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ORIGINAL PAPER

Comparison of outcomes of circumferential versus hemi-gonioscopy-assisted transluminal trabeculotomy in primary open-angle glaucoma: 24-Month results

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Abstract

Purpose To compare the clinical outcomes of circumferential (360°) versus hemi (180°) gonioscopy-assisted transluminal trabeculotomy (GATT) in patients with primary open-angle glaucoma (POAG) over a 24-month follow-up.

Methods This retrospective, comparative study included 90 eyes of 90 patients with POAG who underwent either standalone circumferential GATT (n = 46) or hemi-GATT (n = 44). Inclusion criteria required uncontrolled intraocular pressure (IOP) (≥ 20 mmHg) despite maximal medical therapy or intolerance to medications. Main outcomes included surgical success (complete and qualified), IOP, number of anti-glaucoma medications, and postoperative complications. Complete success was defined as achieving a target IOP of 6–18 mmHg with ≥ 20% reduction from baseline without medications or further surgery. Qualified success allowed medication use.

Results At 24 months, mean IOP reduction was greater in the circumferential GATT group (− 10.1 ± 5.3 mmHg; 39.7%) than the hemi-GATT group (− 8.0 ± 3.8 mmHg; 32%) ($p < 0.05$). Complete success was achieved in 58.7% and 34.1% of eyes in the circumferential and hemi-GATT groups, respectively ($p = 0.006$). Qualified success rates were 78.2% (circumferential GATT) vs. 61.3% (hemi-GATT) ($p = 0.051$). The most common complication was transient hyphema, observed more frequently after circumferential GATT (54.6%) than hemi-GATT (31.8%) ($p = 0.03$). IOP spikes (> 30 mmHg) occurred in 10.8% of circumferential and 9% of hemi-GATT eyes ($p = 0.71$), all managed conservatively.

Conclusions Both circumferential and hemi-GATT effectively lowered IOP in patients with POAG. Circumferential GATT achieved greater IOP reduction and higher complete success, while hemi-GATT was associated with fewer hyphema events. Hemi-GATT may be preferable in patients at higher bleeding risk, whereas circumferential GATT may provide superior IOP control.

Keywords Gonioscopy-assisted transluminal trabeculotomy · GATT · Primary open-angle glaucoma · POAG

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Introduction

Over the past decade, minimally invasive glaucoma surgeries (MIGS) have gained popularity in the management of various types of glaucoma due to their lower complication rates and faster postoperative recovery compared to conventional procedures [1]. Among the MIGS techniques, gonioscopy-assisted transluminal trabeculotomy (GATT), first described by Grover et al. in 2014 [2], has emerged as one of the most widely adopted methods. GATT is a conjunctiva-sparing, circumferential trabeculotomy technique that has demonstrated both safety and efficacy in the treatment of open-angle glaucoma [3, 4].

Although GATT is typically performed as a 360-degree trabeculotomy [1], recent studies have reported favorable outcomes with a 180-degree approach (hemi-GATT) in patients with open-angle glaucoma after 12 months of follow-up. [5, 6]. However, to the best of our knowledge, no studies have directly compared the long-term outcomes of hemi-GATT and circumferential GATT in patients with primary open-angle glaucoma (POAG) over a 24-month follow-up period. In this study, we aim to evaluate the efficacy, safety, and complication profiles of hemi-GATT compared to circumferential GATT, and to provide insight into the long-term outcomes of this relatively newer surgical modification.

Methods

Study design

This retrospective comparative study was conducted to assess the clinical outcomes of hemi-GATT versus circumferential GATT in patients with primary open-angle glaucoma. Ethical approval was obtained from the institutional review board, and the study adhered to the tenets of the Declaration of Helsinki. All patients provided written informed consent prior to surgery after receiving detailed information about the procedure and its potential risks and complications.

