· Clinical Research ·

Perfluorocarbon liquid-assisted inverted multilayer internal limiting membrane flaps covering for macular hole retinal detachment in high myopia with axial length ≥30 mm

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Abstract

● **AIM:** To evaluate the surgical outcomes of the perfluorocarbon liquid (PFCL)-assisted inverted multilayer internal limiting membrane (ILM) flaps covering technique in macular hole retinal detachment (MHRD) in high myopia with axial length (AL) ≥30 mm.

● **METHODS:** In this retrospective, interventional, consecutive comparative study, 44 MHRD eyes were divided into two groups: the PFCL-assisted inverted multilayer ILM flaps covering technique group (Group 1, 21 eyes) and the ILM peeling group (Group 2, 23 eyes). The follow-up period was >12mo. Postoperative outcomes, including retinal reattachment, macular hole (MH) closure, and best-corrected visual acuity (BCVA), were assessed. Statistical analysis using the Mann–Whitney *U* test and Fisher's exact test was conducted to compare differences between groups.

● **RESULTS:** There were no statistically significant differences in baseline preoperative clinical characteristics, including age, sex, AL, diopters, duration of symptom, lens status, posterior staphyloma presence and extent of RD. Retinal reattachment rates were higher in Group 1 (90.5%) than in Group 2 (82.6%), without statistical significance (P=0.667). MH closure rates were significantly higher in Group 1 (85.7%) than in Group 2 (17.4%; P<0.001). The Group-1 BCVA (logMAR) improved significantly from 2.13±0.91 preoperatively to 1.21±0.66 postoperatively (P=0.026). The Group 2 BCVA improved significantly from 1.91±0.53 preoperatively to 1.19±0.41 postoperatively (P=0.032). However, there were no significant differences in visual-acuity improvement between groups (P=0.460).

● **CONCLUSION:** This technique offers a more effective approach for improving MH closure rates and postoperative visual function in MHRD with AL≥30 mm in high myopia.

● **KEYWORDS:** high myopia; inverted multilayer internal limiting membrane flaps covering; macular hole retinal detachment; perfluorocarbon liquid

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INTRODUCTION

Retinal detachment (RD) caused by macular hole (MH) is a serious complication most commonly associated with high myopia, often leading to central vision loss[1]. High myopic macular hole retinal detachment (MHRD) pathogenesis is primarily attributed to preretinal centrifugal and tangential forces resulting from incomplete posterior vitreous detachment (PVD), vitreomacular traction, retinal epiretinal membrane (ERM), and perpendicular traction caused by axial elongation and progressive posterior scleral staphyloma[2-3]. Owing to the influence of severe posterior scleral staphyloma, high myopic MHRD is more challenging to repair than simple idiopathic MH. If the MH does not close, the likelihood of RD recurrence increases[4].

With the global rise in myopia prevalence, some studies predict that the number of individuals with high myopia leading to vision loss will increase sevenfold from 2000 to 2050. By 2050, an estimated 938 million individuals worldwide will have high myopia, accounting for 9.8% of the global population. Consequently, complications such as high myopic MHRD will increase[5]. Currently, pars plana vitrectomy (PPV) and macular buckling are the primary surgical techniques used for MHRD in high myopia patients. Since the introduction of PPV, the classic surgical treatment for high myopic MHRD involves vitrectomy combined with internal limiting membrane (ILM) peeling[6]. To enhance postoperative MH closure, techniques such as inverted ILM flap, ILM covering, and autologous blood covering are progressively applied in the surgical treatment of high myopic MHRD[7-9]. In cases where insufficient ILM is available or it is previously peeled, alternative methods—such as autologous lens capsule grafts, amniotic membrane grafts, autologous retinal neuroepithelial layer grafts, Descemet's membrane grafts—have been reported for treating MHRD in high myopia[10-14]. Owing to severe posterior scleral staphyloma and elongated axial length (AL), high myopia patients with MHRD experience insufficient retinal flexibility to counteract the tension at the MH after ILM peeling alone. Additionally, chorioretinal atrophy and compromised repair capabilities of the retinal pigment epithelium (RPE) in these patients lead to significant challenges in achieving MH closure with only ILM peeling. The MH closure rate in high myopia eyes with an AL of ≥30.0 mm is 0 after PPV with ILM peeling and gas tamponade, suggesting that an AL of ≥30.0 mm raises anatomical failure risks in MH surgery[15]. For high myopic MHRD during the initial surgery, accurately covering the MH using ILM flap when the retina is fluttering in the macular area and ensuring retinal reattachment remain considerable challenges. This study aims to evaluate the effectiveness of perfluorocarbon liquid (PFCL)-assisted inverted multilayer ILM flaps covering in the treatment of MHRD in high myopia and to explore a safer and more effective surgical approach compared to classic ILM peeling.

