Original Article

Long-term outcomes of pars plana Ahmed valve implant and vitrectomy in eyes with refractory glaucoma

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ABSTRACT

Background: Pars plana vitrectomy with implantation of an Ahmed glaucoma valve in the vitreous cavity has been reported with a success rate in the management of refractory and neovascular glaucoma. This study aimed to present the outcomes of pars plana Ahmed glaucoma valve (PPAV) surgical implantation in cases with refractory glaucoma.

Methods: In this single-center, retrospective, comparative study, 87 consecutive patients diagnosed with refractory glaucoma who underwent PPAV surgical implantation between October 2015 and October 2019 were evaluated. A successful postoperative outcome was defined as intraocular pressure (IOP) ≤ 21 mmHg upon examination and a reduction in the number of anti-glaucoma agents used at the latest follow-up.

Results: Finally, 81 eyes of 78 patients with refractory glaucoma were included; 54 (66.66%) of the eyes had neovascular glaucoma. The mean follow-up was 20.65 ± 12.17 months (range: 2–52 months). The mean preoperative IOP was 40.01 ± 1.19 mmHg and reduced significantly to 16.73 ± 0.82 mmHg at the latest follow-up ($P < 0.001$); a successful IOP outcome was achieved in 88.89% of eyes. The mean number of anti-glaucoma agents decreased significantly from 2.86 ± 0.09 preoperatively to 1.46 ± 0.11 at the latest follow-up ($P < 0.001$); while 61 (75.31%) of eyes had a reduction in the number of IOP lowering eye drops, and 14 (17.28%) had no need for IOP lowering eye drops.

Conclusions: PPAV surgery is a successful procedure for IOP reduction in patients with refractory glaucoma. Our study demonstrated either reduction or elimination of IOP lowering eye drops postoperatively. Large scale studies with a comparison group, a longer follow-up, and having various subtypes of glaucoma are required as future research to confirm these outcomes.

KEY WORDS

pars plana, glaucoma drainage implant, neovascular glaucoma, anti-glaucoma agent, intraocular pressure

INTRODUCTION

Glaucoma is a potentially progressive optic neuropathy associated with visual field loss with progression. It is a leading cause of visual impairment and irreversible blindness worldwide. The number of patients aged 40–80 years with glaucoma worldwide is estimated to increase from 76 million in 2020 to 111.8 million by 2040 [1-6].

Glaucoma management is a step-wise approach, starting with medical management. Surgical intervention is performed to lower intraocular pressure (IOP) and preserve vision [7] with trabeculectomy, cyclodestruction, and glaucoma drainage devices, also known as aqueous shunts [8]. Pars plana vitrectomy (PPV) with implantation of a glaucoma drainage device in the vitreous cavity has a success rate comparable to that of conventional surgical modalities [9-11].

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Patients with refractory glaucoma who had underlying retinal pathology showed satisfactory outcomes when treated with PPV with combined [12, 13] or consecutive [14, 15] Ahmed glaucoma valve (AGV) implantation in the anterior chamber (AC). Evidence is limited for combined [16-18] or consecutive [19] AGV implantation with PPV, mainly because it is more commonly placed in AC, although a few studies have been reported [16-21]. Complex refractory glaucoma is treated at our center using vitrectomy combined with AGV placed in the posterior segment rather than the common AC. To the best of our knowledge, this is the first study on AGV implantation for refractory glaucoma in the Caribbean region. Furthermore, the present study had the largest sample size with the longest follow-up among other studies on this topic [16-25].

This study was aimed at investigating the success of PPAV in long-term IOP control and topical anti-glaucoma agent reduction in patients with refractory glaucoma and advantages of avoiding corneal complications of AC insertion of AGV.

METHODS

In this single-center, nonrandomized, retrospective, comparative study, both written and electronic consecutive patient records were retrieved to gather the necessary data. All patients who underwent PPAV at the Trinidad Eye Hospital (Caribbean Vitreous and Retina Surgery Ltd) between October 2015 and October 2019 were identified. The study protocol was approved by our institution's ethics board. The study was performed according to the tenets of the Declaration of Helsinki. Owing to the retrospective study design, only verbal consent was obtained from the patients for inclusion in the study. All patients had provided written informed consent preoperatively according to the medical records. We defined refractory glaucoma as IOP > 30 mmHg despite administering the maximum tolerable anti-glaucoma agents. We only included local patients with refractory glaucoma in our analysis since foreign patients could attend a limited follow-up of 2 weeks before being discharged to return to their country. A total of 115 patients underwent PPAV, 28 of whom were foreigners; finally, 87 patients were included in the analysis.