Patient selection

Medical records of patients diagnosed with primary open-angle glaucoma who underwent gonioscopy-assisted transluminal trabeculotomy were reviewed. All patients had undergone detailed gonioscopic evaluation using a Goldmann three-mirror lens to confirm adequate visualization of anatomical landmarks. Patients were not considered suitable for GATT if they presented with anterior synechiae involving more than 90 degrees of the angle, neovascular glaucoma, poorly defined trabecular meshwork, corneal endothelial decompensation, unstable intraocular lenses, or were receiving systemic anticoagulant therapy.

Patients included in the study were adults with uncontrolled intraocular pressure of 20 mmHg or higher despite receiving maximal tolerated medical therapy involving at least two antiglaucomatous agents, or who were unable to tolerate topical medications due to poor adherence or ocular hypersensitivity. A minimum follow-up period of 24 months after the GATT procedure was required for inclusion. Patients with secondary open-angle glaucoma, irregular follow-up, follow-up shorter than 24 months, a history of prior glaucoma surgery, or who underwent combined phacoemulsification and GATT surgery were excluded. In cases where both eyes underwent GATT, only the eye with the longer follow-up duration was included in the analysis.

Chart review

A retrospective chart review was conducted for patients who underwent GATT for open-angle glaucoma between October 2017 and May 2023. Demographic data, including age, sex, and race, were collected along with clinical information on the number and types of anti-glaucoma medications used before and after surgery.

All patients underwent a comprehensive ophthalmologic evaluation prior to the procedure. This included best-corrected visual acuity (BCVA) assessment using a standard Snellen chart, intraocular pressure (IOP) measurement with a Goldmann applanation tonometer (Haag-Streit, Koeniz, Switzerland), and retinal nerve fiber layer (RNFL) thickness analysis performed with the same optical coherence tomography system (Optovue OCT V 5.1, RTVue 100–2; Optovue, Fremont, CA, USA).

All IOP measurements, both preoperative and postoperative, were performed by the same two examiners (M.O.C. and A.Y.U.) using the Goldmann

tonometer. Preoperative IOP was calculated as the average of the three most recent measurements recorded before surgery.

Surgical technique

All procedures were performed by the same two experienced surgeons (M.O.C. and A.Y.U.) in a standard operating room under topical anesthesia using 0.5% proparacaine hydrochloride (Alcaine; Alcon Laboratories, Fort Worth, TX, USA). Following standard sterile preparation and draping, a 23-gauge paracentesis was created tangentially in the superonasal quadrant to serve as the entry site for the suture. A second paracentesis was made temporally, allowing for controlled hypotony to facilitate blood reflux from Schlemm's canal, confirming its patency.

A cohesive viscoelastic agent (1.4% sodium hyaluronate; CrownVisc 1.4, Medizintechnik AG, Philippsburg, Germany) was injected into the anterior chamber through the temporal paracentesis. The patient's head and the surgical microscope were aligned to optimize visualization of the nasal angle using a Swan-Jacob goniolens. A 5–0 blue monofilament polypropylene suture (Ethicon, Johnson & Johnson, Somerville, NJ, USA) was rounded at the tip using thermal cautery and introduced into the anterior chamber through the superonasal entry site, positioning the tip at the nasal angle.

A 1–2 mm goniotomy was created at the nasal angle with a 23-gauge microsurgical blade via the temporal incision. The suture was then grasped with 23-gauge microsurgical forceps and advanced into Schlemm's canal through the goniotomy site. Circumferential advancement of the suture was performed through Schlemm's canal. Upon successful 360-degree passage, the distal tip of the suture was externalized at the goniotomy site, and final traction was applied to the proximal end to complete the 360-degree ab interno trabeculotomy.

In instances where full circumferential passage was not possible due to resistance encountered—particularly along the inferior half of Schlemm's canal—a partial procedure was completed. In these cases, controlled traction was applied to the accessible portion of the suture, resulting in a 180-degree trabeculotomy. These cases were categorized as hemi-GATT procedures.