PARTICIPANTS AND METHODS

Ethical Approval This study adhered to the Declaration of Helsinki and received approval from the Ethics Committee of Xi'an People's Hospital (Xi'an Fourth Hospital) (ethics approval number 20200025). Informed consent was obtained from all patients after a thorough explanation of the study.

This retrospective, interventional, and consecutive case series was conducted at Xi'an People's Hospital (Xi'an Fourth Hospital) from June 2021 to June 2023. In total, 44 patients (44 eyes) with high myopia-associated MHRD were included. The follow-up period extended to at least 12mo post-surgery.

The inclusion criteria included 1) high myopia with an AL of ≥30 mm; 2) MHRD presence; 3) age: 18-80y. Exclusion criteria included 1) secondary MH caused by RD due to peripheral retinal tears; 2) previous ocular surgery aside from cataract surgery, particularly PPV or scleral buckling; 3) history of ocular trauma, inflammatory eye diseases, or ocular tumors; 4) glaucoma, retinal vein occlusion, retinal artery occlusion and other retinal disease or optic nerve disease.

All patients underwent comprehensive ophthalmic examinations preoperatively, including best-corrected visual acuity (BCVA), intraocular pressure (IOP), slit-lamp examination, indirect ophthalmoscopy, and AL measurement *via* ocular ultrasonography (Aviso; Quantel Medical, Inc, Bozeman, MT, USA). Optical coherence tomography (OCT) performed with a Heidelburg Spectralis-OCT system (Heidelburg Engineering, Germany); fundus photography was performed using the Panoramic Ophthalmoscope-Daytona (P200T) (OPTOS, UK). Postoperative examination, including BCVA, slit-lamp examination, IOP, OCT and fundus photography, were conducted at 1, 3, 6, and 12mo post-surgery. OCT assessment evaluated MH closure and foveal microstructures recovery, including the external limiting membrane (ELM) and ellipsoidzone (EZ). MH closure was defined as the absence of retina defect at the fovea, while retinal reattachment was indicated by complete subretinal fluid (SRF) absorption and total reattachment of the neurosensory retina to the RPE. Postoperative retinal reattachment rate was defined as retinal reattachment within 1mo post-surgery, with recurrent RD defined by initial reattachment within 1mo, followed by detachment of the sensory retina from the RPE at a later stage.

Data collected from medical records included baseline demographic information, preoperative ocular characteristics, surgical techniques, postoperative outcomes, complications, subsequent management, and reoperation.

Surgical Procedures Patients were divided into the study (Group 1) and control (Group 2) groups based on surgical approach. The 21 patients in Group 1 received PFCL-assisted inverted multilayer ILM flaps covering; 23 patients in Group 2 underwent ILM peeling. All procedures were performed by a single experienced retinal surgeon.