The anti-glaucoma regimen was as follows: once per night latanoprost (0.005%, Xalatan®; Pfizer Inc., NY, USA), twice daily 0.5% timolol maleate (Poentimol®), thrice daily brinzolamide 1.0% (Azopt®, Alcon Laboratories, Inc, Fort Worth, TX, USA), twice daily brimonidine tartrate 0.2% (Alphagan®; Allergan, Irvine, CA, USA), and 4% pilocarpine four times per day (Sandoz). When the patient had contraindications or side effects of a particular anti-glaucoma agent, it was not prescribed or discontinued.

The mean preoperative and postoperative IOP, number of anti-glaucoma agents, and best-corrected distance visual acuity (BCDVA) were retrieved from patients' medical records. IOPs were obtained postoperatively at 1 week, 6 weeks, 3 months, 6 months, 12 months, 18 months, 21 months, 24 months, 36 months, and 48 months. Additional related information included sex, age at the time of surgery, coexisting systemic or ocular comorbidities, and preoperative lens status (phakic, pseudophakic, or aphakic).

An ophthalmologist performed detailed anterior and posterior segment examinations preoperatively and postoperatively, according to the medical records. The Early Treatment of Diabetic Retinopathy Study chart (Good-Lite, Elgin, IL, USA) was used to test BCDVA. To compare postoperative BCDVA with preoperative BCDVA, visual acuities equal to counting fingers, hand motion, light perception, and no light perception were converted to 0.014, 0.005, 0.0016, and 0.0013, respectively [26]. IOP was measured using the Goldmann applanation tonometry (Haag-Streit, Harlow, UK) at the hospital and the portable Tono-Pen AVIA tonomoeter (TPA, Reichert Inc., Depev, NY, USA) for feasibility at home visits.

A single surgeon (D.D.) performed all surgeries. Following local and retrobulbar or general anesthesia, cardinal points on the cornea were marked to ensure proper positioning of the AGV in the desired segment. Four self-sealing PPV ports were placed. The Alcon 25-gauge chandelier system (Alcon, Chandelier lighting system, Fort Worth, TX, USA) was used. In all phakic eyes, lens removal was completed using phacoemulsification with the anterior approach via small incisions, emulsification, and aspiration of the crystalline lens using an ultrasonic probe. Intraocular lens (IOL) was implanted in capsular bag following phacoemulsification. Subsequently, 25-gauge PPV was performed in the eye, unless otherwise stated. Following completion of ventral and peripheral PPV using posterior-segment maneuvers, endo-ocular panretinal photocoagulation was performed whenever indicated. The operating IOP was set at 25 mmHg. Vitreous base shaving was performed. Plugs were applied to the ports, and 7.0 corneal stay sutures were placed. A superotemporal partial conjunctival peritomy, 6 mm from the limbus, was performed. Tenon's anterior and posterior dissections to the peritomy created a pocket for the AGV implant (FP7; New World Medical, Inc., Rancho Cucamonga, CA, USA). Diathermy cauterization was performed to ensure hemostasis. The operating IOP at this point was reduced to 10 mmHg, and sclera was marked with a gentian violet marking pen (Viscot Medical, LLC, USA) at 8 and 3.5 mm posterior to the limbus. A partial-thickness scleral tunnel for the tube was made anterior to the 8-mm line using a crescent blade. To check the patency of the AGV tube and mechanism of the open valve, it was irrigated with balanced saline solution. The tube was cut to length, tapering the tip for a bevel-up appearance. The AGV tube was then placed in the tunnel, with suturing of the AGV plate, 8 mm posterior to the limbus, using 9.0 nylon sutures. All knots were buried. Plate flow and function were observed with alterations in IOPs of 60 and 10 mmHg. The flow was verified by observing the balanced saline solution at the plate when IOP was elevated to 60 mmHg. The tube position was checked using the viewing system to ensure no vitreous clogging. A pericardial patch graft (Tutopatch®; Tutogen Medical GmbH, Neunkirchen, Germany) was placed to lie free without sutures, and Tenon's capsule and conjunctiva were sutured with 7.0 Vicryl sutures. For Tenon's capsule, running 7.0 interlocking Vicryl sutures were used. Intravitreal bevacizumab (Avastin®; Genentech, Inc., South San Francisco, CA, USA), or triamcinolone (Volon A, Bristol-Myers Squibb, NY, USA), and intracameral 0.5% moxifloxacin hydrochloride (Vigamox®, Alcon Laboratories, Inc., Fort Worth, TX, USA) were administered.

