BMC Ophthalmology

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Inverted internal limiting membrane flap and scleral buckling for retinal detachment with macular hole

Yu-Pei Chen[1] and Yung-Jen Chen[1*]

Abstract

Background To evaluate anatomical and functional outcomes after vitrectomy with inverted internal limiting membrane flap technique combined with scleral buckling for eyes with rhegmatogenous retinal detachment and a coexisting macular hole.

Methods Eleven consecutive patients of primary rhegmatogenous retinal detachment with a coexisting macular hole who underwent vitrectomy with internal limiting membrane flap technique combined with scleral buckling surgery between September 2014 and September 2023 were evaluated retrospectively. The main outcome measurements were the retinal reattachment rate, macular hole closure rate, and final postoperative best-corrected visual acuity.

Results The primary retinal reattachment rate and macular hole closure rate were 100% (11/11) after initial surgery. Six patients required secondary surgery to improve vision, including cataract surgery in four patients, combined cataract surgery and silicone oil removal in one patient, and combined epiretinal membrane peeling and silicone oil removal in one patient. Visual acuity improved from 2.45 ± 0.52 logMAR preoperatively to 0.9 ± 0.26 logMAR finally ($P = 0.002$). However, only one patient (1/11; 9%) demonstrated microstructural recovery on optical coherence tomography (OCT) images.

Conclusion Vitrectomy with internal limiting membrane technique combined with scleral buckling achieves favorable anatomical reattachment and macular hole closure rates. The final visual outcomes improve after sequential surgeries. However, as confirmed on OCT, the microstructures did not recover in most cases.

Keywords Internal limiting membrane flap, Macular hole, Retinal detachment, Rhegmatogenous retinal detachment

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Introduction

Macular holes rarely occur in macula-off rhegmatogenous retinal detachment (RRD) [1, 2], which is associated with peripheral retinal breaks and retinal detachment (RD) extending to the ora serrata. RRD may present with features such as vitreous hemorrhage, choroidal detachment, or proliferative vitreoretinopathy. Vitreous opacification and highly bullous RD may make the preoperative evaluation of the macula difficult, leading to the coexisting macular holes being discovered during the operation. This differs from macular hole retinal detachment (MHRD) in highly myopic eyes, which typically demonstrates posterior pole extension of the RD without peripheral causative breaks.

In previous case series, the inverted internal limiting membrane (ILM) flap technique successfully achieved macular hole (MH) closure for idiopathic MH and MHRD in highly myopic eyes [3–9]. Vitrectomy using the inverted ILM technique, including ILM insertion and ILM flap technique, has been developed to improve the MH closure rate in MHRD [4, 6, 9–11], and the postoperative best-corrected visual acuity (BCVA) has improved significantly in eyes with MH closure compared to eyes without MH closure [12–14]. These procedures were developed based on the hypothesis that the ILM covering the MH acts not only as a filler but also as a scaffold to correct the anatomical mismatch between the neurosensory retina and the retinal pigment epithelium (RPE)-choroid-sclera complex [3, 4]. One study [15] investigated the outcomes of vitrectomy using the ILM flap technique in cases of rhegmatogenous retinal detachment with a coexisting macular hole (RRD-MH) and found favorable anatomical and visual outcomes.

The study retrospectively evaluated the anatomical and functional outcomes after vitrectomy with the inverted ILM flap technique combined with scleral buckling (SB) for eyes with primary RRD and a coexisting macular hole.