For patients with lens opacity obstructing fundus observation, phacoemulsification with intraocular lens implantation was performed prior to PPV. Subsequently, a standard 23-guage or 25-guage vitrectomy (Alcon Constellation® vision system, Alcon, Fort Worth, TX, USA) was conducted. Anterior and central vitreous were removed; complete PVD was induced with triamcinolone acetonide aqueous suspension staining. The posterior vitreous cortex in highly myopia eyes typically adhered closely to the retina. Complete peeling of the posterior vitreous cortex and the macular ERM (if present), using ocular forceps, may have been required. Peripheral vitrectomy was then performed, applying top pressure to the peripheral scleral with assistance. If areas of peripheral degermation or retinal tears were observed, retinal photocoagulation is performed to surround these areas. Indocyanine green (ICG, 1.25 mg/mL, Eisai, Inc., Shenyang, China) was injected into the vitreous cavity to stain the ILM. Subsequent surgical steps varied depending on the group.

Table 1 Baseline characteristics of all patients with high myopic MHRD mean±SD

Variable	Inverted multilayer ILM flaps covering (*n*=21)	ILM peeling (*n*=23)	*P*
Age (y)	59.80±8.76	54.40±5.66	0.222
Sex (female/male)	18/3	20/3	0.905
Axial length (mm)	31.63±1.86	31.85±1.30	0.667
Refractive error (D)	15.34±5.27	15.76±4.10	0.721
Duration of symptom (mo)	1.35±0.60	1.75±1.05	0.582
Preoperative lens status (phakia/pseudophakia)	17/4	20/3	0.693
Posterior staphyloma (present/absent)	19/2	20/3	1.000
Extent of RD (within vascular arcade/beyond vascular arcade)	18/3	20/3	0.905

MHRD: Macular hole retinal detachment; ILM: Internal limiting membrane; SD: Standard deviation; RD: Retinal detachment.

Control group ILM peeling within upper and lower vascular arcades at the posterior pole was performed with Alcon Grieshaber Revolution® DSP ILM forceps (Alcon, Fort Worth, TX, USA). After fluid-gas exchange, SRF was gently aspirated from the MH using flute needle to minimize macular disturbance. Once SRF was completely drained, the vitreous cavity was filled with silicone oil.

Study group Following ICG staining, fluid-gas exchange was conducted; SRF was aspirated from the MH using a flute needle until the retina was flat. PFCL was gently injected into the vitreous cavity to flatten the posterior pole. The gas above the PFCL was replaced with balanced salt solution through fluid-gas exchange. Under the PFCL, the ILM in areas distant from the MH was peeled to the margins of the vascular arcade with ILM forceps and discarded. The ILM around the MH was retained, and the width of the retained ILM was approximately 1-2 times the diameter of the MH. The retained ILM was peeled centripetally from upper, lower, nasal and temporal sides, creating inverted multilayer ILM flaps to cover the MH. Fluid-gas exchange was repeated to replace the balanced salt solution and PFCL at the optic disc and temporal macula, ensuring the inverted multilayer ILM flaps remained over the MH. The retina was checked for flatness, and the ILM flaps were confirmed to be positioned over the MH; thereafter, silicone oil was injected to fill the vitreous cavity. Participants maintained a face-down position for at least 1mo post-surgery, with silicone oil remaining intraocularly for at least 3mo unless IOP increased uncontrollably.

Statistical Analysis BCVAs for all participants were converted from Snellen visual acuity to logarithm of the minimum resolution (logMAR) visual acuity. 20/2000 is equivalent to counting fingers at a 2-feet distance; 20/20 000 is equivalent to hand motion at a 2-feet distance. Continuous variables that did not demonstrate a normal distribution, such as age, AL, diopters, symptom duration, and preoperative and postoperative logMAR BCVA, were presented as mean±standard deviation and compared using the Mann-Whitney *U* test. The Chi-square test or Fisher's exact test was applied for categorical variables due to the sample size and the expected frequencies, including preoperative sex, lens status, presence of staphyloma, postoperative MH closure, and retinal reattachment rates. All statistical analyses were conducted using IBM SPSS software version 26.0 (IBM Corp., Armonk, NY, USA), with *P*-values <0.05 considered statistically significant.

