• Clinical Research •

A simplified slipknot technique for pupilloplasty in the treatment of mydriasis

Yan-Bo Bao[1], Yi-Fei Tang[1], Su-Yu Liu[2], Zi-Fang He[2], Ya-Jun Liu[2], Qing-Hua Yi[1], Zheng-Gao Xie[1,2,3]

[1]Department of Ophthalmology, Nanjing Drum Tower Hospital Clinical College of Nanjing Medical University, Nanjing 210008, Jiangsu Province, China
[2]Department of Ophthalmology, Nanjing Drum Tower Hospital, the Affiliated Hospital of Medical School, Nanjing University, Nanjing 210008, Jiangsu Province, China
[3]Department of Ophthalmology, Nanjing Drum Tower Hospital, Nanjing University of Chinese Medicine, Nanjing 210008, Jiangsu Province, China
Co-first Authors: Yan-Bo Bao and Yi-Fei Tang
Correspondence to: Zheng-Gao Xie. Department of Ophthalmology, Nanjing Drum Tower Hospital Clinical College of Nanjing Medical University, Nanjing 210008, Jiangsu Province, China. zgxie87@163.com
Received: 2025-11-29 Accepted: 2026-03-26

Abstract

• **AIM:** To evaluate the surgical outcomes of a simplified slipknot pupilloplasty technique for repairing mydriasis, with a focus on postoperative visual recovery, pupil morphological stability, knitting efficiency and knot security.

• **METHODS:** This prospective case series included patients with mydriasis due to trauma, glaucoma attack or iatrogenic damage, who underwent pupilloplasty (with or without intraocular lens implantation) from October 2022 to July 2025. Postoperative follow-ups were performed at 1, 3, 6, and 12mo. All cases had a minimum follow-up period of 3mo (range 3–12mo). Parameters recorded included best-corrected visual acuity (BCVA, logMAR), pupil diameter, and intraocular pressure (IOP).

• **RESULTS:** A total of 32 consecutive patients (32 eyes, 21 males) were included. The mean age was 57.9±15.9y (21 to 85y). The simplified slipknot technique resulted in significant visual improvement: the mean preoperative logMAR BCVA was 1.15±0.79 (range, 0.22 to 2.5), which improved to 0.35±0.32 (range, 0 to 1.398) postoperatively. Postoperative pupil diameter remained stable, with a mean of 3.0±0.5 mm (range, 2.5 to 4 mm). The duration of the pupilloplasty was 4.3±0.5min and there was no loosening or shedding of the line knot in any case.

• **CONCLUSION:** The simplified slipknot technique has a similar treatment effect and safety as the traditional technique but requires a shorter time and is easier to perform in pupilloplasty surgery. It causes minimal trauma to intraocular tissues, and is easy to popularize.

• **KEYWORDS:** mydriasis; pupilloplasty; iris suture; slipknot; polypropylene suture
DOI:10.18240/ijo.2026.10.15

Citation: Bao YB, Tang YF, Liu SY, He ZF, Liu YJ, Yi QH, Xie ZG. A simplified slipknot technique for pupilloplasty in the treatment of mydriasis. *Int J Ophthalmol* 2026;19(10):2003-2009

INTRODUCTION

Clinically, mydriasis is commonly observed after pupillary sphincter muscle tearing or rupture caused by blunt ocular trauma, partial iris defect due to open-globe injuries, and acute attack of primary angle-closure glaucoma results in pupillary sphincter muscle paralysis[1]. Patients with permanent mydriasis affects negatively the quality of vision, who refer a range of visual disturbances, like halos, starburst, and glare[2-3]. Therefore, surgical treatment for reducing the pupil to near-normal size is important[4].

Two main strategies in the literature are commonly employed in clinical practice to reestablish a normal pupil size: The first one is pupil cerclage technique initially proposed by McCannel in 1976, which uses a curved needle and a long needle of 10-0 nylon suture to perform a purse-string suture around the pupillary margin within the anterior chamber, finally tightened to form a round pupil[5-8]. Another method is the interrupted iris suturing technique represented by Siepser sliding knot technique[9]. A loop of suture is taken from the opposite side and brought out through one side of the wound, tied and drawn back into the eye over the tied site. This is repeated to lock the knot. In 2017, a single-pass four-throw (SFT) pupilloplasty technique was reported[10-11], which is actively used in practice currently[10,12-14]. The purpose of improving these techniques is to achieve better results and make the operation easier for the surgeon.

