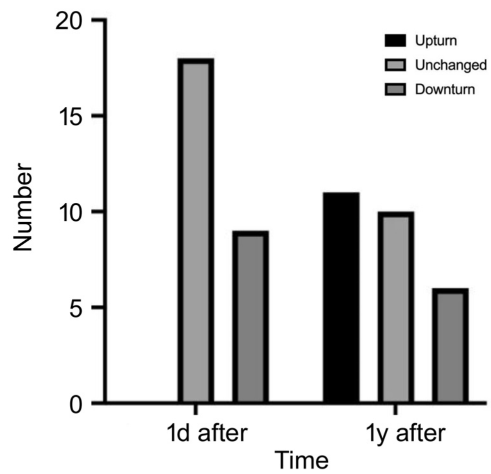


Figure 5 Diagram of visual changes.

Table 4 Changes in the postoperative visual acuity

| Time point | Best-corrected visual acuity (logMAR) | | |
|---|---|---|---|
| | Mean±SD | *t* | *P* |
| Pre | 0.66±0.44 | - | - |
| 1d post | 0.70±0.26 | -2.735 | 0.026 |
| 1wk post | 0.66±0.38 | 0.000 | 1.000 |
| 1mo post | 0.67±0.32 | -0.075 | 0.942 |
| 3mo post | 0.58±0.29 | 1.000 | 0.337 |
| 6mo post | 0.58±0.28 | 1.000 | 0.337 |
| 12mo post | 0.58±0.28 | 1.000 | 0.337 |
| Last follow-up | 0.58±0.28 | 1.000 | 0.337 |

SD: Standard deviation.

was 17.17 mm Hg. The mean reduction in IOP was 45.20%, with 45.16% of patients achieving an IOP below 18 mm Hg and a reduction of over 30%. The above criteria were met by 83.87% of patients with the use of IOP-lowering drugs.

Some previous studies have reported the surgical effect of refractory glaucoma. A study reported that in the group treated with trabeculectomy, the IOP decreased to 14.4±6.6 mm Hg, with an average of 1.4±1.4 medications used[18]. In a multicenter study conducted by Kirwan *et al*[19], the success rate at 2y after trabeculectomy for advanced glaucoma was 64%, defined as IOP below 15 mm Hg, with a reduction of over 40%. Tsagkataki *et al*[20] explored the value of canaloplasty in advanced glaucoma and found a success rate of 60% within 3y, defined as an IOP<16 mm Hg. In our study, the level and magnitude of IOP seem to be less favorable compared to those in the aforementioned studies. This is likely attributed to our patients having a longer disease course and a more advanced stage of the disease at the time of treatment compared to patients in the previous studies. In addition, our target IOP of 18 mm Hg is higher than that in the aforementioned studies, resulting in a reduced need for IOP-lowering drugs compared to that in the previous studies. Another study involving secondary glaucoma reported a postoperative decrease in IOP to 17.1 mm Hg[21], which aligns with our results.

However, notably, several multicenter large-sample clinical studies have demonstrated successful outcomes with simple trabeculectomy in the treatment of early primary open angle glaucoma. In one such multicenter clinical study, 222 patients newly diagnosed with glaucoma underwent trabeculectomy as their initial treatment, achieving an average IOP of 12.4 mm Hg 2y after surgery[22]. In another multicenter study, 132 patients with primary open angle glaucoma underwent trabeculectomy and their IOP decreased from 21.1±5.0 to 11.1±4.3 mm Hg (-45.4%; *P*<0.01) 1y after treatment. The average number of IOP lowering drugs used was 0.3±0.9 (baseline: 3.0±0.9; *P*<0.01), with a success rate of 72.7% and a low IOP incidence rate of 49.6%[23]. Success, defined as an IOP≤15 mm Hg, was achieved in 11 eyes, resulting in a success rate of 31.4%[24]. In another study, the complete success rate of trabeculectomy was 37.5%[25]. Therefore, for patients with early to mid-stage glaucoma, it is possible to achieve the target therapeutic effect by either performing trabeculectomy alone or opting for microcatheter-assisted 360-degree trabeculotomy without the need for combined surgery. The patient should be thoroughly and objectively examined and evaluated before formulating the surgical plan.

Our study also included 10 children with congenital glaucoma, of whom three cases received one local IOP-lowering medication at the 3rd month post-surgery. After the administration of the medication, the IOP remained within the target range, while the other seven children did not require any medication to achieve the target IOP. The 360-degree trabeculotomy assisted by illuminated microcatheters was initially used for the treatment of congenital glaucoma due to the theory of “Barkan membrane”. These factors affect aqueous humor drainage, necessitating surgical incision of the diseased trabecular meshwork to address the drainage issue[26]. The treatment of childhood glaucoma has always posed significant challenges. The earlist angle incision and external trabeculotomy cannot cut large enough meshwork and carry the risk of creating false passages and damaging surrounding tissues, inadvertently entering the retina or choroid during surgery[27-29]. Microcatheter-assisted 360-degree trabeculotomy enables the visualization of the microcatheter’s movement in the Schlemm’s canal, allowing for safe and complete incision of the trabecular meshwork and reducing intraoperative complications[30]. Some studies confirmed that microcatheter-assisted trabeculotomy combined with trabeculectomy for primary congenital glaucoma can achieve positive therapeutic effects in the treatment of primary infantile glaucoma[31-32]. Our study did not achieve such good efficacy, perhaps this difference can be attributed to the higher baseline IOP (31.33±9.24 mm Hg). Considering that the necessity for pediatric patients to undergo examinations and surgeries under general anesthesia, they can neither express themselves autonomously nor be checked frequently, we recommend routine combined trabeculotomy and trabeculectomy surgery for pediatric patients with glaucoma.

