· Clinical Research ·

Efficacy of combining posterior scleral contraction and intravitreal C_3F_8 injection in high myopia with macular hole retinal detachment

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Abstract

● **AIM:** To evaluate the efficacy and safety of combining posterior scleral contraction (PSC) with intravitreal perfluoropropane (C_3F_8) injection in high myopia with macular hole retinal detachment (MHRD).

● **METHODS:** A total of 22 participants (22 eyes) with high myopia [axial length (AL)≥26.5 mm] and MHRD who underwent PSC combined with intravitreal C_3F_8 injection, with at least 6mo of follow-up were retrospectively recruited. Outcome measures included best-corrected visual acuity (BCVA), AL, optical coherence tomography (OCT) findings, and adverse events. Retinal recovery was categorized as type I (macular hole bridging with retinal reattachment) or type II (reattachment without hole bridging).

● **RESULTS:** The mean age of participants was 62.1±8.8y and mean follow-up duration was 9.18±4.21mo. Complete retinal reattachment was observed in 11 eyes (50%) at postoperative day 1, 19 eyes (86.3%) at week 1, and all 22 eyes at month 1. Ten eyes (45.5%) achieved type I recovery and 12 eyes (54.5%) achieved type II. Mean BCVA improved from 1.68±0.84 logMAR before surgery to 1.21±0.65 logMAR after surgery (P<0.001), and AL was significantly reduced compared to baseline (29.07±2.05 *vs* 30.8±2.2 mm; P<0.001). No serious complications were reported.

● **CONCLUSION:** PSC combined with intravitreal C_3F_8 injection is a safe and effective treatment for MHRD in highly myopic eyes, especially for retinal detachment limited within the vascular arcade.

● **KEYWORDS:** posterior scleral contraction; retinal detachment; macular hole; myopia; C_3F_8

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INTRODUCTION

Pathologic myopia is a leading cause of irreversible visual impairment worldwide, particularly in East Asia, and is characterized by excessive axial elongation, posterior scleral staphyloma formation, and degenerative changes at the fundus. Among its vision-threatening complications, macular hole retinal detachment (MHRD) is particularly severe, accounting for approximately 1% to 4% of all rhegmatogenous retinal detachments[1]. The pathogenesis of MHRD in highly myopic eyes is often multifactorial: progressive axial elongation, thinning of the choroid and retina, and the formation of posterior staphyloma collectively exacerbate both tangential and anteroposterior traction at the macula, leading to full-thickness macular hole formation and subsequent subretinal fluid accumulation.

Traditionally, pars plana vitrectomy (PPV) combined with internal limiting membrane (ILM) peeling and gas or silicone oil tamponade has been the predominant strategy for repairing MHRD[2-3]. However, ILM peeling in highly myopic eyes can be complicated by pronounced chorioretinal atrophy, thin retinal layers, and posterior staphyloma. These factors may render membrane peeling challenging and elevate the risk of surgical complications, contributing to comparatively low rates of macular hole closure and retinal reattachment[4-5]. Consequently, external surgical approaches—including macular buckling, scleral imbrication, and posterior scleral contraction (PSC)—have gained attention for their potential to directly modify the contour of the posterior pole and provide more stable anatomic outcomes[6-13].

In particular, PSC has demonstrated promising outcomes in improving best-corrected visual acuity (BCVA) and achieving anatomical recovery for MHRD in highly myopic eyes[6-7]. Nevertheless, complete retinal reattachment following PSC alone can be relatively slow—taking 6 to 12mo in many cases—especially when retinal detachment extends beyond the macular region[6-7]. This limitation has prompted interest in combining PSC with other minimally invasive yet effective adjunctive therapies. Intravitreal gas injection, first described by Miyake[14-15] in 1984, offers a simpler alternative to PPV for selected MHRD cases and has been reported to achieve successful retinal reattachment in 15 of 18 patients. Perfluoropropane (C_3F_8) gas, in particular, provides a long-acting tamponade effect, aiding in apposition of the macular hole edges and counteracting the persistent tractional forces associated with high myopia.