Successful postoperative outcomes were defined as postoperative IOP ≤ 21 mmHg at the latest examination and reduced number of anti-glaucoma agents used at the latest follow-up. The mean preoperative IOP was compared to the mean latest postoperative follow-up IOP. Additionally, the mean number of IOP-lowering agents used was compared between preoperative and the latest postoperative follow-up.

Intraoperative and postoperative complications were recorded. Early postoperative complications were considered to occur in the first 6 weeks, while late complications were considered to occur after 6 weeks. Any postoperative event, such as death, was included in the analysis. Patients who required subsequent tube surgeries, such as repair, clearance, or replacement, were documented. For missing data, patients were contacted for a short interview or scheduled for a checkup to obtain the data and latest possible postoperative IOP measurement. When such methods failed, the researcher visited the patient's home with permission to conduct a checkup. When none of these approaches succeeded in obtaining complete data, reasons, such as death, busy schedule, and patient reluctance, were documented.

Data collection and statistical analysis were performed using Microsoft Excel (Microsoft Corporation, Redmond, Washington, USA), and normality was determined. Qualitative variables, such as sex, glaucoma type, and postoperative complications, are expressed as frequency (percentage), and quantitative variables, such as age, IOP, and BCDVA, are presented as mean ± standard deviation (SD). A paired *t*-test was used to compare the mean preoperative and the latest postoperative follow-up IOP, number of anti-glaucoma agents, and BCDVA. The significance level was set at $P < 0.05$.

RESULTS

Of the 87 patients, 11 had missing data because of illegible or incomplete records, nine of whom had missing main objective measure data of the study. These patients also had missing contact information, which made it impossible to retrieve the missing data. Finally, we enrolled 78 patients (81 eyes) for the analysis. Three patients had bilateral AGV valve implantation, and two had limited follow-up because they died. The study population included 39 men and 39 women. The mean follow-up duration was 20.65 ± 12.17 (range: 2–52 months) months. The mean patient age at the time of surgery was 64 ± 13.37 (range: 17–84) years. Fifty-two patients (54 eyes) had NVG, while the remaining 26 patients (27 eyes) had other types of glaucoma. Table 1 summarizes the baseline characteristics of the participants.

The mean preoperative IOP was 40.01 ± 1.19 mmHg and reduced significantly at the latest follow-up to 16.73 ± 0.82 mmHg ($P < 0.001$). At the latest follow-up, IOP was successfully controlled in 72 (88.89%) eyes. Table 2 summarizes the success rates of IOP control at all follow-ups. Overall, the mean IOP remained within normal range during the postoperative period (Table 2).

The mean number of anti-glaucoma eye drops decreased significantly from 2.86 ± 0.09 preoperatively to 1.46 ± 0.11 at the latest postoperative follow-up ($P < 0.001$). Although 29 patients were on acetazolamide tablets (Diamox®) as part of their preoperative IOP control regime, none of them was on this medication at the latest follow-up. Fifty-two (64.20%) eyes received fewer drops postoperatively, while 14 (17.28%) eyes did not require any drops at the latest follow-up. Fourteen (17.28%) eyes received the same number of drops, while the remaining eye (1.23%) received an increased number of drops used postoperatively.

The mean preoperative BCDVA did not change significantly postoperatively ($P = 0.214$; 0.20 ± 0.31 versus 0.15 ± 0.26 the logarithm of the minimum angle of resolution [logMAR]). However, at the latest follow-up, BCDVA had improved in 37 (45.68%) eyes, worsened in 27 (33.33%) eyes, and remained the same in 17 (20.99%) eyes. Almost half of the eyes were phakic (n = 37; 45.68%) and required cataract removal with IOL implantation during surgery. Of these, 17 (45.95%) eyes showed improvement in BCDVA, and 10 (27.03%) eyes showed unchanged or worsened BCDVA at the latest follow-up. Postoperatively, there were 80 pseudophakic eyes and one aphakic eye that had been aphakic preoperatively.

Intraoperative complications included retinal tears in three eyes that were managed using combined barrier laser and non-expansile sulfur hexafluoride gas as internal tamponade. Additionally, there were two eyes with choroidal effusion and one eye with hyphema, all of which resolved within the early postoperative period without any intervention.