These methods can effectively achieve pupilloplasty. However, the required operating time may be prolonged. Technically, the pupillary cerclage method requires an extra limbal incision, it might be more difficult to perform, more time-consuming, and the open-sky approach may increase the risk of infection[7]. The modified McCannel's method or Siepser's method also require stitches to travel multiple times within the anterior chamber[14]. The purpose of improving these techniques is to achieve better results and make the operation easier for the surgeon[15].

Therefore, we designed a simplified slipknot as a new technique for pupilloplasty in the treatment of mydriasis. The purpose of this retrospective study was to compare the clinical outcomes of 32 eyes with mydriasis due to trauma, glaucoma attack or iatrogenic damage treated by simplified slipknot performed in pupilloplasty. The sutures were manipulated extraocularly to minimize excessive manipulation of the anterior chamber. To our knowledge, this technique has never been used for pupilloplasty.

PARTICIPANTS AND METHODS

Ethical Approval The present study was designed as a prospective, interventional case series study. This study was approved by the Ethics Committee of Nanjing Drum Tower Hospital, the Affiliated Hospital of Medical School, Nanjing University (No.2022S00192). All participants were informed of the surgical plan and potential risks prior to surgery and provided written informed consent. All procedures adhered to the tenets of the Declaration of Helsinki.

Consecutive patients presenting with symptomatic mydriasis requiring surgical intervention were screened for eligibility. The inclusion criteria were as follows: 1) iris injury due to trauma; 2) iris injury due to post-attack sequela of acute angle-closure glaucoma; 3) iris injury due to iatrogenic damage. All included patients showed no significant change after intracameral injection of carbachol during surgery, with a pupil diameter (PD) ≥4.0 mm or pupil deformity due to partial iris defect. Exclusion criteria: 1) patients responsive to carbachol during surgery with a PD<4.0 mm; 2) accompanied by posterior segment injury (*e.g.*, retinal detachment) requiring complex vitreoretinal surgery that could confound outcomes; 3) secondary glaucoma due to ocular trauma, true microphthalmos, iris neovascularization, or other various reasons; 4) active uveitis; 5) severe iris atrophy precluding suture placement. Patient recruitment was conducted consecutively to minimize selection bias, although the non-randomized design is acknowledged as a limitation.

The following data were recorded: 1) Preoperative measurements, including best-corrected visual acuity (BCVA), intraocular pressure (IOP), corneal endothelial density (CED), and PD. PD was assessed under mesopic conditions using two complementary methods to ensure accuracy and reliability. The primary clinical measurement was performed by an experienced examiner using slit-lamp biomicroscope. Additionally, PD was objectively quantified using an optical biometer (IOLMaster 700). This device automatically calculates the PD from high-resolution infrared images of the anterior segment, providing a precise, digital measurement. For each eye and each method, three consecutive measurements were taken. The final PD value used for analysis was the arithmetic mean of these triplicate readings[16]. 2) Postoperative measurements at 1wk, 1, 3, 6, and 12mo, including pupil size, BCVA, IOP, CED, and PD. Additionally, patients were interviewed regarding symptoms such as photophobia, glare, and diplopia. Recognizing that factors such as age, etiology of mydriasis (trauma, glaucoma, iatrogenic), severity of iris injury, combined surgical procedures (lens extraction, vitrectomy), and preoperative ocular comorbidities could influence surgical outcomes, these variables were also systematically documented.

Surgical Technique To ensure consistency, the same surgeon (Xie ZG) performed all the surgeries under an operating microscope. The surgical technique was described as follows. All patients received conventional retrobulbar anesthesia using a 1:1 mixture of 2% lidocaine and ropivacaine. After completing vitreous procedures or lens extraction surgery, pupilloplasty was performed if the pupil was still larger than 4 mm after 1.0 mL carbachol was injected into the anterior chamber (AC). Iris suturing was performed with 9-0 or 10-0 polypropylene sutures.