Given these observations, we hypothesized that a combined approach of PSC and intravitreal C_3F_8 injection would overcome some of the limitations of each technique alone and potentially yield more favorable outcomes in highly myopic MHRD. To test this hypothesis, the present study aimed to comprehensively evaluate postoperative visual acuity, rates of retinal reattachment, and macular hole closure, as well as to document any complications arising from the combined procedure. By elucidating the safety and efficacy of this hybrid strategy, we seek to offer an alternative management approach for MHRD in highly myopic eyes, potentially improving prognostic outcomes in this challenging patient population.

PARTICIPANTS AND METHODS

Ethical Approval The study was approved by the ethics committee of the Eye Hospital of Wenzhou Medical University (No.2024-161-X-01) and adhered to the principles set forth in the Declaration of Helsinki. Written informed consent was obtained from all participants.

Participants This retrospective study patients with high myopia and MHRD who underwent combined PSC and intravitreal C_3F_8 injection at the Eye Hospital of Wenzhou Medical University between May 2022 and September 2024. High myopia was defined as an axial length (AL)≥26.5 mm. MHRD was diagnosed through optical coherence tomography (OCT) and B-scan ultrasonography. Patients were excluded if they presented with retinal detachment due to idiopathic or traumatic macular holes, retinal detachment caused by other types of retinal tears, choroidal detachment, proliferative vitreoretinopathy, or glaucoma. Additionally, individuals with fewer than 6mo of postoperative follow-up were excluded.

All MHRD eyes were classified as Stage 4c according to the Myopic Traction Maculopathy Staging System[16], indicating macular detachment with a full-thickness macular hole. Retinal detachment was further categorized based on a previously established classification system[17]: Type 1, detachment limited within the vascular arcade; Type 2, detachment extending beyond the vascular arcade; Type 3, total detachment.

Surgical Procedure The details of the PSC technique have been previously described[6]. In this study, all procedures were performed under general anesthesia. After sterilization of the conjunctival sac with povidone-iodine solution, the bulbar conjunctiva was incised along the limbus from the inferonasal to the superotemporal quadrant (covering approximately 220°). The inferior and lateral rectus muscles were gently isolated and suspended, and the inferior oblique muscle in the temporal lower quadrant was similarly identified.

The primary method of PSC surgery includes draining a small volume of aqueous humor from the anterior chamber, tightening a strip, and shortening the AL, effectively pushing the posterior sclera inward. This alleviates both internal and external traction on the retina. To briefly summarize, a dural strip crosslinked with genipin is prepared and implanted to create a posterior support or "pouch" around the macula. This strip is navigated through the orbital muscles, with one end fixed at the edge of the medial rectus after passing through the inferior rectus, while the other end is tunneled under the lateral rectus muscle. The nasal-inferior end of the strip is then sutured into place. Subsequently, additional aqueous humor, approximately 2-4 drops, is drained from the anterior chamber to facilitate the maneuvering of the temporal-superior end of the strip. This end is moved forward about 1.5 times the designed amount for AL shortening and then sutured to help maintain normal intraocular pressure. To further adjust intraocular pressure and soften the globe, a 1-mL needle is inserted into the anterior chamber to release a small volume of aqueous humor. These comprehensive surgical steps aim to correct the structural distortions associated with severe myopia and stabilize the retinal environment.

Before the intravitreal injection of C_3F_8 gas, additional aqueous humor was drained from the anterior chamber to soften the eye. Following this, C_3F_8 gas was injected through the pars plana, approximately 3.5–4.0 mm from the limbus, without performing a vitrectomy. The volume of gas administered varied depending on the patient's lens status: phakic eyes typically received 0.2–0.3 mL of C_3F_8, whereas aphakic eyes received 0.4–0.5 mL to achieve the desired tamponade effect. It was crucial to monitor intraocular pressure both during and immediately after the injection. If the intraocular pressure was high, additional aqueous humor could be released drop by drop until the pressure normalized. Subsequently, the free end of the dural strip was anchored near the insertion of the superior rectus, ensuring it did not compress the vortex veins and provided adequate posterior support. The procedure concluded with the closure of the conjunctival incision using interrupted sutures.

