

Modified CO₂ Laser-assisted Sclerectomy Surgery in Chinese Patients With Primary Open-Angle Glaucoma and Pseudoexfoliative Glaucoma: A 2-Year Follow-up Study

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Precis: A modified CO₂ laser-assisted sclerectomy surgery (CLASS) based on the characteristics of Chinese eyeball was carried out in Chinese patient and was confirmed to be effective and safe during long-term follow-up.

Purpose: The purpose of this study was to study the long-term efficacy and safety of modified CLASS in Chinese patients with primary open-angle and pseudoexfoliative glaucoma.

Methods: We enrolled 25 medically uncontrolled primary open-angle and pseudoexfoliative glaucoma patients in this prospective, interventional case series. A combination of modified CLASS and preoperative laser iris management was administered to 29 eyes. Visual acuity, intraocular pressure (IOP), slit-lamp examinations, visual field, and gonioscopy were carried out at baseline and until 24 months postoperatively. Ultrasound biomicroscopy examinations were repeated at 3, 12, and 24 months postsurgically.

Results: Mean patient age was 53.92 ± 12.08 years. Mean preoperative IOP was 30.66 ± 10.41 mm Hg; and mean postoperative IOP was 8.17 ± 3.76, and 13.25 ± 2.73, 13.76 ± 2.50, and 13.76 ± 2.50 mm Hg at 1 day, and 6, 12, and 24 months, respectively. Proportional changes in IOP from baseline at 6, 12, and 24 months was 58.33%, 56.25%, and 58.97% ($P < 0.001$), respectively. Complete postoperative success rates at 12 and 24 months were 62.07% and 48.28%. Qualified success rates at 12 and 24 months postoperatively were both 89.66%. Number of medications administered per patient reduced from 3 at baseline to 0 at 12 and 24 months ($P < 0.0001$). Two patients demonstrated severe peripheral anterior synechiae (6.90%). Ultrasound biomicroscopy examination revealed a severe scleral lake diminution in 1 patient (3.40%) at 12 months and 2 patients (6.90%) at 24 months.

Conclusion: Combination of modified CLASS and preventive laser iris management was effective and safe in the long-term treatment of primary open-angle glaucoma patients.

Key Words: glaucoma, nonpenetrating deep sclerectomy, laser surgery, CLASS, trabeculectomy

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Trabeculectomy was first introduced by Cairns¹ and is currently considered to be the gold standard for filtration surgery to treat primary open-angle glaucoma (POAG).

However, this procedure is associated with a range of potential complications, which may lead to severe sight-threatening consequences.² The aim of nonpenetrating deep sclerectomy (NPDS) is to overcome severe complications, including flat chamber, hyphemia, and choroidal detachment, by keeping the inner wall of the trabecular meshwork (TM) intact and stabilizing the anterior chamber and intraocular pressure (IOP) fluctuations.^{2–5} NPDS has now developed a better safety profile and an effective method to lower IOP, despite it being relatively less effective when compared with trabeculectomy.⁶ However, the manual procedure for NPDS is technically difficult to perform,⁷ especially when dissecting a deep enough flap to permit effective aqueous percolation, while avoiding intraoperative penetration through the thin inner TM wall.⁸ CO₂ laser-assisted sclerectomy surgery (CLASS) is an improved version of NPDS that uses a CO₂ laser to ablate the scleral tissue in a precise and efficient manner, leaving a thin membrane that is just sufficient for aqueous percolation, without penetrating to the anterior chamber. The unique characteristic of CO₂ laser that renders this system perfect for use in sclerectomy is that it is extremely effective in ablating only the dry tissues. Although it loses its efficacy after the opening of the outer wall of the Schlemm canal (SC) due to aqueous percolation, it prevents excessive tissue ablation and ensures that the inner wall of the SC is kept intact.⁹ An Israeli team of experts showed that the CLASS technique is a relatively simple and safe surgical procedure, which is particularly effective in reducing IOP for POAG and pseudoexfoliative glaucoma (PXFG) within the postoperative 3 years.¹⁰ These findings highlight the several advantages of CLASS over the manual NPDS technique.

However, there is considerable variation in the anatomic features of the anterior chamber and adjacent structures, especially when compared between East Asians (including Chinese) and whites. For example, Chinese patients with POAG typically develop a crowded anterior segment.¹¹ Furthermore, the preoperative severity of POAG in Chinese patients is more advanced and refractory and is associated with higher IOP levels, along with scarring.¹² Certain preliminary studies have suggested that the success rate of CLASS and associated incidence of complications are unsatisfactory. To illustrate, the incidence of peripheral anterior synechiae (PAS) and iris incarceration has reportedly been relatively high after CLASS, in both white and Chinese patients.¹³ These preliminary data indicate that modifications to the CLASS procedure and preoperative iris management, including laser peripheral iridotomy (LPI) and argon laser peripheral iridoplasty (ALPI), are necessary to improve the long-term surgical outcomes, and that such modifications should be made considering the specific characteristics of East Asian patients with glaucoma.