Materials and methods

We retrospectively enrolled consecutive patients who underwent vitrectomy combined with circumferential SB surgery to correct primary RRD-MH between September 2014 and September 2023. The study was approved by Chang Gung Medical Foundation Institutional Review Board (No. 202400220B0), and informed consent was obtained from all patients. All investigations adhered to the principles of the Declaration of Helsinki. All patients underwent a comprehensive preoperative ophthalmological examination, including slit-lamp evaluation and ophthalmoscopy. The inclusion criteria were the presence of a macula-off RD with peripheral retinal breaks and a coexisting full-thickness macular hole. MH was diagnosed preoperatively using slit-lamp ophthalmoscopy or optical coherence tomography (OCT) (Spectralis; Heidelberg Engineering, Heidelberg, Germany), or intraoperatively at the time of vitrectomy by the surgeon. The exclusion criteria were as follows: (1) posterior pole RD caused by a macular hole; (2) high myopia with posterior staphyloma, chorioretinal atrophy, and macular schisis; (3) peripheral RD not extending to the ora serrata; (4) evidence of any ocular trauma; (5) inflammatory, vascular, or severe macular degeneration; and (6) less than six months of postoperative follow-up.

Data recorded for the patients included age, affected eye, sex, duration of symptoms, BCVA, intraocular pressure, lens status, presence of a macular hole, location of peripheral breaks, the extent of RD, postoperative complications, postoperative macular hole status measured using OCT, retinal reattachment rate, the number of surgeries, follow-up duration. Nearly total retinal detachment was defined in patients with 4 quadrants without total of the retinal area was detached. The visual acuity data were converted to the logarithm of the minimum angle of resolution (log MAR) for statistical analysis.

All eyes included in this study were treated with conventional 23-gauge three-port pars plana vitrectomy by one surgeon (Y.J.C.). Simultaneous phacoemulsification with posterior chamber intraocular lens implantation was performed if a visually significant cataract was present. All patients underwent a 360° circumferential scleral buckling with silicone explants (type 506 silicone sponge) combined with vitrectomy. Complete removal of the residual posterior vitreous cortex, careful peeling of the epiretinal membrane (ERM), and shaving of the vitreous base were performed in all eyes. After indocyanine green (ICG) staining (0.1–0.2 ml of 0.5% solution of ICG flushing on the temporal macula area and aspirating it immediately), the ILM was peeled off circularly from a point at least two disc diameters temporal to the MH on the mobile retina using end-gripping forceps. During circumferential peeling, the ILM was peeled from the temporal to the superior side of the macula, partially separated from the retina, and left attached to the superior temporal edge of the MH in order to create a superior temporal ILM flap. The initial internal drainage of subretinal fluid (SRF) was performed under fluid through a nasal retinotomy to facilitate the drainage of SRF and temporarily flatten the retina. After lowering the infusion fluid pressure to 20mmHg, the superior temporal ILM flap edge was grabbed to cover the MH and some viscoelastic agent (Viscoat®; Alcon Surgical, Ft. Worth, TX USA) was injected to push and cover the superior temporal ILM flap until the MH was completely covered with the inverted ILM flap. After the fluid-air exchange, the residual SRF was reduced as much as possible through the retinotomy. A 360° endolaser photocoagulation of the peripheral retina, including surrounding individual peripheral breaks and retinotomy, was subsequently

performed. In nine of the eleven patients, the air in the vitreous cavity was replaced with 15–20% perfluoropropane (C_3F_8) gas. A silicone oil (SO) tamponade was performed in two patients: one had dense vitreous hemorrhage and the other was a one-eyed patient. Patients were advised to maintain a face-down position for two weeks. The SO was removed at least four months postoperatively.

Postoperative follow-up was conducted 6 months after surgery and included BCVA measurements, slit-lamp examinations, indirect ophthalmoscopy assessments, and an OCT scan. The primary outcome measures were the retinal reattachment rate, the MH closure rate, and the improvement in final postoperative BCVA from baseline. The final BCVA was recorded in decimals and converted to the logarithm of the minimal angle of resolution (logMAR) for statistical analyses. The visual acuity of counting fingers, hand motion, and light perception were converted to two, three, and four logMAR units, respectively. Some patients obtained secondary surgeries, including cataract surgery, SO removal, ERM peeling, or a combination of these (Fig. 1). The final BCVA and OCT measurements were obtained after the retinal stabilization. The closure of the macular hole was regarded as the central apposition of the edges without a bare central RPE on the OCT scan. The microstructures, including the outer nuclear layer (ONL), external limiting membrane (ELM) line, ellipsoid zone (EZ), and a hyperreflective bridging tissue that plugged the MH without any retinal layer, were evaluated using the OCT exam (Figs. 1 and 2).