Upon completion of surgery, patients were instructed to maintain a face-down or head-low position for at least 1wk. This positioning was emphasized to facilitate macular hole closure and retinal reattachment by maximizing the tamponade effect of the intravitreal C_3F_8. Visual acuity and visual field should be examined as soon as possible after recovery from anesthesia. If the optic nerve is compressed, further symptoms may occur, such as visual impairment, visual field loss (especially upper visual field loss), and abnormal response to light.

If necessary, adjust the strip within a day or two after surgery. Re-shortening/re-lengthening of the amount of AL is estimated based on postoperative (post-operative) AL and OCT images. Adults may be reoperated under local anesthesia. We re-opened the original incision, unwound the sutures at the upper temporal end of the strip, re-extended/re-tightened the upper temporal end of the strip (the strip would be re-extended/re-tightened about 1.5 mm for every 1 mm of AL extension/further shortening), and then reconstructed and re-fixed the strip. To tighten the strip, a few drops of body fluid need to be discharged from the front chamber before tightening the strip and shortening the AL.

Follow-up and Outcome Measures All patients were evaluated on postoperative days 1 and 7 before being discharged from hospital. We also advised the patients to attend postoperative follow-ups at 1, 3, 6, 12, and 24mo. Assessments included comprehensive ophthalmic examinations, such as BCVA, intraocular pressure (IOP) measurement, slit-lamp examination, wide-field fundus photography (Zeiss, Oberkochen, Germany), and B-scan ultrasonography (B-scan Cine Scan, Quantel Medical). BCVA was recorded using the logarithm of the minimum angle of resolution (logMAR) scale; finger-counting vision was assigned a logMAR value of 2.0, and hand-motion vision was recorded as logMAR 3.0.

AL was measured using the IOLMaster (Zeiss, Oberkochen, Germany). Macular status was evaluated by either Optovue OCT (Fremont, CA, USA) or Spectralis SD-OCT (Heidelberg Engineering, Germany), based on availability. The primary clinical outcomes were macular hole closure and retinal reattachment on OCT. Postoperative anatomical outcomes were further categorized according to previous studies[18-19]. Type I recovery: the two edges of the macular hole were bridged with retinal reattachment. Type II recovery: the two edges of the macular hole exhibited retinal reattachment but were not bridged. No recovery: the macular hole remained unbridged with persistent retinal detachment.

Any adverse events, including raised intraocular pressure, diplopia, fundus hemorrhage, optic disc edema, or other complications, were documented throughout the follow-up period.

Statistical Analysis Descriptive statistics were used for both continuous and categorical data, with continuous variables expressed as mean±standard deviation (SD) and categorical variables reported as counts and/or percentages. For comparisons of BCVA between the Type I and Type II recovery groups, analysis of covariance was performed to adjust for potential confounding factors. Changes in BCVA and AL from baseline to the final follow-up within each group were assessed using paired *t*-tests. A *P*-value<0.05 was considered statistically significant throughout all analyses. Statistical analyses were conducted using R statistical software version 4.4.1 and IBM SPSS Statistics version 22.0 (IBM Corp., Armonk, NY, USA).

RESULTS

Patient Demographics A total of 22 patients (22 eyes) were included in this study. Their mean age was 62.1±8.8y (range, 42–79y) and the mean follow-up duration was 9.18±4.21mo. According to the retinal detachment classification[17], 20 eyes were classified as type 1, and 2 eyes were classified as type 2. An overview of patient demographics was shown in Table 1.

Retinal Reattachment and Macular Hole Closure All study subjects (*n*=22) were examined at postoperative day 1, week 1, and month 1. The rate of complete or near-complete retinal reattachment at these follow-up time points were 50% (11 eyes) on the first postoperative day, 86.3% (19 eyes) at one week, and 100% (22 eyes) at one month. Based on the anatomic classification for macular hole/retinal outcomes[18-19], 10 eyes (45.5%) achieved type I recovery (two segments of the macular hole bridged with retinal reattachment), and 12 eyes (54.5%) achieved type II recovery (two segments of the macular hole exhibited retinal reattachment but were not bridged) at the final follow-up, one eye still had a small amount of fluid under the retina.

Axial Length Changes The mean AL was 30.8±2.2 mm preoperatively, decreasing significantly to 29.07±2.05 mm by the last follow-up visit (*t*=11.32, *P*<0.001). The mean change in AL was −1.75±0.72 mm, reflecting a substantial scleral contraction effect (Table 1).