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Herein, we describe a series of Chinese patients with POAG who were treated with CLASS. We aimed to improve the long-term efficacy of this technique and reduce postoperative complications by selecting the ablation site according to the condition of the anterior chamber, followed by managing the iris preoperatively, and modifying and standardizing the CLASS procedure for Chinese patients.

METHODS

This study was approved by the Institutional Review Board of Peking Union Medical College Hospital and conformed to the tenets of the Declaration of Helsinki. Informed consent was obtained from all subjects before recruitment.

Prospective Case Series

We recruited 25 adult Chinese patients (age above 30 y) with medically uncontrolled POAG or PXFG. CLASS was used on 29 eyes, and all patients were followed up postoperatively for 24 months. They received maximally tolerable hypotensive medications (3 or more) with an IOP ≥ 21 mm Hg or a diurnal variation of IOP > 8 mm Hg; furthermore, they showed the progression of glaucomatous visual field defects and glaucomatous optic neuropathy. Patients were excluded in case of presence of other glaucoma-associated etiologies, blindness in 1 eye, a history of eye surgery, presence of eye trauma or inflammation, identification of an opacity that may interfere with optic nerve evaluation, or if the patient was not willing to participate.

Baseline assessments included best-corrected visual acuity (BCVA) and IOP, which were determined with a calibrated Goldman applanation tonometer, stereoscopic optic disc photography (Canon; CR-1 Mark II, Tokyo, Japan), and a visual field examination (Octopus 101 program G1; Interzeag AG, Schlieren, Switzerland). We also assessed the head of the optic nerve using optical coherence tomography (Stratus OCT, Carl Zeiss Meditec, CA). Gonioscopy was performed by a glaucoma specialist (G.C.) using a Goldmann 1-mirror lens at high magnification ($\times 16$).

Surgical Technique

Preoperative Management

Gonioscopy was used to evaluate the superior angle, followed by marking the preferred gonio position, which corresponded to the scleral site for ablation. We prioritized a position with the widest angle and the area demonstrating blood reflux in the SC. The secondary selection was considering a position with the widest angle, presenting with sparse or uniform pigmentation, with an open-angle position demonstrating blood reflux in the SC. An open-angle position and sparse or uniform pigmentation, without the blood reflux in the SC, was given the third priority. The presence of an open-angle position with heavy pigmentation, without the clear appearance of SC, was the last choice.

All eyes underwent LPI+ALPI at the selected iris position within 1 to 3 days before the procedure, corresponding to the planned ablation area. Broad-based LPI was performed as close as possible to the root of the iris and centered in the expectant percolation area. ALPI was then applied, surrounding the LPI hole (minimum 500 μ m in width).

Intraoperative Procedures

All operations were performed under surface anesthesia with Oxybuprocaine Hydrochloride Eye Drops and subconjunctival anesthesia in the operative field with 2%

lidocaine without epinephrine. A superior fornix-based conjunctival flap was created and the Tenon capsule was dissected to expose the sclera. We then created a 5 \times 5 mm rectangular limbal-based flap, of 1/3 to 1/2 partial thickness, and extended by 1 mm into the clear cornea. Mitomycin C (MMC) was then applied using soaked sponges under the scleral flap and conjunctiva; the concentration (0.04%) and duration (1 to 2 min under the flap and 1 to 1.5 min under the conjunctiva) was left to the surgeon's discretion, followed by washing out.

The CO₂ laser beam was then applied over the posterior scleral bed to create a deep rectangle scleral lake. The length of the subscleral lake was 4 mm, the width was at least 2.2 mm, and the depth was $\sim 90\%$ of the scleral thickness. At this depth, it was possible to visualize the color of the pigmentation in the uvea tissue beneath (the ciliary body). Residual charred tissue was wiped away with a BSS damp Weck-Cel sponge. MMC was then applied on the scleral floor for 1 minute, followed by washing out the MMC and estimating the IOP via digital palpations. The presence of a particularly high IOP warranted the use of paracentesis to gradually reduce the IOP. Miosis was applied in pupils with a diameter > 3.5 mm. Following this, we applied the CO₂ laser beam over the surgical limbus to unroof an area of the SC, which was 1.5 \times 4 mm in size; fluid percolation was then observed. Subsequently, the CO₂ laser beam was moved forward to ablate a 1 \times 4 mm area in Trabeculo-Desemet window (TDW) (Fig. 1), before repositioning the scleral flap and closing it with 2 adjustable sutures using 10/0 nylon at the top corners. The adjustable sutures were fastened in a bow-tie pattern after making 4 throws. The conjunctiva was secured using buried 10-0 nylon sutures, and the eye was patched with Tobradex ointment (tobramycin and dexamethasone eye ointment, Novartis Alcon, Switzerland). All laser and surgical procedures were performed by a single experienced glaucoma surgeon (G.C.).