RESULTS

This study included 44 eyes from 44 participants (21 eyes in Group 1 and 23 eyes in Group 2). There were no statistically significant differences in baseline preoperative clinical characteristics, including age, sex, AL, diopters, symptom duration, lens status, posterior staphyloma presence and extent of RD (Table 1).

Both Groups 1 and 2 showed statistically significant improvement in logMAR BCVA post-surgery. BCVA improved from 2.13±0.91 preoperatively to 1.21±0.66 postoperatively in Group 1 (*P*=0.026) and from 1.91±0.53 to 1.19±0.41 in Group 2 (*P*=0.032). There was no statistically significant difference in visual-acuity improvement between groups (*P*=0.460; Table 2).

The retinal reattachment rate was higher in Group 1 than in Group 2, without statistical significance (*P*=0.667). In Group 1, two participants did not achieve full retinal reattachment initially. After maintaining a face-down position for 6mo, SRF was absorbed, and the retina was fully reattached by the last follow-up 1y post-operation. In Group 2, four participants did not achieve complete retinal reattachment. Two of these participants maintained a face-down position and achieved reattachment by the sixth month, sustaining it until the 12-month follow-up. The other two participants achieved reattachment after additional low-energy retinal photocoagulation at the MH rim, with SRF absorbed and reattachment achieved within 2mo of photocoagulation. In all cases, retinal reattachment was confirmed following silicone-oil removal. One participant in Group 2 experienced RD recurrence 4mo post-initial surgery. Following further interventions (including ILM inverted covering and silicone-oil retamponade), reattachment was maintained after a second silicone-oil removal one year later.

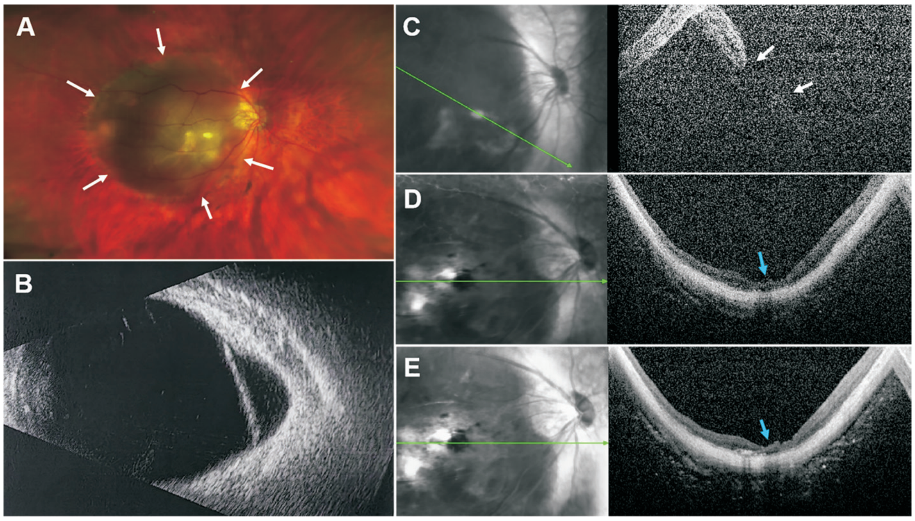

Figure 1 A 72-year-old individual with high-myopia MH retinal detachment (axial length, 32.1 mm; BCVA, 20/20 000) underwent PPV combined with PFCL-assisted inverted multilayer ILM flaps covering Preoperative fundus imaging and ultrasonography showing posterior retinal detachment and scleral staphyloma (A-B). Preoperative OCT image revealed the high myopia MH (white arrow) (C). Postoperative OCT images 1wk (D) and 1mo (E) after surgery demonstrating retinal reattachment and minimal ILM flaps coverage (blue arrow) over the MH under silicone-oil tamponade. Final follow-up BCVA was 20/1000. MH: Macular hole; BCVA: Best-corrected visual acuity; PPV: Pars plana vitrectomy; PFCL: Perfluorocarbon liquid; ILM: Internal limiting membrane; OCT: Optical coherence tomography.