Changes in BCVA from baseline to final follow-up were analyzed using the Wilcoxon signed-rank test. A P-value < 0.05 was considered statistically significant.

Results

Eleven eyes from 11 patients who underwent vitrectomy combined with 360° circumferential SB surgery for RRD-MH were included in the study. Table 1 shows the demographic and baseline characteristics of patients. The mean age of patients was 58.3 +/- 5.8 years (range, 46–65 years). Five patients (5/11; 45%) were men, and six (6/11; 55%) were women. Nearly total retinal detachment was noted in seven patients (63.6%), and totally detached retinas were noted in the other four (36.4%). Preoperatively, six eyes were pseudophakic, and the other five were phakic. No vitrectomy combined with cataract surgery was performed initially. All five patients with phakic eyes

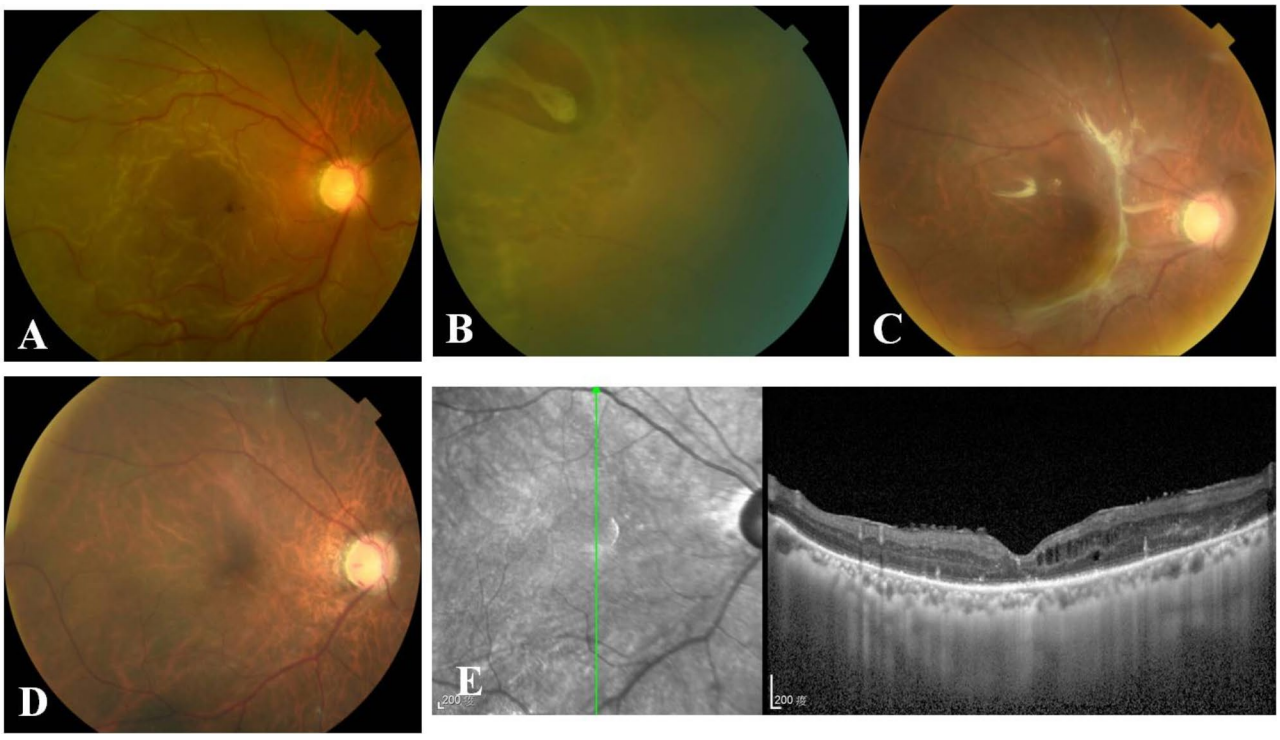

Fig. 1 Fundus photographs and optical coherence tomography (OCT) scans of Patient 8. **A** and **B**. The 64-year-old man had a pseudophakic rhegmatogenous retinal detachment with a peripheral flap tear surrounded by laser scars and a coexisting macular hole of 1-day duration. The best-corrected visual acuity was hand motion. He underwent scleral buckling, vitretomy with inverted internal limiting membrane flap to close the coexisting macular hole, and silicone oil tamponade. **C**. The postoperative fundus photograph at 3 months revealed attached retina and an obvious epiretinal membrane (ERM) on inferionasal macula area. **D** and **E**. Five months after the secondary surgery of ERM and silicone oil removal, the retina remained attached and the macula hole remained closed. The OCT images demonstrated hyperreflective bridging tissue in the fovea without outer nuclear layer, external limiting membrane line, ellipsoid zone (EZ) complete recovery. The final best-corrected visual acuity was 20/100