At the conclusion of the surgery, intraocular blood and the ophthalmic viscoelastic agent were thoroughly evacuated using bimanual irrigation and aspiration. A prophylactic intracameral injection of cefuroxime (1 mg/0.1 mL) was administered to reduce the risk of postoperative endophthalmitis. All incisions were inspected to ensure watertight closure.

Postoperative care included topical moxifloxacin (Vigamox; Alcon) and prednisolone acetate (Allergan Pharmaceuticals, Ireland), both administered five times daily. Moxifloxacin was continued for three weeks, while prednisolone acetate was tapered according to clinical response and discontinued within the same period.

Postoperative follow-up

Postoperative clinical data were retrospectively obtained from patient records at standardized follow-up intervals, including postoperative day 1, week 1, month 1, month 3, month 6, and subsequently at six-month intervals. IOP measurements exceeding 30 mmHg at any follow-up visit were defined as IOP spikes, consistent with criteria described in previous studies [7].

Adjustments to anti-glaucomatous medical therapy were made on an individual basis, taking into account the severity of the disease and clinical response. Target IOP values were stratified according to glaucoma stage, as reported in the literature: ≤ 12 mmHg for advanced, ≤ 15 mmHg for moderate, and ≤ 18 mmHg for early-stage glaucoma [8].

Main outcome measures

Complete success was defined as achieving a target IOP of 6–18 mmHg with $\geq 20\%$ reduction from baseline without IOP-lowering medications, additional glaucoma surgery, or vision-threatening complications during follow-up. Qualified success was defined similarly but allowed the use of IOP-lowering medications. Surgical failure was defined as the need for further IOP-lowering surgical intervention at any time during follow-up, including repeat angle surgery, trabeculectomy, tube shunt implantation, or cyclodestructive procedures.

Outcome measures included the rate of surgical success (complete and qualified), changes in

IOP over time, the number of anti-glaucoma medications required postoperatively, intraoperative and postoperative complications, and the need for subsequent glaucoma procedures. These variables were analyzed and compared between the hemi-GATT and circumferential GATT groups.

Statistical analysis

Patients were divided into two groups for comparative analysis: Group 1 included those who underwent circumferential GATT, and Group 2 comprised patients treated with hemi-GATT. All statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS), version 27.0 (IBM Corp., Armonk, NY, USA).

Descriptive statistics were presented as minimum, maximum, and mean values with corresponding standard deviations. The Kolmogorov–Smirnov test was used to assess the normality of data distribution. For within-group comparisons of preoperative and postoperative parameters the paired samples t-test and Repeated measures variance analysis were employed. Comparisons between the two groups were performed using the independent samples T test for continuous variables and the Pearson chi-square test for categorical variables.

Results

A total of 220 medical records of patients diagnosed with POAG who underwent GATT were reviewed retrospectively. Of these, 90 eyes met the inclusion criteria and were included in the final analysis. Forty-six eyes underwent circumferential GATT, while the remaining 44 received hemi-GATT. Baseline demographic and clinical characteristics, along with average follow-up durations, are presented in Table 1. There were no statistically significant differences between the two groups in terms of age, sex, preoperative IOP, number of anti-glaucoma medications, or follow-up duration.

Clinical outcomes for the circumferential GATT group are summarized in Table 2. At six months postoperatively, a significant mean IOP reduction of 9.9 ± 5.2 mmHg (%38.9) was observed (p = 0.001). This reduction remained stable over time, with mean IOP decreases of 9.8 ± 5.1 mmHg (38.5%) and 10.1 ± 5.3 mmHg (39.7%) at 12 and 24 months, respectively (both p = 0.001). A corresponding decline in the number of anti-glaucoma medications was also noted throughout the follow-up period, as detailed in Table 3. By the end of the follow-up, 58.7% (27 out of 46 eyes) achieved complete surgical success, while 78.2% (36 out of 46 eyes) met the criteria for qualified success when including cases that required ongoing anti-glaucomatous therapy.