A 0.8 mm corneal margin incision was made at the 2, 4, 8, and 10 o'clock and needle was inserted into the AC through the incision, grasp and retract the pupillary margin at the 4 o'clock position and pass the long needle through the pupillary margin (Figure 1A). Insert a 26G needle through the 8 o'clock corneal incision. Insert the intraocular forceps through the 2 o'clock corneal incision and retract the pupillary margin at the 4 o'clock corneal incision. Pass the needle tip through the pupillary margin (Figure 1B). Insert the long needle into the 26G needle cannula and exteriorize the suture through the 4 o'clock corneal incision (Figure 1C). Pass the tail end of the suture from below through the loop and pull it out from above, grasping the tail with non-toothed forceps (Figure 1D). Wrap the suture around the needle holder half a turn, then grasp the tail end and pull to form a slipping knot, reducing the loop size until nearly tight (Figure 1E). Pull the suture end and the tail in opposite directions to draw the knot into the AC and tighten it to form a secure knot (Figure 1F). Cut the suture with micro intraocular scissors, completing one knot (Figure 1G). Suture the opposing sides of the iris using the same method (Figure 1H). Depending on leakage from the corneal paracentesis, suture them with 10-0 nylon if necessary.

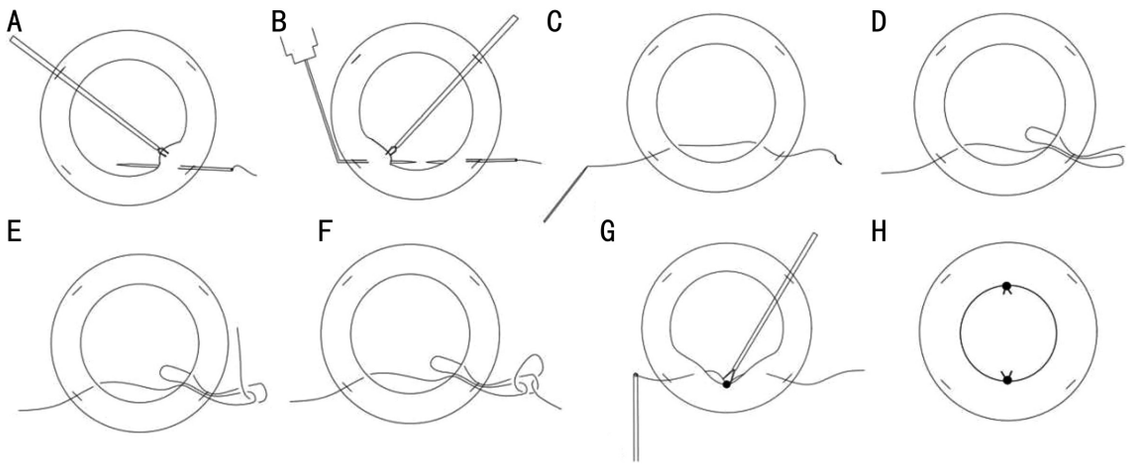

Figure 1 Surgical steps of pupilloplasty surgery A needle was inserted from the corneal limbus into the anterior chamber (A). The needle going through the two margins of the iris defect was assisted using a microhook (B), and the needle went out from the opposite corneal limbus (C). A microhook was used to guide a loop of left sutures from the anterior chamber out through the main/assistant cataract incision (D). The needle is passed through the loop and a second loop is created (E). The needle is passed through the second loop and tighten it to form a secure knot (F). Smooth the loop, and then snip the end of the suture inside the eye (G). Suture the opposing sides of the iris using the same method (H).