In this study, we also included some cases of secondary open angle glaucoma, including one case of pigmentary glaucoma, one case of Posner-Schlossman syndrome, and one case of Axenfeld-Rieger syndrome. Previous studies have applied 360-degree suture trabeculotomy to secondary open angle glaucoma, including uveitic glaucoma, Posner-Schlossman syndrome, pigmentary glaucoma, exfoliation syndrome, trauma, glucocorticoid-induced glaucoma, and almost all types of glaucoma with open angles. These studies achieved the same 1-year success rate as that for primary open angle glaucoma (secondary open angle glaucoma, 89%; primary open angle glaucoma, 84%), and all of them had success rates superior to traditional trabeculotomy surgery (approximately 50%)[33-34]. Additionally, if a patient with angle-closure glaucoma has an open and non-adhesive closure of the angle, a 360-degree trabeculotomy is also suitable[35]. In our study, two cases of primary angle-closure glaucoma were treated with phacoemulsification combined with goniosynechialysis, and preoperative angle endoscopy showed an open state. Therefore, this surgical approach was also adopted and was successful.

This study confirms that the most common complication after 360-degree trabeculotomy combined with trabeculectomy is anterior chamber hemorrhage. The incidence of varying degrees of anterior chamber hemorrhage on the first day after surgery was 86.21%, and the incidence of postoperative high IOP caused by anterior chamber hemorrhage was 34.48%. This finding is similar to that observed in 90% of the reported 360-degree trabeculotomy but significantly higher than the traditional trabeculotomy, as the former involves a relatively large range of trabecular meshwork *via* a circular incision[30,36]. However, in our study, the resolution of anterior chamber hemorrhage and high IOP was fast owing to the filtering bleb of trabeculectomy, which accelerated the elimination and dilution of blood. It is also possible to adjust the scleral flap suture and filter excess aqueous humor according to the postoperative IOP situation. In this study, there were also five cases (17.24%) with strong filtering and a shallow anterior chamber. However, the incidence was not as high as that reported in the literature (49.6%) after simple trabeculectomy[23]. Additionally, there were no serious complications, such as low IOP macular degeneration and choroidal detachment, which were relieved after compression bandaging and enhanced mydriasis. This may be attributed to the surgical procedures, use of adjustable sutures, and small amount of anterior chamber bleeding during surgery that reduced the permeability of the filter bleb. Although the proportion of anterior chamber bleeding in the combined group was significantly higher than that in the simple trabeculectomy group (4 cases, 1.80%). However, no other previously reported complications, including dry eye syndrome, blepharitis, meibomian inflammation, conjunctivitis, itchy eyes, tearing, retinal vascular occlusion, and vitreomacular traction, occurred[22].

Glaucoma is an irreversible eye disease that can lead to blindness, and glaucoma surgery aims to reduce IOP without significantly damaging visual function. However, in our study, it was noted that both early and long-term postoperative patients experienced visual impairment. On the first day after surgery, nine patients experienced visual impairment, which was related to postoperative anterior chamber bleeding, strong filtering, and low IOP. However, at the last follow-up after surgery, six patients still had visual impairment. This may be attributed to the fact that all our patients had refractory late-stage glaucoma, and some may experience unexplained and irreversible central vision loss during trabeculectomy, known as "wipe out"[37]. Two prospective studies specifically exploring the development of "wipe out"[38-39] did not find severe, irreversible, and unexplained cases of central vision loss, indicating that, if it exists, it may be a rare event. Patients with improved vision starting from 1wk after surgery may experience corneal edema due to a preoperative increase in IOP, while a postoperative decrease in IOP improves the blood supply to the optic nerve. However, these patients with improved vision only had slight relief, such as improvement from light perception to hand movement or counting fingers.

Our study has some limitations. First of all, it's a small sample size retrospective study with a lack of long-term follow-up beyond 1y. Further follow-ups with these patients will help us to know the long-term efficacy of this procedure. Additionally, we studied the refractory glaucoma of children and adults together. In the future, glaucoma in adults or children will be studied separately when we include more cases. Moreover, we did not set up control groups. Whether the combined trabeculotomy reduces the filtration volume of the filtration bleb and hinders its long-term maintenance or not is not easy to measure. In the future, we plan to use advanced imaging detection methods, such as anterior segment optical coherence tomography, which has been developed in recent years, to quantitatively observe the internal structure of filtering blebs and the trabecular meshwork status of the angle. Large-sample prospective studies should be conducted to compare the efficacy and safety of trabeculectomy, microcatheter-assisted 360-degree ab-externo trabeculotomy, or a combination of both.

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