Table 2 Anatomical and visual outcomes pre-surgery and post-surgery for patients with high myopic MHRD treated by the inverted multilayer ILM flaps covering or ILM peeling mean±SD/*n* (%)

Variable	Inverted multilayer ILM flaps covering (*n*=21)	ILM peeling (*n*=23)	*P*
Preoperative BCVA	2.13±0.91	1.91±0.53	0.536
Postoperative BCVA	1.21±0.66	1.19±0.41	0.638
Improvement of BCVA	1.01±0.61	0.80±0.61	0.460
Restoration of EZ at the fovea at postoperative 12mo	0	0	1.000
Restoration of ELM at the fovea at postoperative 12mo	0	0	1.000
Retinal reattachment rate	19 (90.5)	19 (82.6)	0.667
MH closure rate	18 (85.7)	4 (17.4)	<0.001
Final lens status (phakia/pseudophakia), *n*	5/16	9/14	0.276

MHRD: Macular hole retinal detachment; ILM: Internal limiting membrane; BCVA: Best-corrected visual acuity; SD: Standard deviation; EZ: Ellipsoid zone; ELM: External limiting membrane.

The MH closure rate was significantly higher in Group 1 (85.7%) than in Group 2 (17.4%; $P<0.001$). Figures 1 and 2 display images of retinal reattachment and MH closure in Group 1; Figure 3 shows a case in Group 2 where the retina attached at the posterior pole but the MH remained post-surgery. None of the eyes exhibited EZ and/or ELM recovery at 12mo postoperatively in either group within 1000 μm diameter of the macular fovea (Figures 1-3). Outside this range, the continuity of the EZ and/or ELM partially recovered in some patients (Figure 2H and 2I).

No complications, such as suprachoroidal hemorrhage or infectious endophthalmitis, occurred in any participant during the follow-up period. Elevated IOP was observed in three of 21 participants from Group 1 and five of 23 patients in Group 2, approximately 2wk post-operation. IOP normalized following anterior chamber paracentesis and treatment with pressure-lowering eye drops.

DISCUSSION

MHRD is a severe complication of high myopia, presenting considerable challenges for treatment. In 1982, Gonvers and Machemer[16] introduced PPV with gas-liquid exchange as a treatment for MHRD. Prior to this, episcleral macular buckling (EMB) was the preferred surgical approach for treating MHRD in high myopia, which is still widely used today[17-20]. The use of PPV became widely accepted by fundus surgeons owing to its versatility with adjunct techniques, such as ILM peeling, the inverted ILM flap[21-22], intraocular gas tamponade[23], silicon oil tamponade[24-25].

PPV alleviates vitreoretinal traction, aiding in retinal reattachment. Complete PVD and ERM peeling are essential for surgery success in high myopia-related MHRD. Research has demonstrated that triamcinolone acetonide aqueous suspension

