Postoperative OCT Microstructural Changes as Predictors of Visual Prognosis Following Epiretinal Membrane Peeling: A Retrospective Study

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Weifeng Min[1], Yanchun Zhu[1], Xinxin Li[1]

[1]Department of Fundus Disease, Huzhou Aier Eye Hospital, 313100 Huzhou, Zhejiang, China

AIM: Idiopathic macular epiretinal membrane (iERM) induces traction and deformation of the macular retina, significantly impairing function and quality of life. This study aimed to evaluate the predictive value of early postoperative optical coherence tomography (OCT) microstructural changes for visual prognosis in patients undergoing vitrectomy with membrane peeling for iERM.

METHODS: A total of 110 patients diagnosed with iERM at Huzhou Aier Eye Hospital between January 2021 and July 2024 were retrospectively enrolled. According to OCT findings, patients were divided into stage I (n = 38), stage II (n = 52), and stage III (n = 20). All patients underwent 23-gauge minimally invasive vitrectomy combined with indocyanine green staining and peeling of the epiretinal membrane and internal limiting membrane. Best-corrected visual acuity (BCVA), central macular thickness (CMT), subfoveal choroidal thickness (SFCT), choroidal thickness at 1000 µm from the nasal side of the macular fovea (NFCT), and choroidal thickness at 1000 µm from the temporal side of the macular fovea (TFCT) were assessed before surgery and at 1 and 3 months postoperatively. Repeated-measures analysis of variance was used to compare intergroup differences over time, and multivariate logistic regression was performed to identify indicators associated with a favorable visual prognosis.

RESULTS: Significant gradient differences were observed among the three groups in CMT, SFCT, NFCT, TFCT, and BCVA, with stage I patients exhibiting significantly lower values than those in stage II and stage III (all $p < 0.05$). During postoperative follow-up, OCT parameters and visual acuity improved in all groups, with significantly greater improvement in stage I patients compared with stage II or stage III (all $p < 0.05$). Repeated-measures analysis demonstrated a significant time × group interaction effect for CMT ($F = 2.334$, $p = 0.032$), with a greater rate of CMT reduction in stage I patients. At 6 months postoperatively, 71 patients (64.55%) achieved a favorable visual prognosis. Multivariate logistic regression analysis indicated that lower CMT at 1 month postoperatively (OR = 0.98, 95% CI: 0.97–0.99, $p < 0.05$) was significantly associated with favorable visual outcomes at 6 months.

CONCLUSIONS: Postoperative anatomical and functional recovery in iERM patients is stage-dependent. Lower CMT at 1 month after surgery is significantly associated with favorable visual outcomes at 6 months, suggesting its potential value as an early postoperative prognostic indicator. These findings underscore the importance of incorporating early postoperative OCT assessment into clinical follow-up to facilitate individualized prognosis and patient counseling.

Keywords: idiopathic macular epiretinal membrane; optical coherence tomography; vitrectomy; membrane peeling; visual prognosis; OCT biomarkers

Introduction

Idiopathic epiretinal membrane (iERM) is a prevalent macular disorder characterized by the proliferation of a fibrocellular layer on the inner retinal surface, predominantly affecting individuals over 50 years of age [1]. As the membrane thickens and contracts, it exerts traction on the macula, leading to macular edema, retinal distortion, decreased visual acuity, and metamorphopsia. With disease progression, this traction may result in significant structural deformation of the macular retina, thereby severely impairing visual function and quality of life. Vitrectomy combined with epiretinal membrane peeling (ERM-P) has become a standard surgical approach for the management of idiopathic epiretinal membrane (iREM). However, controversy persists regarding whether internal limiting membrane peeling should be routinely performed. Previous studies have shown that internal limiting membrane peeling can further improve postoperative visual acuity, reduce macular edema and irregularities on the retinal surface [2,3], and enhance visual prognosis in most patients.