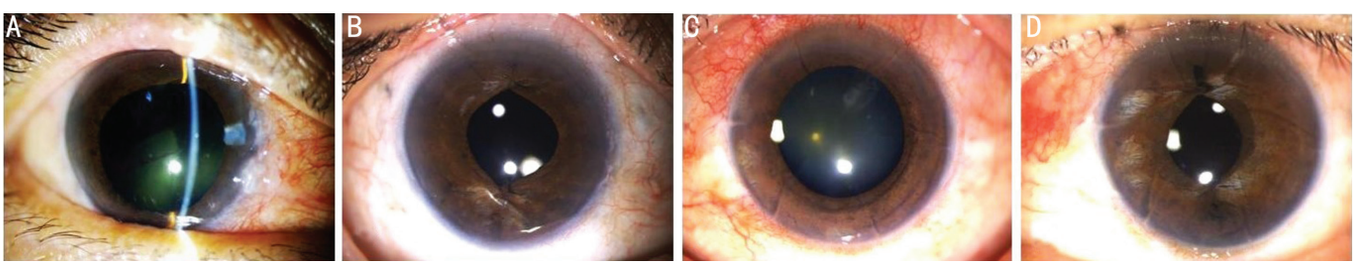

Figure 2 Representative photos before and after pupilloplasty A patient with traumatic mydriasis before (A) and after pupilloplasty with simplified slipknot (B). A patient with iris defect due to post-attack sequela of acute angle-closure glaucoma before (C) and after pupilloplasty with simplified slipknot (D).

Statistical Analysis Data analysis was performed using SPSS 27.0 statistical software. The primary outcomes, including BCVA, IOP, CED, and PD, were compared before and after surgery using paired *t*-test. Continuous data are presented as mean±standard deviation (SD) and categorical data as numbers and percentages. A *P* value <0.05 was considered statistically significant, with Bonferroni correction applied for multiple comparisons.

To explore the potential influence of confounding variables, such as age, etiology, and performance of combined vitrectomy, post-hoc analyses were conducted. Pearson's correlation coefficient was used to assess associations between continuous confounders and the degree of improvement in BCVA or reduction in PD, while categorical variables were employed to stratify the cohort, with between-subgroup differences examined using independent *t*-tests or analysis of variance (ANOVA)[17-18]. As this was an exploratory, prospective case series designed to evaluate the feasibility and short-term outcomes of a novel surgical technique, a formal a priori sample size or power calculation was not performed, consistent with initial technical reports in surgical ophthalmology. The sample of 32 eyes was derived from consecutive eligible patients at our tertiary referral center during the study period, providing preliminary evidence on safety and efficacy. We acknowledge that the lack of a predefined sample size is a limitation and that the findings should be interpreted as preliminary; future comparative studies testing specific hypotheses will require formal power calculations to determine appropriate sample sizes.

RESULTS

From October 2022 to July 2025, a total of 32 consecutive patients (32 eyes) were included in the study. The mean age was 57.9±15.9y (range, 21 to 85y). Baseline characteristics was listed in Table 1. In all surgical cases, combined lens/intraocular lens surgery was conducted on 32 eyes, and combined vitrectomy was carried out on 20 eyes. The mean time required to complete one knot was approximately 4.3±0.5min (range, 3.5 to 5min). Follow-up time ranged from 1 to 12mo, with a mean of 3.5±3.0mo. Changes in BCVA, IOP, CED, PD before and after surgery were showed in Figures 2 and 3. During the follow-up period, no suture breakage in any eye, and no pigment dispersion or anterior uveitis was noted in the study eyes.