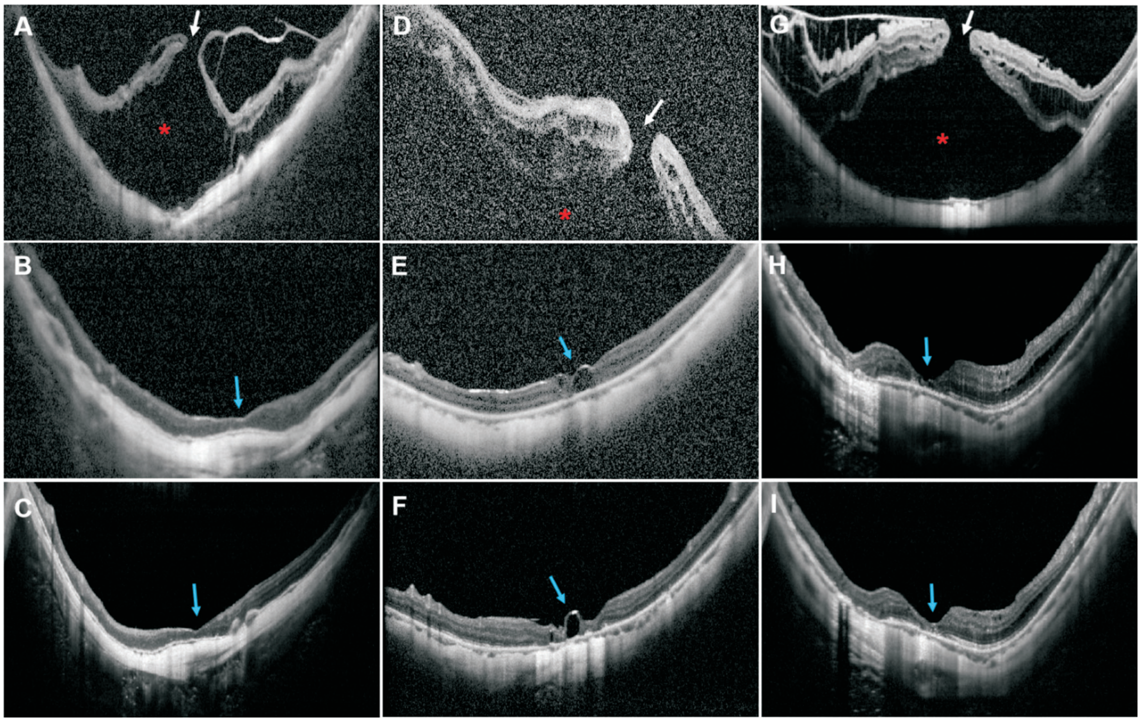

Figure 2 Optical coherence tomography images of three patients with high-myopia MH retinal detachment who achieved MH closure after PFCL-assisted inverted multilayer ILM flaps covering technique Preoperative images (A, D, G) displaying MHs (white arrow) with retinal detachment (red asterisk). Postoperative images showing retinal reattachment and macular hole closure (blue arrow) 1mo (B, E, H) and 12mo (C, F, I) after surgery. The blue arrows in E and F also showing the ILM flap healing with membrane-like bridging in the macular area. Each column represents a patient. MH: Macular hole; PFCL: Perfluorocarbon liquid; ILM: Internal limiting membrane.

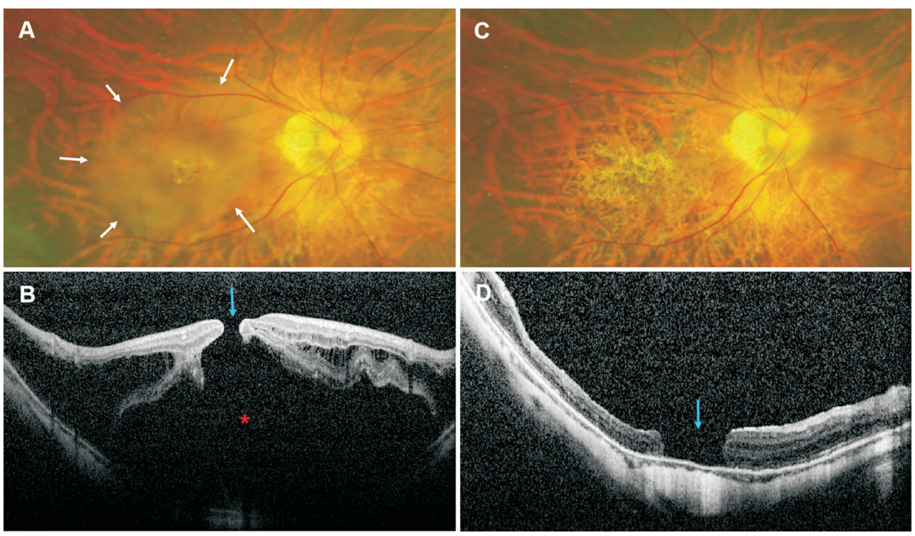

Figure 3 A 49-year-old individual with high-myopia MH retinal detachment (axial length, 30.22 mm; BCVA, 20/10 000) treated with PPV and ILM peeling A-B: Preoperative fundus imaging and OCT revealing posterior retinal detachment (white arrow, red asterisk) and an MH (blue arrow); C-D: Seven months postoperatively, the retina was well reattached, but the MH remained open (blue arrow). Final follow-up BCVA was 20/1000. MH: Macular hole; BCVA: Best-corrected visual acuity; PPV: Pars plana vitrectomy; ILM: Internal limiting membrane; OCT: Optical coherence tomography.