Optical coherence tomography (OCT) is an essential tool for the diagnosis and evaluation of macular epiretinal membrane [4]. It provides high-resolution cross-sectional retinal images and has become indispensable for both diagnostic and prognostic evaluation of macular diseases. Previous studies have confirmed that OCT-derived parame-

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Correspondence to: Xinxin Li, Department of Fundus Disease, Huzhou Aier Eye Hospital, 313100 Huzhou, Zhejiang, China (e-mail: 15244609133@163.com).
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ters, such as central macular thickness (CMT), have predictive value for postoperative visual outcomes [5,6]. However, clinical observations indicate that some patients exhibit satisfactory anatomical recovery of the macula after surgery, while functional visual improvement remains limited. This discrepancy suggests that postoperative visual recovery may depend more on the remodeling of retinal microstructure than on gross anatomical restoration alone [7]. Consequently, the dynamic changes in retinal microstructure during the early postoperative period have emerged as a research focus. Multiple studies have reported that recovery of the ellipsoid zone [8,9] and retinal blood perfusion [10] are closely associated with the final visual outcomes. Therefore, this study aimed to characterize the recovery patterns of key OCT parameters during the early postoperative period (1 month) through retrospective analysis of serial OCT data from patients undergoing iERM surgery, to evaluate their predictive value for mid-term (6 months) visual outcomes, and to provide a basis for individualized prognostic evaluation in clinical practice.

Methods

Subjects

A total of 110 patients diagnosed with iERM in the Department of Fundus Disease at Huzhou Aier Eye Hospital between January 2021 and July 2024 were retrospectively included. Patients were divided into stage I (n = 38), stage II (n = 52), and stage III (n = 20) based on optical coherence tomography (OCT) findings. This study was conducted in accordance with the Declaration of Helsinki and was approved by the Medical Ethics Committee of Huzhou Aier Eye Hospital (No.20250105006). The requirement for informed consent was waived by the Medical Ethics Committee of Huzhou Aier Eye Hospital due to the retrospective study design and the use of de-identified patient data, in compliance with the Declaration of Helsinki.

Inclusion and Exclusion Criteria

Inclusion criteria: (1) After medical history assessment, slit-lamp microscopy, fundus photography, and OCT examination, the diagnosis of iERM was clearly established, and no definitive cause was identified; (2) first vitreoretinal surgery; (3) unilateral eye disease, with the contralateral eye being healthy; (4) follow-up time not less than 6 months with good compliance to related treatment; (5) absence of severe cardiovascular and cerebrovascular diseases, diabetes, or respiratory diseases.

Exclusion criteria: (1) patients with macular epiretinal membrane secondary to ocular trauma, prior vitrectomy, or other identifiable causes; (2) presence of other macular lesions such as age-related macular degeneration or diabetic macular edema; (3) patients with intraoperative findings requiring silicone oil tamponade; (4) co-existence of other fundus-affecting diseases, such as vitreous hemorrhage or glaucoma; (5) failure to complete treatment due to severe diseases, or occurrence of postoperative complications such as persistent high intraocular pressure or infectious endophthalmitis.

Surgical Methods

All surgeries were performed by the same chief physician with extensive surgical experience. Routine lacrimal passage irrigation was performed preoperatively, and levofloxacin eye drops were routinely administered to the operative eye. On the day of surgery, ocular surface irrigation was performed using a solution prepared by diluting 1.3 mL of 5% povidone-iodine in 250 mL of sterile 0.9% sodium chloride solution, yielding a final effective concentration of 0.025%. Compound tropicamide eye drops were administered to achieve adequate mydriasis. All affected eyes underwent 23-G minimally invasive vitrectomy. The epiretinal membrane and internal limiting membrane were peeled with the assistance of indocyanine green (ICG) staining (0.05%, injected under air). The internal limiting membrane (ILM) was routinely peeled in a circular manner, centered on the fovea and covering the macular area within the temporal vascular arcades, with a diameter of approximately 2 disc diameters. Complete removal of the ILM was confirmed by clear visualization of the underlying retinal nerve fiber layer.