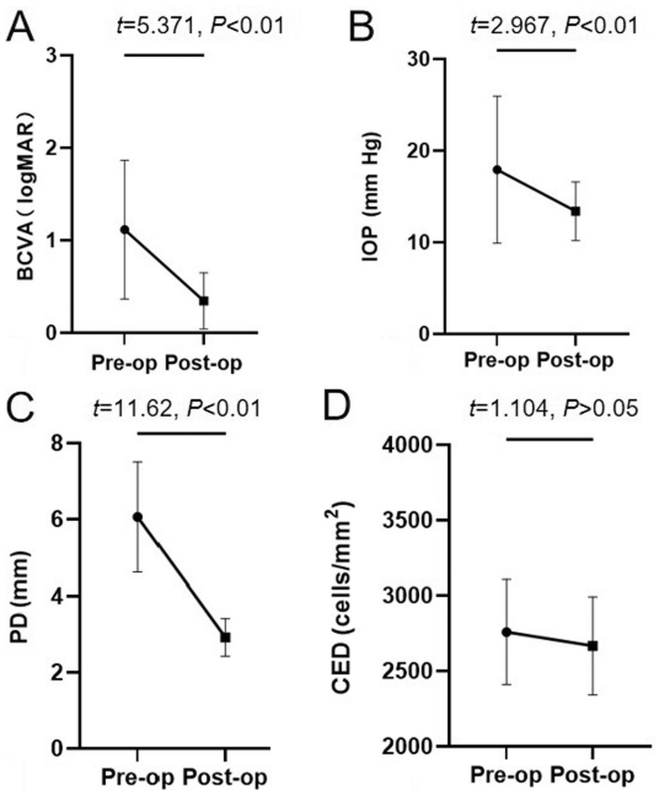

Figure 3 Changes in BCVA, IOP, CED, PD before and after surgery
Pre-op: Preoperative; Post-op: Post-operative; BCVA: Best-corrected visual acuity; IOP: Intraocular pressure; PD: Pupil diameter; CED: Corneal endothelial density.

Table 1 Baseline characteristics

Characteristic	*n* (%)
Total eyes, *n*	32
Age, y, mean±SD	57.9±15.9
Male, *n* (%)	21 (65.6)
Etiology, *n* (%)	
Traumatic	26 (81.3)
Acute angle-closure glaucoma	3 (9.4)
Iatrogenic	3 (9.4)
Combined surgery, *n* (%)	
Combined pars plana vitrectomy	20 (62.5)
Without pars plana vitrectomy	12 (37.5)
Number of pupilloplasty knots, *n* (%)	
1 suture	17 (53.1)
2 sutures	10 (31.3)
≥3 sutures	5 (15.6)
Preoperative BCVA (logMAR)	1.15±0.79
Preoperative PD (mm)	5.9±1.4

BCVA: Best-corrected visual acuity; PD: Pupil diameter; SD: Standard deviation.

Post-hoc analyses revealed no significant correlation between patient age and the magnitude of BCVA improvement (Spearman's ρ=-0.08, P=0.66) or PD reduction (ρ=-0.10, P=0.59). Furthermore, no statistically significant differences were found in ΔBCVA or ΔPD when comparing eyes with traumatic etiology versus non-traumatic causes (glaucoma/iatrogenic), or eyes that underwent combined PPV compared with those that did not. Although eyes requiring ≥2 sutures showed a trend towards greater PD reduction compared to those with a single suture, this did not reach statistical significance (P=0.089). These analyses suggest that within the scope of this study, the key outcomes of the simplified slipknot technique were not substantially modulated by the examined clinical confounders (Table 2).

DISCUSSION

The pupil is an essential component of the optic system of the human eye. The normal PD is 2.5 to 4.0 mm. When the eye suffers trauma or sustained high intraocular pressure, it can lead to rupture or paralysis of the pupillary sphincter, causing permanent mydriasis, which is often unresponsive to miotics[19]. Pupil deformation is associated with several manifestations of vision degradation, including photophobia, monocular diplopia, peripheral aberraions, and light scattering, all of which can reduce optical quality[5,20]. Therefore, the aim of pupilloplasty surgery is to restore the pupil to an appropriate size, which is critical for high visual performance[10,21]. Studies have shown that if the sutured pupil is larger than 4.0 mm, symptoms of photophobia and glare may affect daytime life and work, while if smaller than 3.0 mm, it may affect the patient's night vision, especially in young patients. In clinical practice, it is appropriate to suture the pupil to 2.5–4 mm[19,22].