The patients were postoperatively treated with 1% prednisolone acetate drops (Pred Forte; Allergan, Irvine, CA) 6 times daily and the dose was tapered for minimum 4 weeks; the patients also received ofloxacin ophthalmic solution (Santen Pharmaceutical Co., Osaka, Japan) 4 times

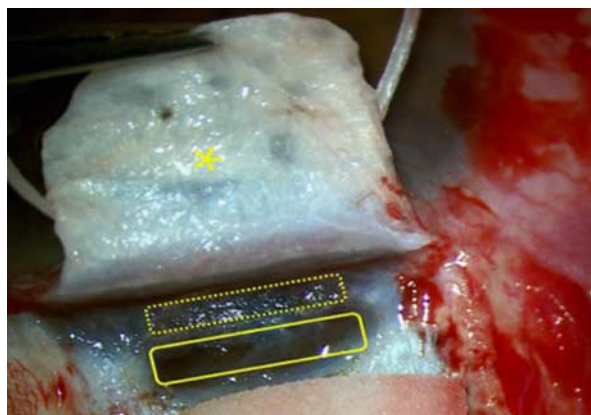


FIGURE 1. A 1/3 to 1/2 partial thickness rectangular limbal-based scleral flap is created and extended by 1 mm into the clear cornea (yellow asterisk). Followed by ablating the Trabeculo-Desemet window (yellow dotted box), unroofing the Schlemm canal, and observing fluid percolation (yellow solid box).

daily for 2 weeks. The patients were examined at 1 day and at 1, 2, 6, and 8 weeks, and at 1, 3, 6, 12, and 24 months postoperatively. The number of hypotensive medications administered to each patient at each visit was compared with the baseline.

Postoperative Care

The inner wall of the TM was assessed using gonioscopy at each hospital visit. Postoperative ultrasound biomicroscopy (UBM) was performed at 1, 3, 12, and 24 months. Additional UBM examinations were performed in the event of IOP fluctuations. UBM was performed by a single experienced investigator (Y.Z.) using a probe operating at 50 MHz. The patient was placed in the supine position to examine the Gonio and the adjacent surgically-created scleral lake was examined with the aid of an emersion scleral shell and an examination gel (Fig. 2). Radial and transverse sections of the sclerectomy area were then explored using an optimized dB gain that produced the best image resolution and quality. Morphologic changes of the intrascleral lake were measured with UBM at 3, 12, and 24 months postoperatively, and were compared with that at 1 month. The morphologic changes were categorized into “stable” (no change) and “unstable,” which included a mild (a change ≤ 30%), moderate (30% > change ≤ 50%), or severe reduction (a change > 50%, impending closure).

“Complete success” was defined as IOP values ranging between 5 and 18 mm Hg and a reduction of ≥ 20%, without the need for additional hypotensive medications or a repeat filtration surgery. “Qualified success” was defined as the same outcome, however, including subjects who required hypotensive medications postoperatively. Adjustable sutures were released transconjunctivally under a slit-lamp shortly after (within 14 d of surgery).

If the IOP exceeded 21 mm Hg and severe reduction of the scleral lake were detected by the UBM, we administered subconjunctival (subscleral flap) injections of 0.2 mL of a 50 mg/mL solution of 5-fluorouracil (5-FU).

Laser goniopuncture (LGP) was performed with a Microruptor II Nd: YAG laser when the IOP exceeded the target level owing to insufficient aqueous percolation through the SC and TDW. Before the LGP, it was important to

exclude internal complications arising from severe PAS or iris incarceration. Tiny holes were created around the TDW (mostly beyond the Schwalbe line), to facilitate the drainage of aqueous humor from the anterior chamber to the scleral lake (Fig. 3). Iris incarceration was prevented by not pointing the laser towards the TM. A Lasag-15 gonioscopy contact lens was used in the Q-switch mode with an energy ranging from 3.5 to 5 mJ. The patients were administered with topical prednisolone acetate 3 times a day for 7 days and 2% pilocarpine twice a day for 2 weeks postoperatively.