Following membrane peeling, the retinal surface was carefully examined for residual epiretinal membrane or ILM tissue, as well as for retinal breaks, hemorrhage, and related abnormalities. If retinal breaks were identified, laser photocoagulation was performed promptly to seal the breaks. For minor hemorrhage, hemostasis was achieved by increasing intraocular pressure or by applying endoocular electrocoagulation. A 14% perfluorocarbon tamponading gas (C_3F_8) was used to fill the vitreous cavity only in patients who developed iatrogenic retinal breaks during membrane peeling. Tobramycin and dexamethasone ophthalmic ointment was applied to the conjunctival sac, and the operative eye was bandaged with sterile gauze. For patients receiving C_3F_8, a standardized protocol was applied: a 14% concentration, non-expansile mixture, with patients instructed to maintain a face-down position for 5–7 days postoperatively. Minor complications, such as self-limiting punctate hemorrhages at the peeling site, occurred in a few patients but resolved without intervention and did not affect surgical outcomes.

Inspection and Measurement Methods

All patients underwent comprehensive ophthalmic examinations preoperatively and at 1, 3, and 6 months postoperatively, including assessment of best-corrected visual acuity (BCVA) and OCT. BCVA was measured using the international standard visual acuity chart and converted to the logarithm of the minimum angle of resolution (logMAR) for statistical analysis. For OCT examination, the Cirrus HD-OCT 5000 (Version 10.0, Carl Zeiss AG, Jena, Germany) was used, with the single-line horizontal scanning mode (B-

scan) selected. Scanning was centered on the fovea centralis, with a scanning line length of 4.5 mm and an observation range of 15°.

Two independent ophthalmologists, blinded to the clinical data of the patients, manually measured OCT parameters using ImageJ software (Version 1.46, National Institutes of Health, Bethesda, MD, USA). In case of discrepancy, the final determination was made by a third senior ophthalmologist. The following parameters were assessed: central macular thickness (CMT), subfoveal choroidal thickness (SFCT), choroidal thickness at 1000 μm from the nasal side of the macular fovea (NFCT), and choroidal thickness at 1000 μm from the temporal side of the macular fovea (TFCT).

CMT was defined as the vertical distance between the ILM and the retinal pigment epithelium (RPE) at the foveal center. SFCT was defined as the vertical distance from the hyperreflective line of the RPE to the inner scleral border, measured at a single point directly beneath the foveal center. The foveal center was identified on the horizontal OCT B-scan as the point of maximal foveal depression in Stages I and II, or as the anatomical center of the foveal region in Stage III, where the foveal contour was obscured.

Lens status was assessed by slit-lamp examination at each follow-up visit. Patients with clinically significant cataract progression or those requiring cataract surgery during the follow-up period would have been excluded from the analysis; however, no such cases occurred in this cohort.

OCT Staging and Staging Criteria

Preoperative macular OCT scans were obtained for all patients. Staging was independently evaluated by two experienced graders masked to clinical data, according to the staging system proposed by Govetto et al. [11], based on the following criteria:

Stage I: A thin hyperreflective membrane partially overlies the fovea, with no ectopic inner foveal layers (EIFL), an intact ellipsoid zone (EZ), and a preserved foveal contour.

Stage II: The membrane contracts, resulting in shallowing or loss of the foveal depression with the presence of EIFL, while the EZ remains intact or exhibits only mild disruption, often accompanied by mild to moderate macular edema.

Stage III: Diffuse macular thickening with complete loss of the foveal contour, extensive EIFL, and disruption or absence of the EZ, frequently associated with cystoid macular edema.

In cases of disagreement between the two graders, a third senior ophthalmologist was consulted, and a consensus was reached through discussion. Inter-grader agreement was assessed using the kappa coefficient, which demonstrated substantial agreement ($\kappa = 0.839$, 95% CI: 0.748–0.929), indicating high reproducibility of the staging criteria applied in this study.