Visual Acuity Outcomes Mean logMAR BCVA improved significantly, from 1.68±0.84 before surgery to 1.21±0.65 at the last follow-up (*t*=4.95, *P*<0.001). BCVA improved in 19 eyes (86.4%) and remained stable in 3 eyes (13.6%). In both type I and type II recovery groups, BCVA was significantly better than the preoperative level at the last follow-up (*P*<0.001). The magnitude of improvement in BCVA did not differ significantly between the two recovery types (type I: −0.439±0.113 *vs* type II: −0.501±0.103; *P*=0.684).

Complications and Safety Outcomes Among all study subjects, three patients experienced elevated IOP (26–28 mm Hg) within the first postoperative week. Both cases' IOP normalized

Table 1 Patient demographics and clinical outcomes at different time points

Parameters	OD (*n*=13)	OS (*n*=9)	Total eyes (*n*=22)
Baseline			
Age (y)	60.8±10.2	64.0±6.6	62.1±8.8
Baseline BCVA	1.7±0.8	1.6±0.9	1.68±0.84
Axial length (mm)	30.9±2.4	30.6±2.2	30.8±2.2
Sex (female, %)	11 (84.61)	9 (100)	20 (90.9)
Lens status (phakic, %)	9 (69.23)	5 (55.55)	14 (63.6)
MHRD type (type 1, %)	12 (92.3)	8 (88.88)	20 (90.9)
MHRD type (type 2, %)	1 (7.6)	1 (11.1)	2 (9)
MHRD type (type 3, %)	0	0	0
Final follow-up			
Follow-up duration (mo)	8.1±2.3	10.7±5.7	9.18±4.21
BCVA	1.3±0.7	1.0±0.5	1.21±0.65
Axial length (mm)	29.2±2.2	28.7±1.7	29.07±2.05
Lens surgery (%)	1 (7.6)	1 (11.1)	2 (9)
Macular hole (type 1, %)	7 (53.8)	3 (33.3)	10 (45.5)
Retinal reattachment (%)	13 (100)	9 (100)	22 (100)

BCVA: Best corrected visual acuity; MHRD: Macular hole retinal detachment; OD: Right eye; OS: Left eye.

Table 2 Influencing factors for clinical outcomes

Parameters	*β*	Standard error	Statistics	*P*
Macular hole closure				
Sex	-0.67	1.86	-0.36	0.72
Age (y)	-0.021	0.065	-0.33	0.74
Eye	-1.37	1.12	-1.22	0.22
Baseline BCVA	0.14	0.80	0.18	0.86
Baseline AL (mm)	0.029	0.33	0.088	0.93
MHRD (type 2)	0.55	1.88	0.29	0.77
BCVA				
Sex	-0.10	0.232	-0.44	0.67
Age (y)	0.00	0.008	0.31	0.76
Eye	-0.15	0.133	-1.09	0.30
Baseline BCVA	0.85	0.095	8.89	1.26E-06
Baseline AL (mm)	0.08	0.040	2.03	0.066
MHRD (type 2)	-0.24	0.234	-1.03	0.32
AL				
Sex	-0.49	0.549	-0.90	0.387
Age (y)	-0.020	0.019	-1.05	0.315
Eye	0.10	0.315	0.30	0.767
Baseline BCVA	-0.14	0.226	-0.60	0.560
Baseline AL (mm)	0.81	0.094	8.65	1.68E-06
MHRD (type 2)	0.051	0.553	0.091	0.929

AL: Axial length; BCVA: Best corrected visual acuity; MHRD: Macular hole retinal detachment.

after a 3-day course of twice-daily topical timolol eye drops. Two eyes underwent phacoemulsification with intraocular lens implantation 6mo after surgery due to progressive cataract. No other serious complications were observed throughout the follow-up period, including prolonged hypotony, persistent diplopia, or optic disc swelling. Cases demonstrating successful surgical outcomes and macular hole closure were demonstrated in Figures 1 and 2, respectively.