Statistical Analysis

Statistical analysis was performed using SAS version 9.2 (SAS Institute, Cary, NC). Descriptive statistical results are presented as means ± SD, as medians and interquartile range for continuous variables, or as n (%) for categorical variables. Data were tested for normality using the Kolmogorov-Smirnov test; parametric or nonparametric tests were then applied accordingly. A mixed model was used for the parametric data (IOP) over different timepoints, and the Wilcoxon paired signed-rank test was used for nonparametric data (BCVA, medications). One-way analysis of variance (analysis of variance, parametric) was used to compare multiple groups, while the Bonferroni correction was used for multiple comparisons. The BCVA was expressed as the standard logarithmic value of VA and was converted to a

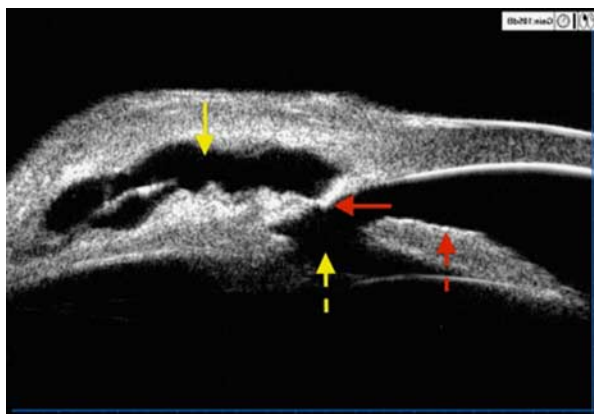


FIGURE 2. An ultrasound biomicroscopic radial scan clearly showing the intrascleral lake (yellow solid arrow), Trabeculo-Descemet window (red solid arrow), laser peripheral iridotomy hole (yellow dotted arrow), and argon laser peripheral iridoplasty spot (red dotted arrow). Figure 2 can be viewed in color online at www.glaucomajournal.com.

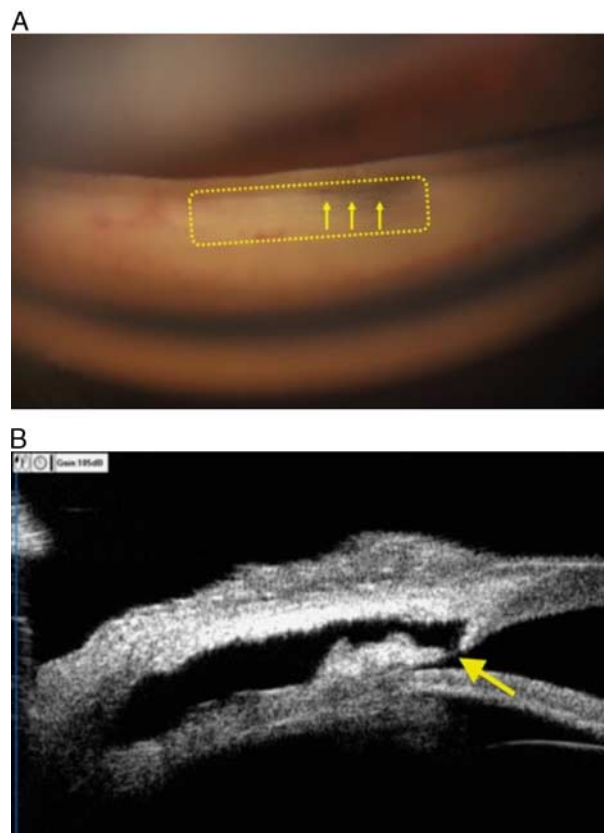


FIGURE 3. Laser goniopuncture is performed within the Trabeculo-Descemet window (yellow dotted box). A, Identification of a tiny hole after laser goniopuncture (yellow solid arrows). B, Ultrasound biomicroscopic radial scan showing the hole in the Trabeculo-Descemet window (yellow solid arrow).

logarithm of the minimal angle of resolution (logMAR) for statistical analysis. Kaplan-Meier life-table curves were created to present the duration of qualified success, and data were considered to be statistically significant when *P*-value <0.05.

RESULTS

Overall, 25 subjects (29 eyes) met our specific inclusion criteria and were enrolled in this study. Mean patient age was 53.92 ± 12.08 years and 52% (n = 13) of our study cohort were men. The numbers of patients under 45, 45 to 60, and over 60 years were 7 (28%), 9 (36%), and 9 (36%), respectively. Of these, 28/29 (96.6%) were diagnosed with POAG and 1/29 (3.4%) was diagnosed with PXFG. Demographic data and baseline disease information are summarized in Table 1. There were no statistically significant differences across the age groups with regard to the baseline characteristics.