Definition of Good Prognosis

A good visual prognosis was defined as a logMAR BCVA ≤0.3 (equivalent to Snellen visual acuity ≥0.5) at 6 months postoperatively [12,13]. This threshold is widely accepted as representing a functional level of vision sufficient for daily activities, including reading and driving, and has been adopted as a clinically relevant cutoff in previous studies of macular diseases and vitreoretinal surgery [14]. Moreover, it approximates the minimum visual acuity required for driving in many countries and thus represents a meaningful functional endpoint.

Statistical Analysis

Statistical analyses were performed using SPSS Statistics version 27.0 software (IBM Corp., Armonk, NY, USA). All continuous variables were initially tested for normality using the Shapiro-Wilk test. Variables following a normal distribution were expressed as mean ± standard deviation ($\bar{x} \pm s$), while non-normally distributed variables were expressed as median with interquartile range (IQR) and analyzed using non-parametric tests (Mann-Whitney *U* test or Kruskal-Wallis test, as appropriate). Categorical variables were presented as frequencies and percentages and analyzed using the chi-square test or Fisher's exact test. Comparisons of repeated measurements before and after surgery were conducted using repeated-measures analysis of variance (ANOVA). The assumption of sphericity was evaluated using Mauchly's test; when violated ($p < 0.05$), the Greenhouse-Geisser correction was applied to adjust the degrees of freedom. Both main effects (time and group) and the interaction effect (time × group) were evaluated. Post-hoc pairwise comparisons were performed with Bonferroni correction to control for multiple testing.

Multivariate logistic regression analysis was conducted to identify factors associated with good postoperative visual prognosis (logMAR BCVA ≤0.3 at 6 months, coded as 1). The primary independent variables were OCT parameters at 1 month postoperatively (CMT and SFCT). The model was adjusted for potential confounders, including baseline BCVA, disease duration, OCT stage, lens status, and use of gas tamponade. Results were presented as adjusted odds ratios (ORs) with 95% CIs.

Model performance was assessed by evaluating calibration using the Hosmer-Lemeshow goodness-of-fit test and discrimination using the area under the receiver operating characteristic curve (AUC). An AUC value >0.70 was considered acceptable. A two-sided *p*-value < 0.05 was considered statistically significant.

Results

Comparison of General Data of Three Groups of IREM Patients

During the 6-month follow-up, no patient underwent cataract surgery, and no clinically significant cataract progression was observed in any case. As shown in Table 1,

Table 1. Baseline clinical characteristics of patients across three iERM stages.

Variable	Stage I (n = 38)	Stage II (n = 52)	Stage III (n = 20)	F/χ^2	*p*-value
Age (years, $\bar{x} \pm s$)	63.53 ± 6.60	64.92 ± 6.63	63.90 ± 6.37	0.531	0.589
Gender (n, %)				1.591	0.451
Male	17 (44.74)	29 (55.77)	12 (60.00)		
Female	21 (55.26)	23 (44.23)	8 (40.00)		
Affected eyes (n, %)				0.526	0.769
Left	19 (50.00)	22 (42.31)	9 (45.00)		
Right	19 (50.00)	30 (57.69)	11 (55.00)		
Disease course (months, $\bar{x} \pm s$)	4.43 ± 1.46	4.39 ± 1.55	4.31 ± 1.86	0.039	0.962
Baseline BVCA (logMAR, $\bar{x} \pm s$)	0.44 ± 0.11	0.52 ± 0.16	0.74 ± 0.23	21.808	<0.001
Lens status (n, %)				/	0.428
Transparent lens	35 (86.84)	49 (94.23)	17 (85.00)		
Mild lens opacification	3 (13.16)	3 (5.77)	3 (15.00)		
Gas tamponade (n, %)				/	0.706
Pure C_3F_8	5 (7.89)	4 (7.69)	2 (10.00)		
C_3F_8 + Air	33 (92.11)	48 (92.31)	18 (90.00)		