The iris suture surgical method has been continuously improved[3,23]. The mainstream techniques are the Siepser method and its modifications, which is relatively simpler to perform, completing two slipping knots from corneal side ports to form a stable square knot. Unfortunately, Siepser's sliding suture is conceptually more difficult to understand and more challenging to teach. Even an experienced surgeon can become confused and not create a true locking knot[24]. Although SFT is widely used and effective, it typically requires multiple intraocular instrument passes and a relatively complex knotting sequence, which may prolong surgical time and increase the risk of intraocular tissue trauma. In contrast, our simplified slipknot technique described herein reduces the number of AC entries, utilizes an extraocular knot-tying maneuver, and allows for adjustable pupil sizing with fewer sutures. These modifications aim to enhance surgical efficiency, reduce endothelial cell loss, and simplify the procedure for surgeons with varying levels of experience.

We believe this modified technique offers the following advantages: 1) Surgical simplicity: The procedure is straightforward and typically requires only one to two sutures to achieve a significant reduction in pupil size. It also reduces the number of times the microhook enters the AC; on average, the hook enters one time for each knot. Each time the AC is

Table 2 Analysis of primary outcomes stratified by confounding factors Median (IQR)

Confounding factors	*n*	ΔBCVA (logMAR)	*P*	ΔPD (mm)	*P*
Overall	32	0.40 (0.20, 0.91)	-	3.0 (2.5, 3.5)	-
Etiology			0.721		0.883
Traumatic	26	0.40 (0.21, 0.92)		3.0 (2.5, 3.5)	
Glaucoma/iatrogenic	6	0.35 (0.11, 0.71)		3.0 (2.5, 3.5)	
Combined PPV			0.534		0.812
Yes	20	0.40 (0.21, 0.98)		3.0 (2.5, 3.5)	
No	12	0.35 (0.19, 0.71)		3.0 (2.5, 4.0)	
Number of sutures			0.406		0.089
1 suture	17	0.40 (0.22, 0.70)		3.0 (2.5, 3.5)	
≥2 sutures	15	0.40 (0.15, 1.35)		3.5 (3.0, 4.0)	

ΔBCVA: Preoperative BCVA−Postoperative BCVA (positive value indicates improvement); ΔPD=Preoperative PD−Postoperative PD (positive value indicates reduction). *P* values are derived from the Mann-Whitney *U* test (for two groups) or the Kruskal-Wallis *H* test (for multiple groups). BCVA: Best-corrected visual acuity; PD: Pupil diameter; IQR: Interquartile range; PPV: Pars plana vitrectomy.

breached, the risk of infection and corneal endothelial cell loss increases[25]. 2) Adjustable pupil size: The final PD can be precisely controlled by varying the number of sutures placed. 3) Secure knotting with polypropylene suture: The use of a polypropylene suture allows for the creation of a highly secure knot between suture strands, obviating the need for additional throws. 4) Operative efficiency: Compared to traditional pupillary cerclage techniques, this modified approach may substantially reduce total operative time. Compared to the SFT pupilloplasty technique, which typically requires 22.32±4.58min and involves repeated intraocular instrument manipulation[14], our simplified slipknot technique averaged 4.3±0.5min per knot with fewer AC entries. 5) Surgical safety: Studies on SFT reported postoperative PDs of 3.02±0.516 mm[14], similar to our mean of 3.0±0.5 mm, yet our method may offer advantages in knot security and reduced endothelial trauma due to extraocular knot formation. Unlike pupillary cerclage techniques that necessitate additional limbal incisions, our approach maintains a closed-chamber environment, potentially lowering infection risk and improving AC stability.

Several key technical considerations should be noted when applying this method: 1) Polypropylene 10-0 or 9-0 suture recommended to be used. Compared to nylon suture, polypropylene has higher friction and better anti-slip properties[26]. Its monofilament structure and surface characteristics enhance static friction at the suture interface, reducing the risk of knot slippage. In contrast, nylon sutures are more prone to slippage and surface wear under friction, which may compromise long-term knot stability[27]. Additionally, the favorable elongation and plastic deformation capacity of polypropylene suture contribute to secure knot formation through the interaction of friction and elastoplasticity during ligation[28]. Therefore, using polypropylene suture is critical for ensuring surgical success and stability in pupilloplasty. 2) When passing the needle through the pupillary margin, try to avoid the edge and prevent tearing of the pupillary margin when tightening the suture into the AC. 3) When retrieving the suture through the corneal side port, it is advisable to use micro end-grasping forceps or a micro metal hook. Direct grasping and pulling of the suture should be avoided to minimize the risk of iris root detachment. 4) Before final tightening, the suture should be gently cinched and create a small loop externally. The knot should be fully tightened after it slid into the AC to prevent inadvertent incorporating iris tissue into the knot. 5) If the iris has high tension, suturing should begin peripherally and proceed toward the center of the pupillary margin. This sequential approach helps distribute tension and reduces the risk of tearing at the margin.