Mean preoperative IOP was 30.6 ± 10.41 mm Hg in the presence of 3 to 4 hypotensive medications; mean postoperative IOP was 8.17 ± 3.76 mm Hg at 1 day; 8.47 ± 2.39 mm Hg at 1 week; and 15.22 ± 5.78, 12.86 ± 3.44, 13.25 ± 2.73, 13.76 ± 2.50, and 13.51 ± 2.30 mm Hg at 1, 3, 6, 12, and 24 months, respectively. At 12 and 24 months postoperatively, the number of drugs taken per patient was reduced to only 0 to 1 hypotensive medications, although there was no significant difference in the number of therapeutic drugs taken when compared between 12 and 24 months (Table 2). The mean IOP reduction (%) at 1 day; 1 week; and 1, 3, 6, 12, and 24 months was 78.26% [95% confidence interval (CI), 60.00-81.58]; 76.67% (95% CI, 57.69-78.95); 48.72% (95% CI, 17.65-68.29), 56.52% (95% CI, 35.71-73.18), 58.33% (95% CI, 37.65-6.67), 56.25% (95% CI, 30.43-66.67), and 58.97% (95% CI, 34.78-64.10), respectively (*P* < 0.001). Please refer to Table 3 and Figure 4 for the aforementioned data.

TABLE 1. Baseline Patient Demographics and Disease Characteristics

Parameters	Results [n (%)]
Patients	25 (100.00)
Eyes	29 (100.00)
Sex	
Male	13 (52.00)
Female	12 (48.00)
Age of patients (y)	
Mean ± SD	53.92 ± 12.08
Minimum, maximum	33, 80
No. drugs [median (Q1, Q3)]	3 (3, 4)
Three drugs	19 (65.52)
Four drugs or above	108 (34.48)
Initial IOP (mean ± SD) (mm Hg)	30.66 ± 10.41
Initial logMAR BCVA [median (Q1, Q3)]	0.3 (0.1, 0.5)
Initial VF	
Early	5 (17.24)
Moderate	12 (41.38)
Severe	12 (41.38)
Diagnosis	
POAG	28 (96.6)
PEXG	1 (3.4)

BCVA indicates best corrected visual acuity; IOP, intraocular pressure; PEXG, pseudoexfoliative glaucoma; POAG, primary open-angle glaucoma; Q1, lower quartile; Q3, upper quartile; VF, visual field.

TABLE 2. Number of Medications at Baseline and at 12 and 24 Months Postoperatively

Timepoint	No. Drugs [Median (Q1, Q3)]	No. Drugs Reduction From Baseline [Median (Q1, Q3)]	<i>P</i> *
Preoperative	3 (3, 4)	—	—
12 mo	0 (0, 1)	3 (3, 3)	<0.0001
24 mo	0 (0, 1)	3 (2, 3)	<0.0001

*Wilcoxon paired signed rank test between baseline and postbaseline values (reduction in the number of drugs taken per patient from baseline was not normally distributed). Bonferroni correction was used for multiple comparisons and the corrected significance was determined as 0.05/2 = 0.017. Q1 indicates lower quartile; Q3, upper quartile.

The area of the scleral lake was 4.0 mm × (2.22 ± 0.33) mm and did not demonstrate any significant correlation with the IOP at any of the timepoints postoperatively. Moreover, the BCVA (logMAR) decreased significantly on day 1 postoperatively from 0.3 (0.1, 0.5) to 0.5 (0.2, 0.9), *P* = 0.019. Visual acuity returned to 0.2 (0.1, 0.4) within 1 month after surgery and remained stable over the following 24 months (Table 4).

The complete success rates after 12 and 24 months were 62.07% and 48.28%. The qualified success rates after 12 and 24 months were both 89.66% (Fig. 5).

There was a statistically significant difference between UBM stable and unstable groups in terms of preoperative IOP at 12 and 24 months (*P* < 0.001 for both timepoints) (Table 5).

Subconjunctival injections of 5-FU were performed in 6 eyes (20.69%). The mean number of injections administered was 1.17 ± 0.40, and the mean time interval between the procedure and 5-FU injection was 12.42 ± 15.94 months. LGP was performed with the Nd: YAG laser in 15 patients (51.72%). Mean amount of time between laser and CLASS was 3.0 ± 2.9 months. Mean IOP before LGP was 21.8 ± 4.0 mm Hg, which decreased significantly to 12.5 ± 3.1 mm Hg after LGP (*P* < 0.001).