Clinical outcomes for the hemi-GATT group are presented in Table 2. A significant reduction in

Table 1 Baseline demographical and clinical characteristics of patients

	GATT *n*:46	Hemi-GATT *n*:44	Total	*p* value
Mean age at GATT surgery (years)	59.2 ± 12.6 (29–81)	60.8 ± 12.2 (41–80)	60.0 ± 12.4 (29–81)	0.561*
Mean follow-up (Months)	30.0 ± 5.05 (24–36)	29.1 ± 5.2 (24–36)	29.6 ± 5.1 (24–36)	0.454*
Female (*n*, %)	25 (54.3%)	16 (36.4%)	41 (45.5%)	0.087**
Average baseline IOP (mmHg)	25.4 ± 3.9 (21.0–36.0)	25.0 ± 3.7 (21.0–37.0)	25.6 ± 4.2 (21–37)	0.282*
Average number of medication	3.1 ± 0.5 (2–4)	3.0 ± 0.6 (2–4)	3.0 ± 0.6 (2–4)	0.510*
Mean BCVA (LogMAR)	0.13 ± 0.20 (0.0–1.0)	0.15 ± 0.21 (0.0–1.0)	0.14 ± 0.20 (0.0–1.0)	0.587*
Pseudophakic (n, %)	21 (45.7%)	25 (56.8%)	46 (51.1%)	0.289*
Average C/D ratio	0.67 ± 0.12 (0.4–0.9)	0.68 ± 0.11 (0.4–0.9)	0.67 ± 0.11 (0.4–0.9)	0.466*
Average RNFL thickness (µ)	81.3 ± 7.5 (61–95)	81.5 ± 8.1 (63–96)	81.4 ± 7.7 (61–96)	0.896*

GATT gonioscopy-assisted transluminal trabeculotomy, *IOP* intraocular pressure, *RNFL* retinal nerve fiber layer, *m*: month, *SD* standard deviation

*Independent Samples t test, **Pearson chi-square test

Table 2 Comparison of circumferential GATT and hemi-GATT in terms of IOP

Parameters mean IOP ± SD (mm Hg) (min–max)	Efficacy of circumferential GATT on IOP n:46	Efficacy of hemi GATT on IOP n:44	Intergroup analysis
Preop	25.4 ± 3.9 (21–36)	25.0 ± 3.7 (24–41)	$P = 0.605$**
Postop 1 m	14.8 ± 4.1 (8–30) $p = 0.001$*	17.1 ± 3.6 (10–27) $p = 0.001$*	$P = 0.027$**
Postop 3 m	15.2 ± 3.7 (10–24) $p = 0.001$*	16.5 ± 3.7 (11–24) $p = 0.001$*	$P = 0.034$**
Postop 6 m	15.5 ± 3.3 (11–23) $p = 0.001$*	16.5 ± 3.2 (11–23) $p = 0.001$*	$P = 0.060$**
Postop 12 m	15.5 ± 3.1 (11–23) $p = 0.001$*	16.7 ± 3.1 (10–24) $p = 0.001$*	$P = 0.071$**
Postop 24 m	15.2 ± 3.5 (10–24) $p = 0.001$*	16.9 ± 3.2 (11–24) $p = 0.001$*	$P = 0.048$**
Postop Final	14.8 ± 3.5 (9–23) $p = 0.001$*	17.1 ± 4.1 (11–23) $p = 0.001$*	$P = 0.013$**

GATT gonioscopy-assisted transluminal trabeculotomy, *IOP* intraocular pressure, *m* month, *SD* standard deviation, *Postop* postoperative, *Preop* preoperative. *n* number of eyes

*Intragroup analysis Repeated measures variance analysis -Bonferroni Adjustment, **Intergroup analysis Independent Samples t test

Table 3 Comparison of circumferential GATT and hemi-GATT in terms of medication use