Factors Associated with the Clinical Outcomes We conducted further analyses to identify potential predictors of clinical outcomes, as detailed in Table 2. Our findings indicated that baseline BCVA and baseline AL were significant predictors of BCVA and AL at the final follow-up, respectively ($P<0.05$). However, we did not identify any significant predictors for macular hole closure at the final follow-up ($P>0.05$).

DISCUSSION

Our study evaluated 22 eyes in 22 patients with highly myopic MHRD undergoing PSC combined with intravitreal C_3F_8 injection. All eyes achieved retinal reattachment within 1mo postoperatively, and the mean AL decreased by 1.75±0.72 mm. These findings suggest that the external support provided by PSC and the internal tamponade exerted by C_3F_8 effectively counteract both anteroposterior and tangential tractional forces, facilitating rapid anatomic recovery in MHRD.

Retinal reattachment rates following PPV for MHRD with high myopia vary widely, ranging from 81% to 100%[2-3,20-22]. In contrast, macular buckling achieves reattachment rates between 88% and 96%[9,23], while PSC alone has been reported to yield rates as high as 98%[6]. Our study's 100% reattachment rate at 1mo is consistent with the high efficacy of external buckling-type procedures in highly myopic eyes. Previous research has highlighted that PSC shortens AL, remodels the disproportion between the retina and sclera, and relieves anteroposterior traction, ultimately favoring macular hole closure[6-7].

In highly myopic eyes, progressive axial elongation distorts posterior segment structures, leading to the formation of scleral staphyloma. PSC effectively counteracts this elongation by exerting an inward push on the posterior pole. This action decreases AL, remodels the disproportion between the retina and sclera, and alleviates anteroposterior traction. Such modifications not only reduce the traction exerted by the vitreous and internal limiting membrane on the retina but also shorten the distance between the retinal neuroepithelial layer and the pigment epithelial layer. When combined with an intravitreal injection of C_3F_8, this strategy significantly enhances therapeutic outcomes. C_3F_8 injection introduces an internal tamponade, which, when aided by face-down or head-low positioning, exerts an outward force that assists in retinal flattening and directly applies pressure to seal the macular hole. This internal tamponade, coupled with PSC, ensures direct contact between the gas bubble and the macular region, preventing the ingress of liquefied vitreous through the hole. It promotes rapid absorption of subretinal fluid and enables the retinal pigment epithelium and choroidal capillary pump to function effectively, thereby facilitating the reattachment of the retina. Together, these mechanisms underscore the promising effects of combining PSC with C_3F_8 injection in the treatment