One patient (3.40%) suffered from early hyphemia, 4 patients (13.79%) developed cataracts, and 2 patients (6.90%) experienced severe PAS during the 2-year follow-up period. No vision-threatening or irreversible complications, such as incarceration, choroidal detachment, aqueous misdirection, or endophthalmitis, were observed. Furthermore, the anterior chamber remained deep and stable in all cases.

DISCUSSION

It is widely accepted that CLASS, a laser-assisted modification of NPDS, is an effective treatment to reduce IOP in POAG patients, with several advantages over the manual NPDS. For example, in CLASS, the inner wall of the SC and juxtacanalicular connective tissue are not removed since the laser energy can be absorbed by the percolation of the aqueous humor through the SC. Instead, it is possible to create TDW with the CO₂ laser; therefore, the extent of aqueous percolation could be theoretically increased. Furthermore, previous molecular and clinical studies have shown that fibrotic response may be reduced in areas treated by a CO₂ laser because of thermal denaturation.¹⁴ Another factor to consider is the numerous variations in anatomic characteristics when comparing different ethnicities.¹⁵ Furthermore, the fibrotic response is even more remarkable in the Chinese population.¹²

TABLE 3. IOP at Baseline, 1 Day, 1 Week and at 1, 3, 6, 12, and 24 Months Posttreatment

Timepoint	IOP (Mean ± SD) (mm Hg)	IOP Reduction From Baseline (Mean ± SD)	IOP (% Reduction From Baseline) [Median (Q1, Q3)]	t	P*
Preoperative	30.66 ± 10.41	—	—	—	—
1 d	8.17 ± 3.76	22.48 ± 11.87	78.26 (60.00, 81.58)	18.34	<0.0001
1 wk	8.47 ± 2.39	22.18 ± 11.25	76.67 (57.69, 78.95)	17.26	<0.0001
1 mo	15.22 ± 5.78	15.44 ± 12.80	48.72 (17.65, 68.29)	11.96	<0.0001
3 mo	12.86 ± 3.44	17.80 ± 11.31	56.52 (35.71, 73.18)	13.78	<0.0001
6 mo	13.25 ± 2.73	17.90 ± 10.37	58.33 (37.65, 66.26)	13.33	<0.0001
12 mo	13.76 ± 2.50	16.90 ± 10.84	56.25 (30.43, 66.67)	13.08	<0.0001
24 mo	13.51 ± 2.30	17.14 ± 10.74	58.97 (34.78, 64.10)	13.27	<0.0001

*A mixed model was used to test IOP over different timepoints. P values indicate the difference between IOP preoperatively and each postoperative timepoint.

IOP indicates intraocular pressure; Q1, lower quartile; Q3, upper quartile.

These factors inspired us to develop and test a more suitable CLASS approach for Chinese patients, with long-term efficacy and safety. Our study highlighted several key points associated with the CLASS approach. First, we designed and carried out preventative LPI+APLI preoperatively, which revealed that this approach reduced the incidence of PAS, only 2 patients (6.90%) experienced severe PAS during the 2-year follow-up period. This was an important advancement, considering the high incidence of PAS and incarceration as 80% (unpublished study) associated with procedures that do not involve preoperative lasers. Second, during CLASS surgery, we created a larger scleral flap (5×5 mm, compared with 4×4 mm) and an intrascleral lake that was large and deep enough to ensure increased levels of drainage and percolation of the aqueous humor. Previously published studies do not seem to fully appreciate the importance of the size and depth of the scleral lake. Some surgeons even proposed to create smaller and shallower scleral lakes.¹⁶ These previous considerations could be primarily due to the feasibility aspects and fear of penetrating the uveal tissue. We considered that the long-term maintenance of a larger scleral lake would be easier, along with the fact that more aqueous humor may percolate into the scleral lake. Furthermore, a deeper ablation may even facilitate aqueous drainage to the suprachoroidal space for absorption, and we also observed that microperforation was not associated with safety issues and does not sacrifice long-term efficacy; these considerations have also been suggested by other studies.¹⁷

Notably, we revealed the SC during surgery, while using the laser to extend the area of ablation forward to

create a TDW. This practice increased the area for percolation and was convenient for subsequent LGP, if required. In addition, the location of filtration was relatively far from the root of the iris, consequently reducing the incidence of PAS and iris incarceration.