Parameters	Preop mean number of med ± SD (min–max)	Postop final mean number of med ± SD (min–max)	Intragroup analysis P
Circumferential GATT	3.1 ± 0.5 (2–4)	0.8 ± 1.2 (0–4)	0.001*
Hemi-GATT	3.0 ± 0.6 (2–4)	1.5 ± 1.4 (0–4)	0.001*
Intergroup anaylsis p	0.958**	0.033**	

GATT gonioscopy-assisted transluminal trabeculotomy, *IOP* intraocular pressure, *m*: month, *SD* standard deviation, *med* medications, *Postop* postoperative, *Preop*: preoperative

*Paired samples t test **Independent Samples t test

IOP was observed at all follow-up intervals. At six months postoperatively, the mean IOP reduction was 8.4 ± 3.9 mmHg (33.6%) (p = 0.001), which remained stable at 12 months (8.3 ± 4.0 mmHg, p = 0.001) (33.2%), and at 24 months (8.0 ± 3.8 mmHg, p < *0*.001), (32%). The reduction in the number of anti-glaucoma medications was also significant, as shown in Table 3. At the last visit, 34.1% (15 out of 44 eyes) achieved complete success without medications, while the qualified success rate, including those requiring pharmacological therapy, was 61.3% (27 out of 44 eyes).

Comparative outcomes between the two surgical groups are presented in Table 2, Table 3 and Table 4. It is also summarized in Table 5. At 24 months, circumferential GATT resulted in a significantly greater mean IOP reduction compared to hemi-GATT ($p = 0.036$) along with a lower mean number of medication ($p = 0.033$). Additionally, when the two groups were compared, preoperative and postoperative retinal nerve fiber layer thickness values were statistically comparable between the circumferential GATT and hemi-GATT groups; however, although a statistically significant postoperative thinning was observed within the hemi-GATT group compared with preoperative values, the magnitude of this change was not clinically meaningful (Table 4).

Kaplan–Meier survival analysis also performed to compare the success rates of groups and it demonstrated higher complete surgical success rates in the circumferential GATT group compared to the Hemi-GATT group at the end of the follow-up period (58.7% vs. 34.1%, $p = 0.006$) (Fig. 1A). Qualified surgical success rates were also higher in the circumferential GATT group (78.2%) than in the Hemi-GATT group (61.3%) though this did not reach statistical

Table 4 Comparison of circumferential GATT and hemi-GATT in terms of RNFL thickness

Parameters	Preop mean RNFL (μ) ± SD (min–max)	Postop Final mean RNFL (μ) ± SD (min–max)	Intragroup analysis P
Circumferential GATT	81.3 ± 7.5 (61–95)	80.0 ± 8.1 (59–97)	0.061*
Hemi-GATT	81.5 ± 8.1 (63–96)	79.8 ± 7.8 (59–90)	0.023*
Intergroup anaylsis p	0.832**	0.810**	

GATT gonioscopy-assisted transluminal trabeculotomy, *IOP* intraocular pressure, *RNFL* retinal nerve fiber layer, *m* month, *SD* standard deviation, *Postop* postoperative, *Preop* preoperative

*Paired samples t test **Independent Samples t test

Table 5 Comparison of circumferential GATT and hemi- GATT In terms of surgical success

Parameter	Circumferential GATT	Hemi-GATT	P
Mean Reduction In IOP (6 months)	9.9 ± 5.2 (%38.9)	8.4 ± 3.9 (33.6%)	0.13*
Mean Reduction In IOP (12 months)	9.8 ± 5.1 (38.5%)	8.3 ± 4.0 (33.2%)	0.12*
Mean Reduction In IOP (24 months)	10.1 ± 5.3 (39.7%)	8.0 ± 3.8 (32%)	0.036 *
Complete surgical success rates	58.7%	34.1%	0.006**
Qualified surgical success	78.2%	61.3%	0.051