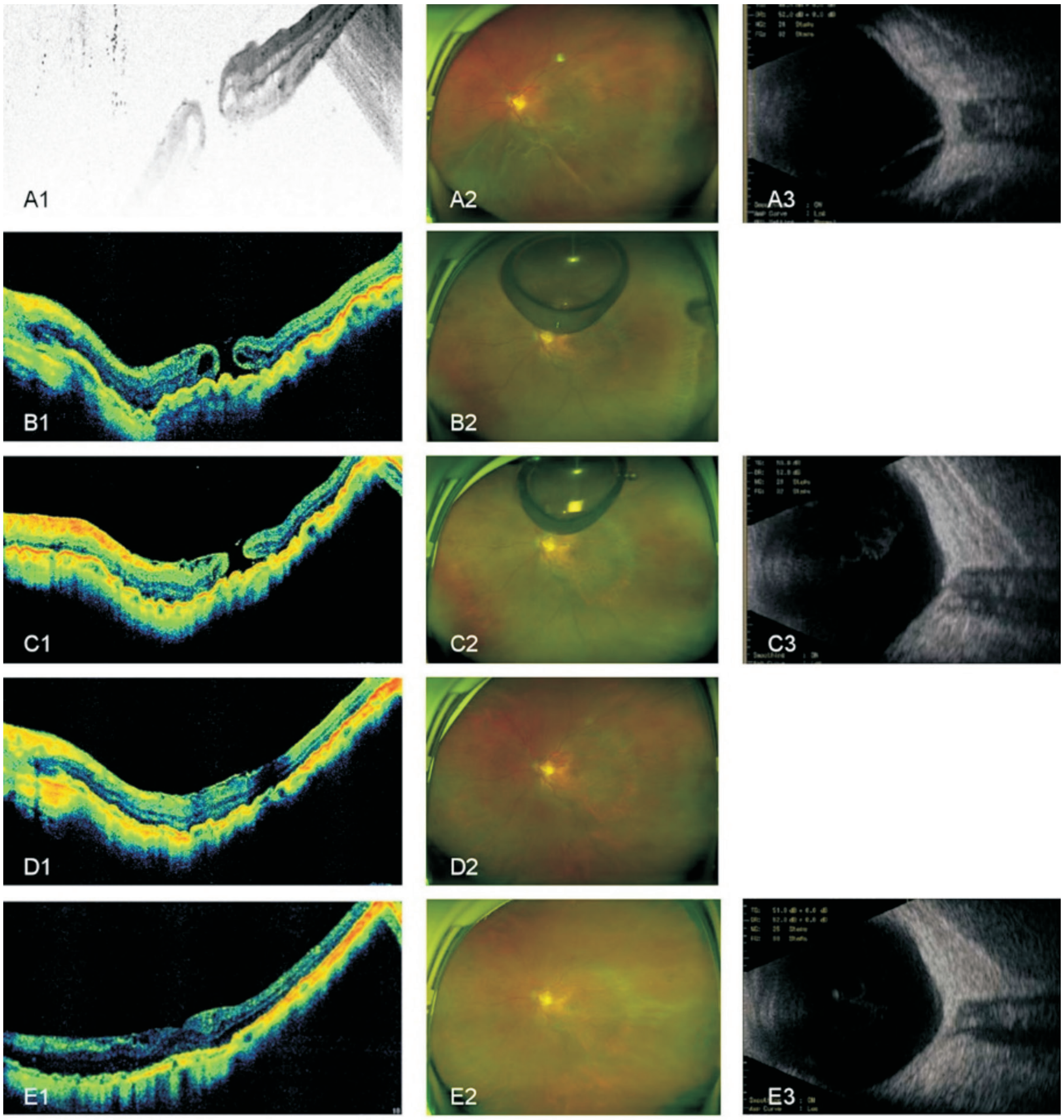

Figure 1 Representative case 1 with the longest follow-up time-24mo Preoperatively, optical coherence tomography (OCT; A1) showed a macular hole with retinal detachment, widefield fundus photography (A2) reveals a grayish elevation of the retina in the temporal, inferior, and inferonasal regions, and B-scan ultrasound (A3) confirms the detachment. On postoperative day 1, the retina appears essentially reattached on OCT, although the macular hole remains unclosed (B1), and widefield fundus photography (B2) showed a flattened retina with a visible perfluoropropane (C_3F_8) gas bubble. At 1wk postoperatively, OCT still indicates an unclosed macular hole despite retinal reattachment (C1), widefield imaging shows a reduced gas bubble and a flattened retina (C2), and B-scan ultrasound confirms the flattened retina (C3). By 1mo, OCT demonstrates a reattached retina with a closed macular hole (D1), corroborated by widefield imaging (D2). At 24mo, OCT confirms stable retinal reattachment and macular hole closure (E1), widefield imaging shows the retina remains flat (E2), and B-scan ultrasound verifies persistent retinal flattening (E3).

of macular holes, offering a comprehensive approach to addressing both internal and external retinal stresses.

In our cohort, type I recovery (bridged macular hole edges with complete reattachment) was observed in 10 eyes (45.5%), and type II recovery (reattached edges without bridging) in 12 eyes (54.5%). These proportions differ from the rates reported by Ye *et al*[6], 63.0% in type I and 35.6% in type II, possibly due to variations in study design, population, and macular hole characteristics. By contrast, reported closure rates after PPV vary from 25% to 100%[2-3,20-22], with some studies finding higher closure rates when using an inverted ILM flap[20-22]. Our results indicated that while PSC plus intravitreal C_3F_8 is effective at achieving anatomical closure, concurrent tangential forces or large hole diameters may still hinder bridging of the hole edges, highlighting the potential necessity of supplementary procedures (*e.g.*, PPV with inverted ILM flap) in select cases[24-25]. Nonetheless, eyes that had type II recovery remained stable without re-detachment over follow-