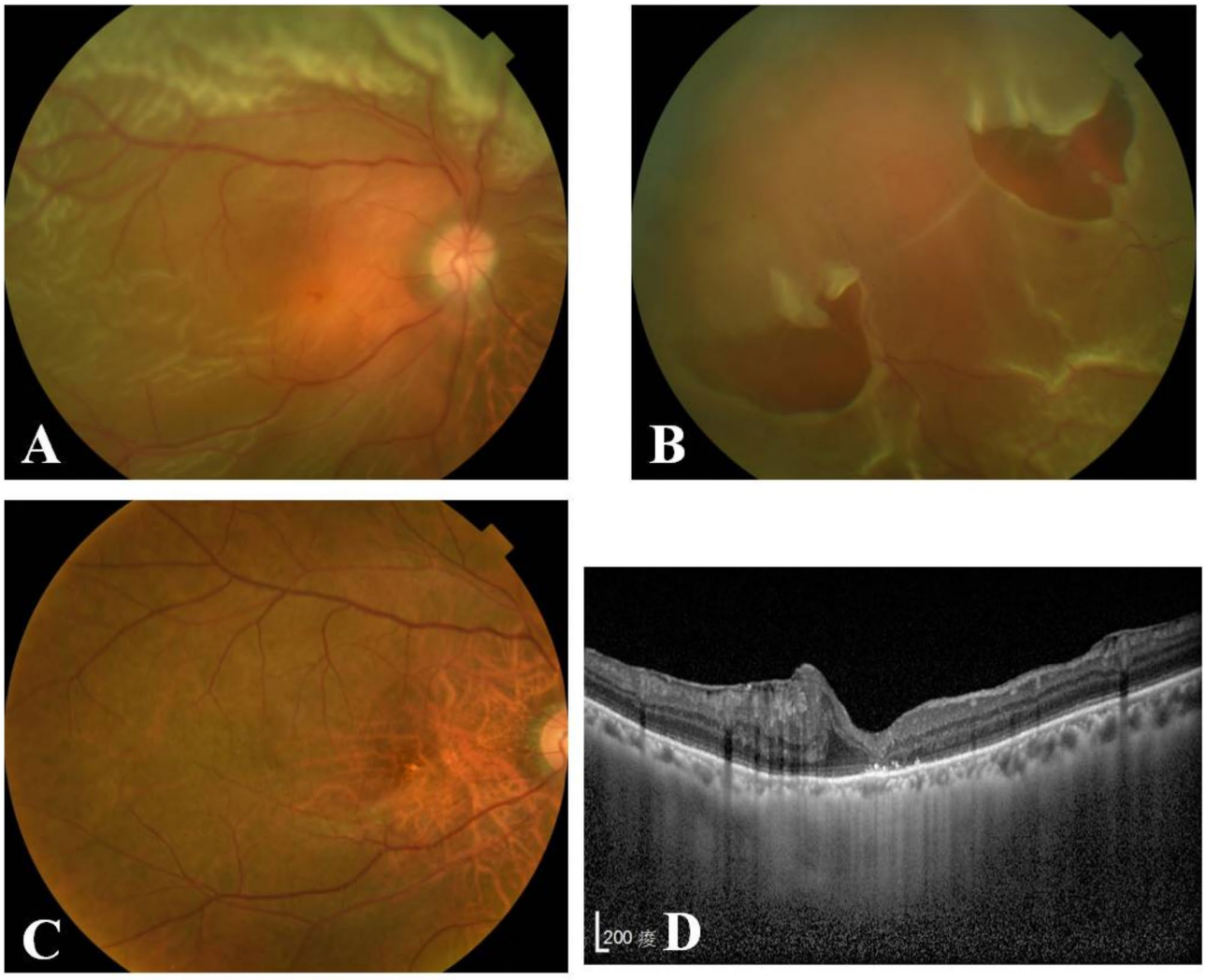

Fig. 2 Fundus photographs and optical coherence tomography (OCT) scans of Patient 10. **A** and **B**. The 61-year-old female had a pseudophakic rhegmatogenous retinal detachment with peripheral flap tears and a coexisting macular hole of 2-week duration. The best-corrected visual acuity was counting fingers. She underwent scleral buckling, vitretomy with inverted internal limiting membrane flap to close the coexisting macular hole, and perfluoropropane gas tamponade. **C** and **D**. The postoperative fundus photograph at 4 months revealed attached retina and some retinal foldings on inferionasal macula area. The OCT images demonstrated hyperreflective bridging tissue in the fovea without outer nuclear layer, external limiting membrane line, ellipsoid zone (EZ) complete recovery. The final best-corrected visual acuity was 20/200

required secondary cataract surgery. All patients were followed up for a minimum of 6 months. The mean follow-up period was 22.6 ± 18.1 months.

The retinal reattachment and macular hole closure rates were 100% (11/11) after initial surgery. No major intraoperative or postoperative complications occurred. Six patients required secondary surgery within 12 months of the initial operation for better vision achievement, including cataract surgery in four patients, combined cataract surgery and silicone oil removal in one patient (patient no. 7), and combined ERM and SO removal in one patient (patient no. 8). Notably, the MH remained closed and did not reopen even after ERM peeling in patient no. 8 (Table 2).

Final vision improved postoperatively in all patients. The mean preoperative BCVA was 2.45 ± 0.52 logMAR and the mean BCVA at the final postoperative visit was 0.9 ± 0.26 logMAR. The final postoperative BCVA significantly improved compared with the preoperative BCVA (Table 2). However, only one patient (patient no. 7) attained ONL, ELM line, and EZ recovery on the OCT image. The other 10 patients had a hyperreflective bridging tissue that plugged the MH without any retinal layer on OCT images after surgeries (Figs. 1 and 2).

Discussion

The inverted ILM flap technique was first described by Michalewska et al. [3] for large MH and further used for treating myopic MH with or without retinal detachment