At the end of the surgery, we sutured the scleral flap tightly using adjustable sutures to avoid deformation during the early phases of recovery after CLASS; previous publications have referred to the use of nonsutured scleral flaps.¹⁸ Another benefit to our modified procedure was to keep the scleral lake closed to prevent inflammatory infiltration from the subconjunctival area and to ensure that the scleral lake remained well-shaped to maintain the space over the long term. Subsequently, and based on the IOP, we removed the sutures within the first 2 weeks after surgery to maintain smooth outflow during the scar formation stage. We also recommend the administration of miotic as a postoperative treatment to help prevent PAS.

The results of this study show that our interventions led to a significant decrease in IOP, with a significant reduction in medical therapy over the 2-year follow-up period (P<0.0001). These data are comparable with Skaat previous data, which showed a 46.7% reduction in IOP at 12 months,¹⁹ and the findings of a previous multicenter study that showed a reduction of mean IOP from 25.8 ± 5.4 mm Hg at baseline to 13.5 ± 4.1 and 13.0 ± 3.1 mm Hg at 12 and 24 months, respectively, following CLASS.¹⁰ In this respect, the mean preoperative IOP in our study was relatively higher, despite

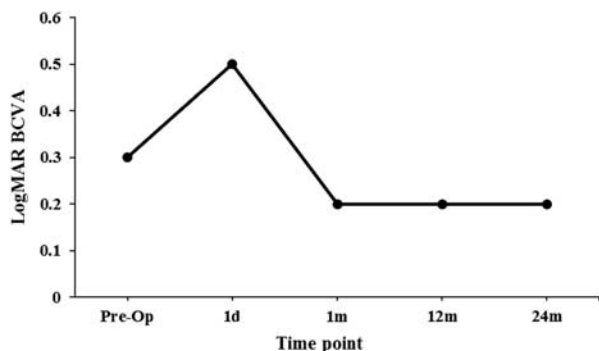


FIGURE 4. Intraocular pressure (IOP) at baseline, 1 day, 1 week and 1, 3, 6, 12, and 24 months postoperatively (pre-op).

TABLE 4. LogMAR BCVA at Baseline, 1 Day and 1, 12, and 24 Months Postoperatively

Timepoint	LogMAR BCVA [Median (Q1, Q3)]	LogMAR BCVA Reduction From Baseline [Median (Q1, Q3)]	P*
Preoperative	0.3 (0.1, 0.5)	—	—
1 d	0.5 (0.2, 0.9)	-0.1 (-0.4, 0.1)	0.0195
1 mo	0.2 (0.1, 0.4)	0.0 (0.0, 0.2)	0.0255
12 mo	0.2 (0.0, 0.4)	0.2 (0.0, 0.2)	0.0035
24 mo	0.2 (0.1, 0.4)	0.1 (0.0, 0.2)	0.0043

*Wilcoxon paired test between baseline and postbaseline data (The logMAR BCVA reduction from baseline was not normally distributed). Data underwent Bonferroni correction for multiple comparisons and the corrected significance was determined as 0.05/10=0.005.

BCVA indicates best corrected visual acuity; Q1, lower quartile; Q3, upper quartile.

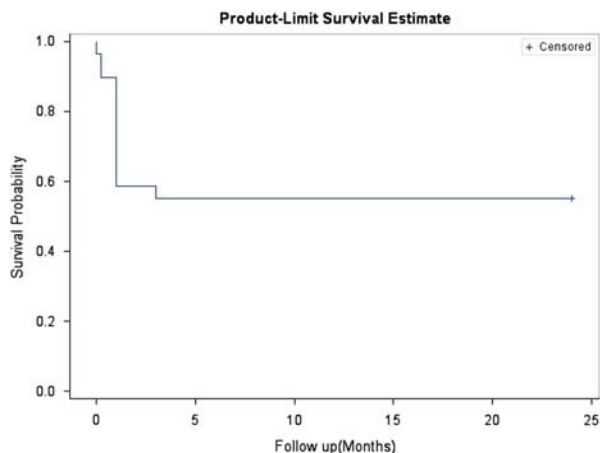


FIGURE 5. Kaplan-Meier curves of complete success 2 years after CO₂ laser-assisted sclerectomy surgery. Figure 5 can be viewed in color online at www.glaucomajournal.com.

the maximum use of hypotensive medications; consequently demonstrating a relatively more remarkable reduction in the IOP.

Here, a decrease in the number of hypotensive medications compared favorably with previous studies of CLASS.^{20,21} In addition, the visual acuity of our patients also remained fairly stable, with only a transitory fall during the first week postoperatively. In our study, the success rates in Chinese patients were consistent with those of a previous multicenter study,¹⁰ which showed a complete success rate of 60.2% and 57.9% and a qualified success rate of 79.6% and 91.2%, after 12 and 24 months, respectively.