Regarding tube-related complications, six (7.41%) eyes had tube blockage, four (4.94%) eyes had failure, four (4.94%) eyes had tube extrusion, and three (3.70%) eyes had tube migration in the late postoperative period. The blocks were then successfully cleared. Extrusion and migration were successfully repaired with further surgery. Out of the four cases of failure, two were managed with removal and replacement of the valve with continued use of the maximal anti-glaucoma topical regime. Owing to these being secondary valves, these outcomes were not evaluated in this study. The other two eyes were comfortable, and thus followed up without further intervention.

The most common late postoperative complications were vitreous hemorrhage in 13 (16.05%) eyes and hyphema in four (4.94%) eyes, both of which resolved with conservative management or intravitreal bevacizumab. Furthermore, uveitis was observed in two (2.47%) eyes, which were managed successfully with anti-inflammatory eye drops. No corneal complications were observed. None of the eyes had undergone enucleation. Four (4.94%) eyes developed early postoperative hypotony with IOP < 5 mmHg, which resolved spontaneously.

DISCUSSION

In the current study, PPAV was a successful procedure for IOP reduction in patients with refractory glaucoma during the long-term follow-up. Furthermore, patients experienced reduction or elimination of anti-glaucoma agents.

AGV is commonly implanted into the AC [27, 28]. However, it can also be placed within the ciliary sulcus [29] or PP, with the latter involving an initial vitrectomy [16, 19]. Posterior placement of an AGV tube in the PP has several advantages over anterior placement in the AC. First, many patients requiring valve installation have concomitant posterior-segment disease [18] that can be treated simultaneously. For example, the initial stage of vitrectomy can address coexisting VH [19] or allow applying the endolaser [16]. Second, PP insertion avoids the risks of AC surgery, such as corneal edema, corneal decomposition, corneal endothelial touch, refractive change, and iris injury [24, 28]. Corneal endothelium disturbance could result from tube placement in the AC, which may induce corneal decompensation and edema. The cause of corneal decompensation could be increased flow of aqueous solution proximal to the endothelium, AC inflammation, tube-corneal touch, and foreign body reaction to the tube. The long-term frequency of corneal complications in patients with AGV implantation ranges from 9% to 27% [28].

Table 1. Baseline characteristics of study participants

Parameters	Value
Age (y), Mean ± SD	64.0 ± 13.37
Sex (Male/ Female), n of patients (%)	39 (50%) / 39 (50%)
Lens status (pseudophakic/phakic/aphakic), n of eyes (%)	43 (53.09) / 37(45.68) / 1(1.23)
BCDVA (logMAR), Mean ± SD	0.20 ± 0.31
IOP (mmHg), Mean ± SD	40.01 ± 1.19
Anti-glaucoma agents, n (%)	2.86 ± 0.09
Cause of refractory glaucoma, n of eyes (%)	NVG: 54 (66.67) POAG: 20 (24.69) Angle closure glaucoma: 4 (4.94) Uveitic glaucoma: 3 (3.70)
***Systemic comorbidities, n of patients (%)**	DM: 55 (70.51) HTN: 24 (30.77) None: 18 (23.08) Cardiac disease: 3 (3.85) Breast cancer: 1 (1.28) CKD: 1 (1.28) Hypothyroid: 1 (1.28)
***Ocular comorbidities, n of eyes (%)**	DR: 47 (58.02) None: 25 (30.86) CRVO: 7 (8.64) NR: 4 (4.94) BRVO: 3 (3.70) OIS: 3 (3.70) HRVO: 2 (2.47)

Abbreviations: y, years; SD, standard deviation; n, number; %, percentage; BCDVA, best-corrected distance visual acuity; logMAR, the logarithm of the minimum angle of resolution; IOP, intraocular pressure; mmHg, millimeter of mercury; NVG, neovascular glaucoma; POAG, primary open-angle glaucoma; DM, diabetes mellitus; HTN, hypotension; None, no ocular or systemic comorbidity; CKD, chronic kidney disease; DR, diabetic retinopathy; CRVO, central retinal vein occlusion; NR, not recorded; BRVO, branch retinal vein occlusion; OIS, ocular ischemic syndrome; HRVO, hemiretinal vein occlusion. Note: *There were subjects or eyes with more than one systemic or ocular comorbidity, thus, the sum of this variable exceeds 100%.