**GATT* gonioscopy-assisted transluminal trabeculotomy, *IOP* intraocular pressure, SD standard deviation
*Independent samples t test
**Kaplan–meier analysis

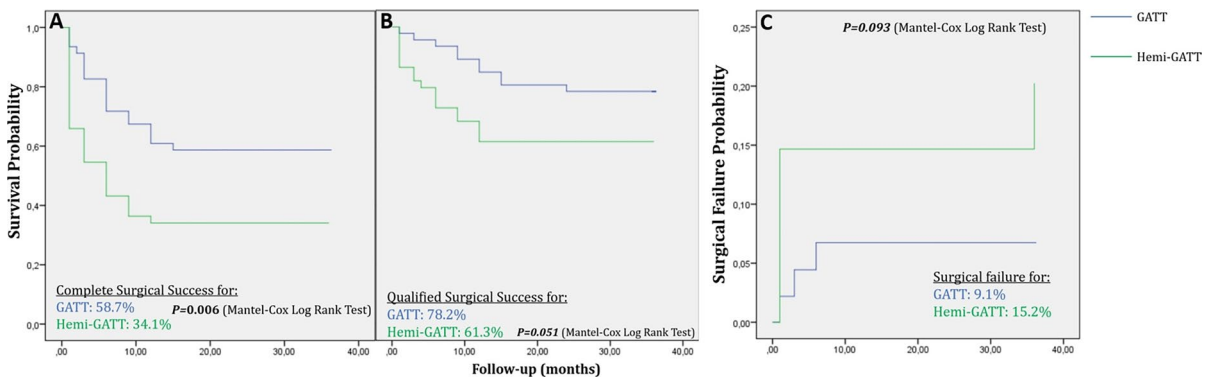

Fig. 1 Kaplan–Meier survival curves comparing surgical outcomes between circumferential GATT and Hemi-GATT procedures. **A** Complete surgical success rates (Mantel-Cox Log Rank test, $P = 0.006$). **B** Qualified surgical success rates (Mantel-Cox Log Rank test, $P = 0.051$). **C** Surgical failure probability (Mantel-Cox Log Rank test, $P = 0.093$). lue lines represent GATT, and green lines represent Hemi-GATT. Survival probabilities and percentages are annotated on each graph

significance ($p = 0.051$) (Fig. 1B). The cumulative probability of surgical failure at the end of the follow-up was 9.1% for GATT and 15.2% for Hemi-GATT, with no statistically significant difference between the groups ($p = 0.093$) (Fig. 1C).

Postoperative complications are detailed in Table 6. Descemet's membrane detachment occurred

Table 6 Intraoperative and postoperative complications

Parameter	Circumferential GATT	Hemi-GATT	P
Intraoperative			
Descemet Detachment	2/46 (4.3%)	1/44 (2.2%)	0.43*
Postoperative			
Hyphema	25/46 (54.6%)	14/44 (31.8%)	0.03*
IOP Spike	4/46 (10.8%)	4/44 (9.0%)	0.71*

GATT gonioscopy-assisted transluminal trabeculotomy
*chi-square test

in three cases: two in the circumferential GATT group and one in the hemi-GATT group. The difference between groups was not statistically significant ($p=0.43$), and all cases were managed successfully with intracameral air injection. Hyphaema was the most frequently encountered complication, occurring in 25 eyes (54.6%) in the circumferential GATT group and 14 eyes (31.8%) in the hemi-GATT group ($p=0.03$). None of the cases required anterior chamber lavage.

Transient IOP spikes during the first postoperative week were observed in four eyes (10.8%) in the circumferential GATT group and in three eyes (9%) in the hemi-GATT group ($p=0.71$). These elevations were effectively managed by tapering or discontinuing topical corticosteroid therapy with additional medication if necessary.