Greifner et al¹³ previously stated that nearly 50% of patients studied developed iris incarceration, subsequently indicating that part or all of the filtering zone was blocked by iris prolapse, resulting in IOP elevation. Iris prolapse following LGP has been observed in several cases, although in some cases prolapse can occur without any previous intervention. It is vital to maintain an intact inner TM wall without inadvertently creating an opening; this practice helps to resist the excessive percolation of aqueous humor. In our study, we did not intraoperatively observe any remarkable perforation. We performed preventive LPI +ALPI within the percolation area, ablated further forwards the TDW but without penetration, and administered pilocarpine as postoperative treatment. As expected, these procedures effectively prevented incarceration during IOP fluctuations caused by high flow filtration and PAS after surgery.

TABLE 5. Ultrasound Biomicroscopy at 3, 12, and 24 Months Postoperatively

Timepoint	n (%)			
	Stable	Mild Diminution	Moderate Diminution	Severe Diminution
3 mo	15 (51.72)	10 (34.48)	3 (10.35)	1 (3.45)
12 mo	13 (44.83)	8 (27.59)	7 (24.14)	1 (3.44)
24 mo	11 (37.93)	9 (31.03)	7 (24.14)	2 (6.90)

Fisher exact test indicated that there was no significant difference ($P=0.78$) across the 3 timepoints.

We recommend careful postoperative examinations, including gonioscopy and UBM, to immediately recognize and treat fibrosis, prevent PAS or iris incarceration, and identify increased outflow resistance through the TDW. The latter can be treated using LGP; furthermore, we suggest that this is used as an adjunctive practice to transform the technique from a nonpenetrative approach into a microperforation approach to prolong the increased flow of aqueous humor. Published studies on LGP following NPDS report an LGP rate of 41% to 63%.^{22–24} The overall incidence of goniopuncture in this study was 51.72%. On the basis of our experience, LGP should be applied carefully in terms of the site and the number of laser shots to ensure that only a microperforation is created perioperatively. The prerequisite to this is to successfully create a TDW during the CLASS surgery. This practice may effectively reduce the rate of iris incarceration. As expected, the preservation of a thin and intact inner wall of the SC and TDW and the use of tightly adjusted sutures reduced the rate of complications, including a shallow or flat anterior chamber and hypotony, that are more commonly seen in classic penetrating glaucoma surgeries.

UBM after CLASS can reveal the status of the anterior chamber, perforation of the TDW and iris, the formation of a subsclear lake, overlying blebs, as well as PAS and iris incarceration. We also found that UBM images of the surgical area showed a characteristic “dolphin head sign,” as described previously by Abdelrahman et al²⁵; the presence of this sign indicates the success of deep sclerectomy. According to morphologic changes of the intrascleral lake, as visualized by UBM, we divided the cases into stable and differential levels of volume reduction. Here, there was no statistical significance detected between the state of the scleral lake (as imaged by UBM) and IOP after CLASS surgery. This suggested that following the formation of the intrascleral lake, IOP was not dependent upon the shape and size of the lake; instead, the existence of the scleral lake was more important. One interesting finding was that statistical significance was detected in preoperative IOP levels when compared between the stable and unstable scleral lake groups: IOP was higher in the stable group preoperatively. This significant difference was detected at both 12 and 24 months. The precise mechanisms responsible for this phenomenon remain unknown. One possible explanation may be that the high-velocity circulation of liquid arising from IOP before and after CLASS may result in a more stable intrascleral lake via a “washing effect.”

To the best of our knowledge, our study is the first prospective study to evaluate the safety and efficacy of a modified version of the CLASS procedure for Chinese patients with POAG. We also performed successive postoperative UBMs to confirm the status of the outflow pathway of aqueous humor. However, there were several limitations to our study that need to be considered. First, our study involved a relatively small number of patients, inevitably leading to error and bias. However, despite this, we demonstrated statistically significant reductions in the use of medications and IOP after surgery. Second, our study involved a nonrandomized and non-comparative series of patients. Consequently, there was no subgroup analysis to compare the precise effects of the procedures performed in addition to the traditional form of CLASS.

To conclude, a modified CLASS procedure combined with preventive laser iris management is an effective and safe approach to provide long-term care for Chinese POAG

patients. Future studies involving larger sample sizes and performed in a prospective and randomized/controlled manner may be needed to compare with other filtering glaucoma surgeries to identify a standardized CLASS procedure for Chinese patients.

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