Table 2. Mean postoperative intraocular pressure at various follow-ups and the corresponding success rate

Follow-up	1 week	6 weeks	3 months	6 months	12 months	18 months	21 months	24 months	36 months	48 months	Latest follow-up
N	81	80	77	62	58	34	22	31	10	4	81
IOP (mmHg), Mean ± SD	13.35 ± 7.29	17.90 ± 6.83	18.43 ± 8.16	17.00 ± 6.67	15.66 ± 9.37	15.09 ± 4.84	15.59 ± 6.95	14.41 ± 4.56	12.78 ± 3.16	14.75 ± 1.48	16.73 ± 0.82
Success rate (%)	96.30	50.62	75.32	83.87	89.66	94.12	90.91	96.67	100	100	88.89

Abbreviations: N, Number of eyes examined; mmHg, millimeter of mercury; SD, standard deviation; %, percentage.

However, not all cases of corneal decompensation are caused by valves. Prolonged high IOP, eye drop preservatives, variable aqueous humor compositions, and long or complicated surgeries may play a role [28]. Third, PPAV siting is a good alternative in patients with shallow or closed AC angles because tube placement can be relatively difficult [23]. With AGV implantation into the vitreous cavity combined with PPV, the success rate for IOP control in the current study at the 4-year follow-up was 88.89%. No signs of late corneal decompensation were found in our cohort beyond 4 years. The mean IOP at the latest follow-up was 16.73 ± 7.35 mmHg. Additionally, in 75.31% of the patients, the number of anti-glaucoma agents decreased at the latest postoperative follow-up, with no use of acetazolamide tablets.

Table 3 summarizes the previous studies on AGV implantation in the PP [16-25, 30, 31]. IOP control was achieved at a maximum follow-up of 28 months, with most studies reporting reduction in anti-glaucoma agents at the last follow-up. Our latest mean postoperative IOP was almost equal to that reported in these studies, with a significant decrease compared to the preoperative IOP. Our mean number of anti-glaucoma agents decreased postoperatively, similar to the findings of Schlote et al. [25] and Dada et al. [30]. All of these studies concluded that PPAV implantation is a safe and effective option for reducing IOP in eyes with refractory glaucoma. Our study included 81 eyes with refractory glaucoma, which was more than the highest number reported before (51 eyes) [16]. Furthermore, to our knowledge, the present study had a longer follow-up period compared to similar previous studies [16-25, 30, 31].

Compared to recent studies on AGV placement in the AC or ciliary sulcus [32-35], the present study showed a higher success rate. Regardless of the different definitions of success across studies, this higher success rate could be due to differences in the study population, glaucoma type, or site of AGV implantation. Future studies should explore success rate for various subtypes of glaucoma and surgical approaches for AGV tube implantation. The success rate in similar studies on AGV implantation in the PP and PPV varied from 71.4% to 100%, with follow-up periods ranging from 12 to 28 months and various ocular comorbidities but the same IOP preset for successful control, which was < 21 mmHg [16, 17, 20, 21, 23-25, 31]. Our success rate ranged from 50.62% to 100% across follow-ups and reached 88.89% at the latest follow-up; the mean IOP was always < 18 mmHg.

Table 3. Summary of studies on combined or consecutive Ahmed glaucoma valve placement within the vitreous cavity and vitrectomy