Discussion

In this study, we retrospectively compared the clinical outcomes of circumferential versus hemi-GATT in patients with POAG over a 24-month follow-up period. Our findings demonstrate that while both surgical techniques effectively reduced IOP and the need for anti-glaucomatous medications, circumferential GATT was associated with a significantly greater mean IOP reduction in long term period and higher complete surgical success rate compared to hemi-GATT. However, the incidence of hyphemia was significantly lower in the hemi-GATT group, suggesting that this technique may be a more suitable option for patients at higher risk of intraocular bleeding, while still providing a clinically meaningful reduction in intraocular pressure.

GATT has been widely reported as an effective and safe procedure for the management of open-angle glaucoma [3, 4, 7, 9, 10]. Previous reports in the literature indicated that mean IOP reduction following GATT for POAG typically ranges between 35 and 40%, with success rates—varying according to the criteria used—ranging from 63 to 88% at 12 to 24 months postoperatively [3, 4, 7, 9].

In a study by Aktas et al. [9], which included patients who underwent standalone circumferential GATT and combined circumferential GATT with cataract extraction, mean IOP reductions of 9.4 mmHg (36%) and 9.0 mmHg (33%) were reported at 12 and 24 months, respectively, in the POAG subgroup. These results are consistent with our findings, which demonstrated a mean IOP reduction of 9.8 ± 5.1 mmHg (38.5%) at 12 months and 10.1 ± 5.3 mmHg (39.7%) at 24 months following standalone circumferential GATT. Therefore, we believe that concurrent cataract extraction may not confer additional benefit in terms of IOP reduction in patients with POAG. Furthermore, their study reported a decrease in the number of anti-glaucoma medications by 2.0 at 12 months and 1.8 at 24 months postoperatively, which is comparable to the outcomes observed in our cohort [9]. Regarding qualified success rates in the standalone GATT–POAG subgroup, Aktas et al. [9] reported rates of 74.7% in phakic patients and 73.5% in pseudophakic patients at the 3-year follow-up, which closely align with the 78.2% success rate observed in our study at a mean follow-up of 30 ± 5.05 months. These findings further support the long-term efficacy of standalone circumferential GATT in reducing IOP in patients with POAG.

There is limited literature evaluating the outcomes of hemi-GATT [5, 6, 11, 12], and only one study has specifically investigated its efficacy and safety in patients with POAG [12]. In that study, a mean IOP reduction of 8.3 mmHg (37.9%) was reported following cataract extraction combined with hemi-GATT, along with complete and qualified success rates of 64.8% and 93.4%, respectively. A significant reduction in the number of anti-glaucoma medications

was also observed, decreasing from 2.0 ± 1.5 to 0.5 ± 0.8 at the 24-month follow-up. Although the degree of IOP reduction was comparable to that achieved in the current study, the success rates reported in their cohort was notably higher [12]. This difference may be attributed to the lower baseline IOP in their population (21.9 ± 5.8 mmHg) compared to that of the present study (25.0 ± 3.7 mmHg). Additionally, their study evaluated a combined procedure including cataract extraction, whereas our analysis focused on standalone hemi-GATT [12].

In our cohort, standalone hemi-GATT resulted in a sustained and statistically significant reduction in IOP at all follow-up intervals. The number of anti-glaucoma medications was also significantly reduced postoperatively. At the final follow-up, 34.1% of eyes achieved complete success without medication, while the overall qualified success rate, including patients on medical therapy, was 61.3%. Furthermore, the cumulative probability of surgical failure was 15.2%. These outcomes suggest that standalone hemi-GATT provides a durable IOP-lowering effect and may serve as a viable surgical option for patients with POAG, particularly in cases where a less invasive approach is preferred.