Table 1 Patient demographics and baseline characteristics

Patient No.	Lens status	Intra-op findings	SRF drain	Tamponade	MH	RD	Secondary surgery	Pre-op BCVS	Final BCVA	F/U (M)
1	IOL	NTRD	MH	C_3F_8	closed	attached	-	HM (+3)	20/63 (+0.5)	41
2	IOL	NTRD	MH	C_3F_8	closed	attached	-	CF (+2)	20/200 (+0.6)	12
3	IOL	TRD, CD	MH	C_3F_8	closed	attached	-	CF (+2)	20/400 (+1.3)	59
4	Phakic	NTRD	MH	C_3F_8	closed	attached	C	CF (+2)	20/100 (+0.7)	38
5	Phakic	TRD	MH	C_3F_8	closed	attached	C	CF (+2)	20/400 (+1.3)	39
6	Phakic	TRD, PVR CP-3	MH	C_3F_8	closed	attached	C	HM (+3)	20/400 (+1.3)	14
7	Phakic	NTRD, VH	MH	SO	closed	attached	C, SO removal	CF (+2)	20/100 (+0.7)	12
8	IOL	NTRD	retinotomy	SO	closed	attached	ERM and SO removal	HM (+3)	20/100 (+0.7)	12
9	Phakic	NTRD	MH	C_3F_8	closed	attached	C	HM (+3)	20/200 (+0.6)	8
10	IOL	TRD	MH	C_3F_8	closed	attached	-	CF (+2)	20/200 (+0.6)	8
11	IOL	NTRD	MH	C_3F_8	closed	attached	-	HM (+3)	20/200 (+0.6)	6

Intra-op = intraoperative; MH = macular hole; RD = retinal detachment; pre-op = preoperative; BCVA = best-corrected visual acuity; F/U = follow-up; M = months; IOL = intraocular lens; NTRD = nearly total retinal detachment; C_3F_8 = perfluoropropane; HM = hand movement; CF = counting fingers; TRD = total retinal detachment; CD = choroidal detachment; C = cataract; PVR = proliferative vitreoretinopathy; VH = vitreous hemorrhage; SO = silicone oil; ERM = epiretinal membrane

Table 2 Demographics summary and surgical analysis

	Preoperative data	Final data	
Age (year)			58.3 ± 5.8
Sex (male: female)			5 (45%):6 (55%)
TRD: NTRD			4 (36.4%): 7(63.6%)
IOL	6/11(55%)	11/11(100%)	
Log MAR BCVA	2.45 ± 0.52	0.9 ± 0.26	$P = 0.003$*
Follow-up (M)			22.6 ± 18.1
ONL		1/11(9%)	
ELM		1/11(9%)	
EZ		1/11(9%)	
HBT	10/11(91%)		

ELM = external limiting membrane; EZ = ellipsoid zone; HBT = hyperreflective bridging tissue; IOL = intraocular lens; Log MAR BCVA = Logarithm of the Minimum Angle of Resolution Best-corrected visual acuity; M = months; NTRD = nearly total retinal detachment; ONL = outer nuclear layer; TRD = total retinal detachment

*Wilcoxon signed ranks test

[3, 4]. The MH closure after PPV for MHRD in the myopic eye has been reported to be an important predictor of favorable visual outcome [12, 14]. Zhu et al. [9] reported that the inverted ILM flap technique was more effective in improving postoperative BCVA in patients with MH-associated retinal detachment when compared with the ILM insertion technique. Scleral buckling is a valuable surgical option for RRD repair, either as the primary or adjunctive treatment. In this study, our results demonstrated that all patients (11/11; 100%) obtained primary retinal reattachment and MH closure after vitrectomy with an inverted internal limiting membrane flap combined with SB. However, secondary surgeries, including cataract surgery, SO removal, ERM peeling, or combination of these are necessary to achieve a relatively normal physiological status and better vision.

RRD-MH is relatively uncommon, with an incidence rate of only 2.3–4%.[1,2] The pathogenesis of coexisting MH formation may include the co-occurrence of posterior vitreous detachment with peripheral tears formation or the dehiscence of chronic cystoid macular edema in long-standing RRD [1, 16]. Compared to cases of MHRD with posterior staphyloma and RPE atrophy [17], RRD-MH may have a better visual outcome after surgery [6, 18–21]. In previous reports on RRD-MH, the MH closure rate was variable after vitrectomy without using the ILM flap technique [22, 23]. Only one report [15] has shown that vitrectomy using the inverted internal limiting membrane flap technique achieved favorable anatomical retinal reattachment rates, recovery of the central macular anatomy, and vision improvement in patients with RRD-MH. The present study yielded similar results (Table 2).