Author (Year of Publication)	Study design	Methodology	Results	Conclusions
Bernal-Morales et al. (2021) [16]	Retrospective case series	Maximum 2-year follow-up was performed for 51 eyes from 50 patients with severe NVG who were treated with PPV, AGV, and PRP and/or cryotherapy in a single surgical setting. Surgical success defined as IOP between 6 and 21 mmHg with or without topical medication.	Success rate for IOP control at 1, 6, 12, and 24 months postoperatively were 76.0%, 88.3%, 74.4%, and 71.4%, respectively.	Combined AGV implantation into the vitreous cavity and PPV in a single setting may be reasonable for severe forms of NVG for effective IOP control and complete PRP.
de Frutos-Lezaun et al. (2018) [17]	Retrospective case series	Maximum 1-year follow-up was performed for 10 eyes from 9 patients with secondary glaucoma, refractory to other treatments, who underwent 23-gauge PPV and AGV implantation in the vitreous base.	Absolute success, IOP < 21 mmHg without medication, was 60%. Qualified success, IOP < 21 mmHg with medication, was 100%. A significant decrease in postoperative IOP in all cases was recorded. No significant changes in postoperative BCVA compared to preoperative values were seen. Early complications were hyphema, athalamia, and retinal detachment, and late complications were cystic bleb and PP clip extrusion.	PP AGV implantation is a safe and useful treatment modality to manage secondary refractory glaucoma if the patient is a candidate for PPV or has undergone vitrectomy.
El-Saied et al. (2017) [19]	Case series	Maximum 6-month follow-up was performed for five patients with traumatic secondary glaucoma and vitrectomized, aphakic, and aniridic eyes who underwent AGV implantation into the vitreous cavity and complete filling of the vitreous cavity with non-expansile C3F8 for approximately 2 months after vitrectomy to treat VH.	Although multiple risk factors, such as aphakia, vitrectomized eyes, and aniridia, were presented, no postoperative hypotony or SCH was recorded. The C3F8 was absorbed over 2 months and mean postoperative IOP was 14.8 mmHg at 6 months. The final postoperative BCVA was 0.66 ± 0.13.	Complete filling of the vitreous cavity with non-expansile C3F8 gas prevented SCH following AGV implantation in the vitreous cavity in management of secondary glaucoma in vitrectomized, aphakic, and aniridic eyes.
García-Delpech et al. (2013) [20]	Case series	Maximum 28-month follow-up was performed for 17 eyes from 17 patients with refractory glaucoma who underwent AGV scleral suture-less implantation via PP using cyanoacrylate suturing of the plate. Refractory glaucoma defined as IOP ≥ 21 mm Hg with anti-glaucoma agents, good adherence to treatment, and no history of glaucoma surgery.	IOP control, defined as IOP ≤ 21 mmHg with or without anti-glaucoma agents, was achieved in 82.2% of patients. Of all patients, 58.8% did not require IOP-lowering medications. Postoperative complications were transient IOP rise, transient hyphema, early hypotony, and tube block by the vitreous, and both resolved with the second intervention. No case of AGV tube or plate extrusion, plate migration, choroidal or retinal detachment, or VH was reported.	AGV implantation into the vitreous cavity with cyanoacrylate was a safe and effective treatment for refractory glaucoma.
Wallsh et al. (2013) [18]	Case series	Maximum 28-month follow-up was performed for 31 eyes with glaucoma associated with posterior-segment disease who underwent combined PPV and AGV implantation.	In 24 eyes with NVG, IOP decreased from 37.6 to 13.8 mmHg, and BCVA improved from 2.13 to 1.40 logMAR. In 15 eyes with steroid-induced glaucoma, IOP deceased from 27.9 to 14.1 mmHg, and BCVA improved from 1.38 to 1.13 logMAR. Complications included four cases of cystic bleb formation and one case of choroidal detachment and explantation for hypotony.	Combined AGV implantation via the PP and vitrectomy is an effective treatment in complex cases of glaucoma without using the PP clip.
Jeong et al. (2012) [21]	Retrospective case series	Maximum 25-month follow-up was performed for 11 patients with PDR and refractory NVG who underwent combined 23-gauge sutureless PPV with PP AGV implantation.	The mean preoperative IOP reduced from 35.9 ± 6.3 to 13.3 ± 3.2 mmHg at the last postoperative follow-up. IOP control was achieved in all patients, 91% of whom required anti-glaucoma agents with a mean number of medications of 1.2 ± 0.6. The postoperative visual acuity improved from 1.67 ± 0.61 to 0.96 ± 0.67 logMAR. No unmanageable complications were reported.	Combined 23-gauge PPV and AGV implantation was safe and effective in patients with PDR and refractory NVG.
Milla et al. (2012) [22]	Case report	A 41-year-old woman had bilateral lens subluxation, medically uncontrolled glaucoma, and Marfan syndrome confirmed by complete systemic examination and genetic analysis of the fibrillin 1 gene.	To control severe glaucoma in the right eye, the patient underwent PPV with lensectomy and AGV implantation in the vitreous cavity.	Aggressive secondary glaucoma after Marfan syndrome with lens subluxation requires surgical management with lensectomy, PPV, and AGV implantation to avoid progressive glaucomatous optic atrophy.
Diaz-Llopis et al. (2010) [23]	Prospective case series	The PP clip in the AGV tube was inserted via the PP combined with PPV in 10 patients with secondary refractory glaucoma.	IOP control was achieved in 90% of patients, and no anti-glaucoma medication was required in 70% of patients. The complications were transient hypotony in three cases, choroidal detachment in two cases, and intraocular hemorrhage in one case. No tube extrusion or tube kink was found.	Combined implantation of the AGV tube modified with the PP clip via the PP with PPV was safe and effective in management of secondary refractory glaucoma.