To the best of our knowledge, this is the first study to directly compare hemi-GATT with circumferential GATT in the management of POAG. According to our findings, although hemi-GATT is significantly effective in controlling IOP and reducing the need for anti-glaucoma medications, its efficacy in lowering IOP at the 24-month follow-up was inferior to that of circumferential GATT. Furthermore, circumferential GATT achieved superior complete success rates compared to hemi-GATT, suggesting that performing a circumferential trabeculotomy may provide more robust long-term IOP control without medications. While the difference in qualified success did not approach statistical significance, the trend favored circumferential GATT, implying potential benefit even when adjunctive medications are considered. Surgical failure rates were relatively low in both groups and did not differ significantly, indicating that both procedures maintain a favorable safety profile over time. Collectively, these results highlight the potential advantage of circumferential GATT in maximizing surgical success, although hemi-GATT remains a viable option in cases where complete circumferential access is limited.

In contrast, with respect to postoperative complications, hyphema—identified as the most frequently observed adverse event—was significantly less common in the hemi-GATT group (31.8%) compared to the circumferential GATT group (54.6%). This finding is consistent with prior reports demonstrating a lower incidence of hyphema following hemi-GATT [5, 6, 11, 12]. The increased rate of hyphema in the circumferential group is likely attributable to the more extensive trabeculotomy, which may allow for greater blood reflux from the collector channels. Based on these observations, hemi-GATT may be considered a more appropriate option for patients at elevated risk of intraocular bleeding, whereas circumferential GATT may be better suited for those requiring a more robust IOP-lowering effect.

Another noteworthy postoperative complication is the IOP spike. In the literature, the incidence of IOP spikes—defined as IOP > 25 mmHg—following hemi-GATT in patients with POAG has been reported as 16.9% [12]. For circumferential GATT, the rate was reported to be 13.2%, although no specific definition for IOP spike was provided [9]. In our study, using a stricter definition of IOP spike (IOP > 30 mmHg), the incidence was 9.0% in the hemi-GATT group and 10.8% in the circumferential GATT group ($p = 0.71$). The lower observed rates in our cohort are likely attributable to the more conservative threshold used to define an IOP spike. Although IOP spikes appeared numerically less frequent in the hemi-GATT group, the difference was not statistically significant.

Previous studies have indicated that postoperative IOP spikes may be influenced by several factors, including hyphema, corticosteroid use, and the severity of glaucomatous damage [13, 14]. Moreover, the occurrence of IOP spikes has been associated with an increased risk of surgical failure [15]. However, in our cohort, none of the patients who experienced IOP spikes progressed to surgical failure. Importantly, all cases were effectively managed by tapering or discontinuing topical corticosteroids, with adjunctive anti-glaucoma medications used when necessary, suggesting that steroid-induced ocular hypertension was the primary contributing factor. These findings highlight the importance of closely monitoring IOP in the early postoperative period and support early

tapering of corticosteroid therapy following both hemi-GATT and circumferential GATT procedures.

The main limitation of the present study was its retrospective design. Additionally, the relatively small sample size and the involvement of two different surgeons may limit the generalizability of the findings. As previous research has demonstrated no significant difference between inferior and superior Hemi-GATT approaches, this distinction was not evaluated in the current study [11].

In conclusion, both circumferential GATT and hemi-GATT were effective surgical options for lowering intraocular pressure. Circumferential GATT appeared to provide greater intraocular pressure reduction; however, it was associated with a higher incidence of postoperative hyphema. In contrast, hemi-GATT may be a more favorable option for patients who did not require substantial intraocular pressure reduction and who presented with risk factors for intraocular bleeding.

Author Contributions All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Mehmet Ozgur Cubuk, Rukiye Kilic Ucgul, Pinar Orenc, and Ahmet Yucel Ucgul. The first draft of the manuscript was written by Mehmet Ozgur Cubuk, and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript. The corresponding author was Mehmet Ozgur Cubuk.

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Data Availability No datasets were generated or analysed during the current study.

Declarations

Conflict of Interests The authors declare no competing interests.

Ethical Approval This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of Istanbul Training and Research Hospital.

Consent to Participate Informed consent was obtained from all individual participants included in the study.

Consent to Publish The authors affirm that all human participants provided informed consent for publication of their anonymized data included in this manuscript.

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