The shortcomings of our study are that it is retrospective, and the postoperative pupil circularity may be slightly imperfect, which might require the use of a vitrectomy probe or bipolar cautery to achieve. Furthermore, this study was not analyzed and compared the pre-operative and post-operative visual quality for the patients. We have conducted a preliminary evaluation of this novel pupilloplasty technique, confirming its feasibility and favorable perioperative safety. However, as an initial technical exploration, the study didn't systematically compare its postoperative outcomes with other mainstream pupilloplasty methods. Therefore, the current findings just primarily reflect the technique's operability and short-term efficacy.

The majority of studies published so far in the field of pupilloplasty focus mainly on morphological outcomes, not visual outcomes. Our study also evaluated functional improvement through BCVA. Our results demonstrate a significant improvement in BCVA postoperatively compared

to preoperative values. Improvements in visual function after pupilloplasty is unsurprising, as the iris helps to achieve good quality vision by reducing aberrations from the lens and cornea by decreasing the amount of light entering the pupil, preventing excessive glare, and enhancing the depth of focus. An appropriate PD makes an additional pinhole effect and may contribute to better visual acuity[29-30]. While BCVA is influenced by multiple preoperative and surgical factors, its improvement remains a clinically relevant indicator of successful visual rehabilitation in patients with mydriasis. Improvement in BCVA thus reflects the combined benefit of the pupilloplasty and any associated procedures. Nevertheless, we acknowledge that BCVA alone is a limited endpoint, as it does not fully capture dimensions of visual quality such as contrast sensitivity, dysphotopsia, or patient-reported visual function. Future studies incorporating standardized questionnaires, wavefront analysis, and contrast sensitivity testing will be needed to more comprehensively assess the visual outcomes of this technique[31].

Nextly we plan to conduct a prospective controlled study to directly compare this technique with traditional or existing modified approaches, focusing on differences in visual quality, contrast sensitivity, pupil morphological stability, surgical efficiency, and long-term complications. Such a comparative study will provide more evidence-based insights to guide clinical surgical decision-making. And we will use imaging techniques to visualize the knot and iris position as this was done in a study by Kumar *et al*[32]. They analyzed the results of spectral-domain optical coherence tomography in 26 patients and found that only one eye developed early knot loosening. This is important as we can presume that the normal iris ultrastructure can be altered after surgical procedures and intervening sutures. A significant change in iris configuration was noted after pupilloplasty, and a vertically oriented retained prolene suture was predominant with good endothelial vault[33]. In conclusion, this modified technique can effectively reshape the dilated pupil. It is simple to perform, has a short learning curve for surgeons, causes minimal trauma to intraocular tissues, and is easy to popularize. However, the sample size of this study is small, the observation period is short, and long-term outcomes are still under ongoing long-term follow-up.

ACKNOWLEDGEMENTS

Authors' Contributions: Bao YB and Tang YF made substantial contributions to the design of the study, data analysis, data interpretation, and drafting of the manuscript. Liu SY made substantial contributions to data acquisition and data interpretation. He ZF and Liu YJ made substantial contributions to data acquisition and supervision. Yi QH made substantial contributions to critical revision of manuscript and statistical analysis. Xie ZG made substantial contributions to the concept and design, data acquisition, and critical revision of the work.

Data Availability Statement: The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

AI-Generated Content Disclosure: No artificial intelligence (AI) tools were used in the preparation of this manuscript.

Conflicts of Interest: Bao YB, None; **Tang YF,** None; **Liu SY,** None; **He ZF,** None; **Liu YJ,** None; **Yi QH,** None; **Xie ZG,** None.

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