Author (Year of Publication)	Study design	Methodology	Results	Conclusions
Dada et al. (2010) [30]	Case series	Maximum 12-month follow-up was performed for 11 eyes with uncontrolled IOP on maximum tolerable anti-glaucoma medication who underwent AGV implantation with triamcinolone-assisted PPV.	The mean preoperative IOP of 33.64 ± 5.99 reduced to 17.09 ± 2.26 and 17.45 ± 1.81 mmHg at the 6- and 12-month postoperative follow-ups. The mean number of anti-glaucoma agents reduced from 3.27 ± 0.05 to 0.64 ± 0.67 and 0.55 ± 0.6 at the 6- and 12-month postoperative follow-ups.	Combined PP AGV implantation and triamcinolone-assisted vitrectomy was a suitable treatment modality to manage refractory glaucoma with aphakia, particularly in eyes with endothelial cell decompensation.
Adachi et al. (2008) [31]	Case series	Maximum 12-month follow-up was performed for five eyes with refractory glaucoma that underwent PPV and posterior-chamber AGV implantation.	The mean IOP reduced from 46.8 ± 15.7 mmHg preoperatively to 16.0 ± 2.0 mmHg postoperatively. The visual acuity improved in three eyes or 60% of patients and reduced in two eyes: one due to retinal detachment and another due to transient high IOP and VH. IOP control was achieved in 80% of patients.	AGV implantation in the posterior chamber for refractory glaucoma was effective.
Faghihi et al. (2007) [24]	Case series	Maximum 28-month follow-up was performed for 18 eyes from 17 patients with NVG who underwent PPV with PP AGV implantation.	The mean preoperative IOP with an oral and two or three topical anti-glaucoma agents reduced from 53.3 ± 10 to 16.3 ±7.1 mmHg without oral anti-glaucoma agents at the final visit. The success rate, defined as IOP of 5–21 mmHg with or without anti-glaucoma agents, was 72.2%. Seven (38.8%) patients experienced a postoperative hypertensive phase, and all but one patient was managed with medication. Visual acuity improvement or stabilization was recorded in 77.7% of eyes. Postoperative complications ranged from mild VH to corneal ulceration. Two eyes developed phthisis bulbi.	Combined PPV and AGV implantation was a suitable and safe treatment modality to manage NVG with preexisting posterior-segment pathology.
Schlote et al. (2006) [25]	Case series	Maximum 18-month follow-up was performed for 11 eyes of 9 patients with aphakic, neovascular, traumatic, inflammatory and pseudoexfoliation glaucoma who had PPV before AGV implantation.	IOP ≤ 21 mmHg was achieved in 91% of eyes. Of all patients, 64% required no anti-glaucoma agents. The mean preoperative IOP decreased significantly from 32.2 ± 8.3 to 15.7 ± 7.7 mmHg postoperatively. The mean number of topical anti-glaucoma agents decreased significantly from 2.9 ± 1.2 to 0.545 ± 0.78. Complications included transient hypotony, transient choroidal effusion, and an intermediate increase in IOP. One eye had tube exchange, and two eyes required needling/bleb excision.	PP-modified AGV implantation was effective and safe in vitrectomized eyes with advanced glaucoma. Close follow-up and IOP monitoring were required for 1 year.

Abbreviations: NVG, neovascular glaucoma; PPV, pars plana vitrectomy; AGV, Ahmed glaucoma valve; PRP, pan-retinal photocoagulation; IOP, intraocular pressure; mmHg, millimeter of mercury; BCVA, best-corrected visual acuity; PP, pars plana; C3F8, perfluoropropane; VH, vitreous hemorrhage; SCH, Suprachoroidal hemorrhage; logMAR, the logarithm of the minimum angle of resolution.

Thirty-seven (45.68%) eyes showed improvement in BCDVA, 17 (45.95%) of which had cataract preoperatively. We could not infer whether the BCDVA improvements in these eyes were due to postoperative IOP control or removal of the cataract. However, similar to de Frutos-Lezaun et al.'s study [17], in our cohort, the overall BCDVA did not differ significantly from the preoperative value to the latest follow-up value. In contrast, Wallsh et al. [18] and Jeong et al. [21] reported postoperative improvements in BCVA. Furthermore, Faghihi et al. [24] found visual acuity improvement or stabilization in 77.7% of the eyes.