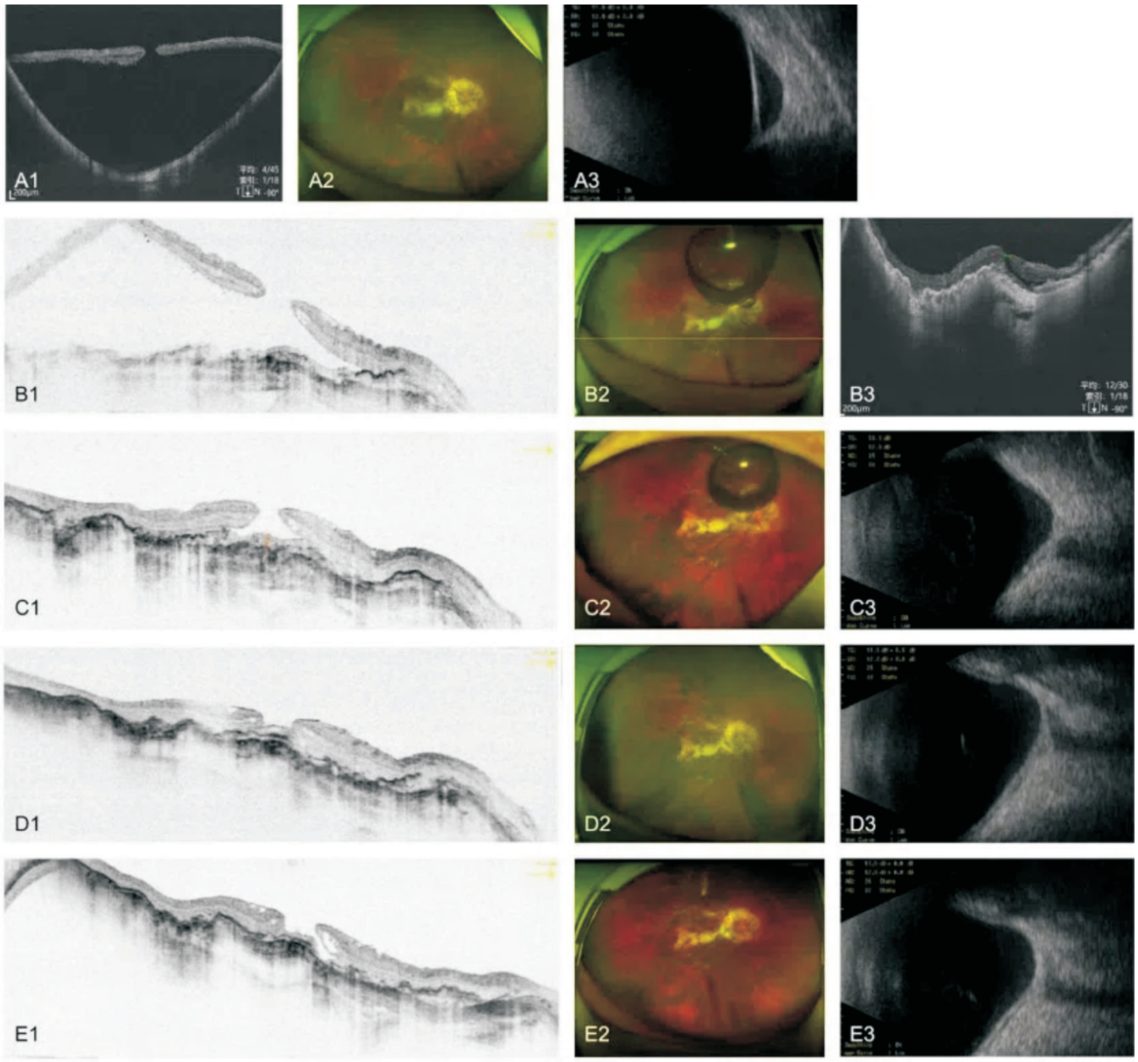

Figure 2 Representative case 2 Preoperatively, optical coherence tomography (OCT; A1) showed a macular hole with retinal detachment, widefield fundus photography (A2) reveals a grayish retinal elevation within the vascular arcade, and B-scan ultrasound (A3) confirms partial retinal detachment. On postoperative day 1, OCT (B1) indicated a reduced extent and height of the detachment, and widefield imaging (B2) shows a large perfluoropropane (C_3F_8) gas bubble with less pronounced retinal elevation. By postoperative day 3, OCT (B3) confirmed that the retina has reattached. At 1wk, OCT (C1) still showed an unclosed macular hole despite retinal reattachment, while widefield imaging (C2) demonstrated a smaller gas bubble and a flattened retina within the vascular arcade; B-scan ultrasound (C3) corroborated these findings. At 1mo, OCT (D1) showed a reattached retina with type II macular hole closure; widefield imaging (D2) and B-scan ultrasound (D3) further confirm retinal flattening. By 6mo, OCT (E1) indicated stable reattachment with persistent type II hole closure, and widefield imaging (E2) and B-scan ultrasound (E3) both show a flat retina.

up, suggesting that PSC adequately supports the posterior pole even if the hole edges do not fully bridge.

Best-corrected visual acuity improved significantly after surgery, consistent with prior reports[2,6-7,9,21]. Notably, BCVA failed to improve in three patients, likely due to irreversible pathologic changes, such as chorioretinal atrophy and prolonged macular detachment leading to insufficient nutrient supply at the fovea[7]. Importantly, both type I and type II recovery groups showed significant visual gains, and there was no statistically significant difference in BCVA improvement between these two groups. These findings underscore that even when the macular hole edges remain unbridged (type II), the overall restoration of retinal anatomy can stabilize retinal function and yield visual benefit.

Regarding the safety of the combined surgery procedures, three patients experienced transient IOP elevation which resolved with short-term topical timolol therapy. No other severe complications were observed. These indicated that the combined surgery is well-tolerated in highly myopic eyes with MHRD.

Despite promising findings, our study had a relatively small sample size, a single center source, a retrospective design, and a short follow-up period. The insignificant associations between the baseline features and the macular hole closure could be due to limited sample size which lead to insufficient statistical power in the analysis. An inherent limitation of our study is the predominance of type 1 retinal detachment cases within our sample, which primarily consist of detachments confined within the