facilitate complete removal of the posterior vitreous cortex and ERM during PPV, which is associated with higher retinal reattachment rates in MHRD[26]. Kadonosono *et al*[27] proposed that myofibroblasts contraction on the ILM surface surrounding the MH in high myopia induces tangential macular traction; ILM peeling alleviates this traction, promoting MH closure and allowing complete ERM removal alongside ILM peeled. Additionally, due to atrophic RPE dysfunction and backward displacement within posterior scleral staphyloma, adhesion between the retina and RPE may be weak. Removing the ILM and overlying ERM could increase retina flexibility, potentially counteracting centrifugal tension from posterior scleral staphyloma and aiding retinal reattachment.

The inverted ILM flap technique, first described by Michalewska *et al*[28], was shown to improve MH closure rate and postoperative visual function in cases with MH>400 μm in diameter. Subsequent clinical studies applied this technique to myopic MH and MHRD, demonstrating an increased MH closure rate[21-29]. Michalewska *et al*[28] suggested that the inverted ILM flap acts as a scaffold for glial cell proliferation, promoting MH closure and supporting photoreceptor cell relocation to the fovea, which enhances postoperative visual acuity. Sasaki *et al*[30] further proposed that proliferating glial cells can fill MH, compensating for relative retina loss. In MHRD patients, MH closure rate using the inverted ILM flap and PPV ranges from 75% to 100%, whereas rate with ILM peeling and PPV range from 25% to 89%[29,31-33]. Postoperative BCVA with the inverted ILM flap technique has been shown to surpass that achieved with ILM peeling[34]. Another study found that, compared to ILM peeling, the inverted ILM flap technique produced stronger ELM and EZ morphology at the MH, with BCVA improvement positively correlated with ELM and EZ integrity[35]. Collectively, these findings support the inverted ILM flap technique as a viable approach for improving postoperative morphology and visual function in MHRD patients with high myopia.

In our study, the MH closure rate after ILM peeling in high-myopia MHRD patients with an AL of ≥30.0 mm was only 17.4%. Achieving simultaneous MH closure and retinal reattachment remains a challenge in MHRD surgery for patients with high myopia. To address this, many surgeons opt for ILM tamponade or covering during surgery to facilitate MH closure[7-8,32]. Covering or filling the MH with ILM flap can be challenging if the retina is floating in balanced saline solution. Even if the ILM flap is successfully filled, substantial SRF beneath the MH may remain unabsorbed due to choroidal atrophy and retinal pigment epithelium dysfunction. Additionally, ILM flaps may dislodge if SRF is aspirated through the MH, while aspiration through a supratemporal detached retinal stoma risks iatrogenic damage and proliferative retinopathy. We proposed a PFCL-assisted, multi-layer inverted ILM flaps technique to address these issues. This technique involves performing gas-liquid exchange after complete vitrectomy and ERM peeling at the MH, followed by aspirating SRF through the MH to flatting the retina. PFCL is then injected to maintain retinal stability at the posterior pole, allowing ILM manipulation under PFCL. Peeling the ILM under PFCL reduces retinal vibration and potential damage, enabling smoother, more stable ILM flap coverage over the MH, with the retina in a flattened state. After gas-liquid exchange, silicone oil is injected to ensure stable ILM flap positioning. During MH closure, the ILM serves as a scaffold for Müller cell proliferation and migration, promoting cell activation. Activated Müller cells release neurotrophic factors and basic fibroblast growth factor (bFGF), which may aid in MH closure[36].