Macular ERM has been reported in approximately 5–8% of eyes following SB or vitrectomy for primary uncomplicated retinal detachment [24]. In our case series, obvious ERM developed in one case (1/11; 9%), and secondary surgery for ERM removal was necessary for better vision achievement. The ERM located on the

inferior nasal macula may be caused by a lack of ILM as a result of the superior temporal ILM flap peeling leaving no ERM development on superior temporal macula. Notably, the MH remained closed and did not reopen after ERM removal.

The surgical results were difficult to interpret because of variability in the presentation, including initial vision, duration of macula-off RD, and complexity of RRD-MH. The aim of surgery is to restore the anatomical structure of the retina and MH closure, reduce intraoperative injury and postoperative complications, reduce the number of sequential surgeries, and achieve maximal vision recovery. Only one patient in our study showed microstructures recovery on OCT images. Several surgical procedures may have influenced the final outcomes in these cases. First, vitrectomy without SB may have been adequate in these patients. However, adjuvant SB was performed intuitively for our patients with total or nearly total RD. Second, the mobile retina can be stabilized during ILM peeling by using heavy perfluorocarbon liquids, which might improve the procedure's safety. However, the ILM peeling of the mobile retina can be carefully achieved by ICG staining. Third, there are different ILM flap techniques, the ILM is peeled centripetally, leaving it attached to the edges of the MH, or a piece of ILM is peeled to cover the MH. Finally, SO tamponade provides less tension than the C_3F_8 gas, which may reduce the chance of a hyperreflective bridging tissue plugging the MH totally and obtain microstructures formation of the MH. However, secondary surgery for SO removal is necessary in cases of SO tamponade. The limitations of our study include its retrospective nature without a control group, and its relatively small sample size.

In conclusion, vitrectomy using the ILM flap technique combined with SB achieved favorable anatomical reattachment and MH closure rates. The final visual outcomes improved after sequential surgeries, including cataract surgery, SO removal, and ERM peeling, or combination therapy. However, as confirmed on OCT, the microstructures did not recover in most cases. Considering the limitations of our study, further prospective studies with larger sample sizes, and longer follow-up times are required to compare the benefits of the different techniques.

Abbreviations

RRD	Rhegmatogenous retinal detachment
RD	Retinal detachment
MHRD	Macular hole retinal detachment
ILM	Inverted internal limiting membrane
MH	Macular hole
BCVA	Best-corrected visual acuity
RPE	Retinal pigment epithelium
RRD-MH	Rhegmatogenous retinal detachment with a coexisting macular hole
SB	Scleral buckling
OCT	Optical coherence tomography
log MAR	Logarithm of the minimum angle of resolution
ERM	Epiretinal membrane
ICG	Indocyanine green
SRF	Subretinal fluid
C3F8	Perfluoropropane
SO	Silicone oil
ONL	Outer nuclear layer
ELM	External limiting membrane
EZ	Ellipsoid zone

Acknowledgements
We appreciated the Biostatistics Center, Kaohsiung Chang Gung Memorial Hospital.

Author contributions
Both authors contributed to study design and paper writing. Dr. YPC analyzed and interpreted the patient data and revised the manuscript. Dr. YJC was responsible for performing surgery and enrollment of patients.

Funding
There was no funding.

Data availability
All data included in this study are available upon request by contact with the corresponding author.

Declarations

Ethics approval and consent to participate
This study was approved by Chang Gung Medical Foundation Institutional Review Board with IRB number of 202400220B0. Informed consent was obtained from all patients.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Received: 27 October 2024 / Accepted: 26 March 2025
Published online: 08 April 2025

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