vascular arcade. This skewed distribution might introduce bias in assessing the efficacy of the combined treatment of PSC with intravitreal C_3F_8 injection, as it limits our findings' applicability to more complex cases, such as type 2 and type 3 retinal detachments that extend beyond the vascular arcade. These types are more frequently managed with vitrectomy due to their severity and complexity. Future studies should aim to include a more diverse range of retinal detachment types to provide a more balanced evaluation and determine the generalizability of this treatment approach across different severity levels of retinal detachment. This would help in establishing the method's efficacy more comprehensively and guide clinical decision-making for a broader spectrum of cases. Future research employing larger patient cohorts and longer follow-up intervals is warranted to confirm the long-term efficacy and safety of this combined approach. Additionally, prospective and direct comparative studies between vitrectomy-based interventions and PSC combined with intravitreal C_3F_8 would help clarify their relative efficacies in treating MHRD in highly myopic eyes. Another notable limitation of our study is the use of dura mater and genipin in the surgical technique for managing myopic traction maculopathy. These materials, while effective, are not universally available and may present challenges in terms of accessibility and regulatory approval across different regions. This limitation could restrict the feasibility and widespread adoption of our proposed surgical method. Recognizing this, it becomes essential to explore alternative materials and techniques that maintain the efficacy of the treatment while enhancing its availability. Such alternatives could include the use of more commonly available surgical materials or simplified procedures that could be adopted more broadly, thereby expanding the potential impact of our findings in clinical practice.

In summary, our results suggest that PSC combined with intravitreal C_3F_8 injection is a safe and effective option for treating MHRD in highly myopic eyes, especially for retinal detachment limited within the vascular arcade (type 1 detachment). This combined procedure facilitates rapid and stable retinal reattachment, reduces AL, and yields significant visual acuity improvement with minimal complications. With further validation in large-scale, long-term studies, this combined procedure may emerge as an important alternative or adjunct to conventional vitrectomy techniques in managing challenging cases of MHRD.

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Data Availability: Data can be made available from the corresponding author at zsq@mail.eye.ac.cn on a reasonable request.

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