Intraoperative complications included three cases of retinal tear, two cases of transient choroidal effusion, and one case of hyphema, all of which were manageable. Faghihi et al. [24] and García-Delpech et al. [20] reported no intraoperative complications. In our cohort, the late postoperative events included vitreous hemorrhage, hyphema, and uveitis, all of which resolved without clinical significance and were manageable. Table 3 outlines the early and late postoperative complications in studies on similar surgical approaches. Faghihi et al. [24] reported postoperative complications, ranging from mild vitreous hemorrhage to corneal ulceration. Two eyes developed phthisis bulbi. Owing to the diversity in ocular comorbidity and ocular status among the included eyes in studies on PPAV [17, 18, 20, 21, 23, 24, 25, 31], the exact cause of some complications is difficult to determine, and relating these complications to the method of AGV implantation seems to be irrational.

Our cohort had four patients with failed AGV implantation. Failure was defined as IOP > 30 mmHg at the latest follow-up. The present and previous PPAV studies [16-25] revealed that PP implantation of the AGV is a relatively safe and effective treatment modality for IOP reduction in patients with refractory glaucoma. It decreases patients' dependence on a large number of eye drops by a significant decrease in the number of ocular hypotensive agents used postoperatively or eliminating them altogether [21, 25, 30], as found in the current study. It is also effective in reducing IOP as AGV implantation within the AC or ciliary sulcus [32-35] and avoids the complications of AC insertion.

None of our patients developed postoperative corneal decompensation. This is an important finding because previous studies have attested to decreased likelihood of corneal decompensation with ciliary sulcus or PP siting compared to AC siting [36-39]. Imamoglu et al. [37] showed a low risk of corneal decompensation (4.3%) due to posterior AGV implantation in the ciliary sulcus.

They advocated that as a good option for patients at risk of corneal decompensation. Seo et al. [38] compared the changes in corneal endothelial cells after PP and AC implantations of AGV and found lower corneal endothelial cell damage in the PPAV group for refractory glaucoma than in the AC-implanted AGV group. They indicated a PPAV preference due to lower levels of endothelial cell damage and similar efficacy in IOP control. These findings were supported by Chihara et al.'s study [39].

Complications of postoperative hypotony, such as shallow or flat AC, hypotony maculopathy, choroidal detachment, and suprachoroidal hemorrhage, can be serious and vision-threatening [40-42]. In our study, four eyes developed early postoperative ocular hypotony, which resolved spontaneously. This low number indicates the advantage of using a valved instead of a non-valved glaucoma tube implant because patients with non-valved glaucoma tube implants are more likely to experience hypotony-related vision-threatening complications compared to those with AGV implantation [43].

At the latest postoperative follow-up, tube complications included six (7.41%) cases of blockage, four (4.94%) cases of exposure, and three (3.70%) cases of migration. Blockage occurs when vitreous or clotted blood enters the tube [44]. Tube exposure is a common complication in AGV surgery, with incidence ranging from 5% to 14.3% of all cases [28]; therefore, our rate was lower than expected. Furthermore, uveitis was observed in two (2.47%) eyes, which were managed successfully with anti-inflammatory eye drops. None of the patients had endophthalmitis or any other form of ocular infection.

Although our results demonstrated a high success rate in IOP control and significant reduction in anti-glaucoma agents over a long follow-up period, our study had several limitations warranting future recommendations. Large-scale studies, with longer follow-ups without missing data, should be performed on the long-term outcome of AGV implantation in the posterior segment. In our study, the retrospective study design was responsible for missing data and loss of patients to long follow-up. Therefore, prospective studies would be more effective in maintaining the original sample size throughout the follow-up period. Future randomized controlled trials should compare PPAV to its counterpart in the AC and all other surgical options, particularly in the postoperative complication profile. These aforementioned recommendations would address the current paucity of evidence on this topic and possibly advocate PPAV implantation furthermore.

CONCLUSIONS

PPAV reduces IOP of patients with refractory glaucoma. Our study demonstrated reduction or cessation of anti-glaucoma agents postoperatively in the long-term. PPV is a safe procedure with an advantage of reducing corneal risks of the more common AC implantation.

ETHICAL DECLARATIONS

Ethical approval: The study protocol was approved by our institution's ethics board. The study was performed according to the tenets of the Declaration of Helsinki. Owing to the retrospective study design, only verbal consent was obtained from the patients for inclusion in the study. All patients had provided written informed consent preoperatively according to the medical records.

Conflict of interest: None.

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