In idiopathic MHs cases, the inverted ILM flap can provide adequate scaffolding with a single-layer flap, promoting MH closure and favorable visual prognosis[28,37]. However, in high-myopia MHRD cases with AL of ≥30 mm, first, it is difficult to obtain an enough large, complete ILM flap to cover the MH because the ILM is very brittle and firmly adheres to the retina in eyes with high myopia, second, retinal reattachment in these cases enlarges the MH, and severe posterior scleral staphyloma and retinochoroidal atrophy hinder retinal repair. Therefore, we believe that a single-layer ILM flap may not provide adequate scaffolding for MH closure. Instead, the multi-layer inverted ILM flaps offer multiple scaffolds layers, potentially enhancing neurotrophic factors and bFGF production to support MH healing. Postoperative fundus examination and OCT confirmed the safety and efficacy of this technique. On the first postoperative day, macular OCT showed no abnormal high-reflectance signals at the macula, which are typically seen when excessive ILM tissue covers the MH intraoperatively, potentially leading to scarring and affecting visual prognosis. Important considerations for the inverted multi-layer ILM flaps covering technique include the following: First, before ILM peeling, the posterior vitreous cortex and ERM in the macular area should be thoroughly cleaned, to avoid scar formation from residual tissues covering the MH. Second, the ILM flap should be sized appropriately to cover the MH without excess or insufficiency, with smooth placement to minimize wrinkles and accumulation. This approach helps maintain MH closure and reduce postoperative scarring, potentially improving visual prognosis. Further studies with larger sample sizes are needed to confirm these findings.

The improvement of BCVA after surgery of high-myopic MHRD is closely associated with the recovery of the foveal microstructure, particularly restoration of the ELM and the EZ. In a retrospective study of patients with high-myopia MHRD and an AL≥30 mm, the ILM flap-covering and ILM flap-insertion groups achieved a high rate of initial anatomical success. However, foveal microstructure recovery was suboptimal, with no eyes in either group demonstrating EZ or ELM recovery 12mo postoperatively[8]. Similarly, our study observed no recovery of EZ and/or ELM at 12mo postoperatively in either group within 1000 μm diameter of the macular fovea. This may be attributed to the significant posterior scleral staphyloma, retinochoroidal atrophy and posterior pole ischemia seen in high-myopic MHRD patients with AL≥30 mm. It has been reported that choroidal thinning was observed after vitrectomy in eyes with MHRD[38]. We hypothesize that this phenomenon may also contribute to the limited recovery of EZ and ELM in the macular region. The damage to the macular outer layer is often irreversible, even with retina reattachment and MH closure, as the foveal microstructure may be irreparably compromised. However, we also found that there was partial recovery of ELM and/or EZ out of the 1000 μm diameter of the macular fovea in some patients in this study. Therefore, extended follow-up period may be necessary, as foveal microstructures recovery could require additional time.

Postoperative BCVA improvement in high-myopia MHRD may also be influenced by factors such as MH size and duration (despite the challenges in measuring MH diameter in RD situations), duration of retinal detachment, axis length, and degree of retinochoroidal atrophy. This study's retrospective observational design means that surgical approaches were selected based on individual patient conditions and severity, introducing some level of selection bias. The PFCL-assisted multi-layer inverted ILM flaps technique has demonstrated favorable outcomes in terms of retinal reattachment and MH closure in high-myopia MHRD patients with extremely long ALs (AL≥30 mm). However, larger prospective studies are required to generate more reliable data and conclusions. Our findings, consistent with other studies, indicate that despite achieving high rates of retinal reattachment and MH closure in high-myopia MHRD, macular microstructure recovery remains inadequate, impacting postoperative visual acuity outcomes. Enhancing macular microstructure recovery presents a significant challenge that warrants further investigation. Therefore, the development of safer, more effective, and practical surgical techniques, or highly implantable, functional reparative biomaterials could potentially improve surgical outcomes in high-myopia MHRD treatment.

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