BCVA, best-corrected visual acuity; iERM, idiopathic epiretinal membrane; logMAR, logarithm of the minimum angle of resolution. "/" indicates that Fisher's exact test was used, for which no test statistic is reported.

there were no statistically significant differences in general characteristics among the three groups of patients ($p > 0.05$), indicating that the groups were comparable at baseline. However, there was significant difference in baseline BVCA among three groups ($p < 0.001$). Given this baseline imbalance, multivariate logistic regression analysis was subsequently performed with adjustment for baseline BCVA and other potential confounders to ensure that the identified prognostic factors were independent of disease severity at presentation.

Comparison of BCVA Among Three Groups of Patients

As shown in Table 2, a comparison of BCVA among the three groups at different time points before and after surgery demonstrated a significant time effect ($F = 91.054$, $p < 0.001$), indicating that BCVA in all the groups improved significantly with increasing postoperative time. The group effect was also significant ($F = 53.987$, $p < 0.001$), indicating statistically significant differences in BCVA among the three groups overall, with patients in earlier stages exhibiting better BCVA. Additionally, the interaction effect between time and group for BCVA was significant ($F = 2.754$, $p < 0.05$), indicating that the rate of BCVA improvement over time differed among the groups.

Comparison of OCT-Related Parameters Across Three Groups of Patients

As shown in Table 3, comparisons of CMT, SFCT, NFCT, and TFCT across the three groups at different time points before and after surgery revealed significant time effects ($p < 0.001$), indicating that CMT in all groups decreased with increasing postoperative time. The group effects were also significant ($p < 0.001$), demonstrating statistically significant differences in CMT, SFCT, NFCT, and TFCT among the three groups overall, with values showing a stage-dependent gradient; patients in earlier stages exhibited lower thickness values compared with those in more advanced stages. The interaction effect between time and group was significant for CMT ($p < 0.05$), indicating that the rate of CMT reduction over time differed among the three groups. However, the interaction effects between time and group for SFCT, NFCT, and TFCT were not significant ($p > 0.05$), suggesting that the rates of change for these choroidal thickness parameters were similar across groups over time.

Univariate Analysis of Good Prognosis in iERM Patients

At 6 months postoperatively, 71 of 110 patients (64.55%) achieved a good prognosis, while 39 patients (35.45%) had a poor prognosis. Univariate analysis showed that the 1-month postoperative CMT, SFCT, and TFCT, as well as the 3-month postoperative CMT and SFCT, in the good-prognosis group were significantly lower than those in the poor-prognosis group ($p < 0.05$; Table 4). Additionally, the distribution of OCT staging differed significantly between the two groups ($p = 0.002$; Table 4), with a higher proportion of Stage III patients in the poor-prognosis group (33.33%) compared with the good-prognosis group (9.86%). No significant differences were observed in age, gender, affected eye, disease course, baseline BCVA, lens status, or gas tamponade between the two groups (all $p > 0.05$). As shown in Table 5, multivariate logistic regression analysis revealed that 1-month postoperative CMT (OR = 0.98, 95% CI: 0.97–0.99, $p < 0.05$) was significantly associated with favorable visual outcomes at 6 months. As shown in Table 6, after adjustment for potential confounding factors, 1-month postoperative CMT remained signif-

Table 2. Comparison of BCVA before and after surgery among three groups of patients ($\bar{x} \pm s$).

Time point	Stage I (n = 38)	Stage II (n = 52)	Stage III (n = 20)	*F*-value	*p*-value
Before surgery	0.44 ± 0.11	0.52 ± 0.16[a]	0.74 ± 0.23[a,b]	21.808	<0.001
1 month after surgery	0.34 ± 0.11[c]	0.39 ± 0.13[c]	0.52 ± 0.13[a,b,c]	12.835	<0.001
3 months after surgery	0.27 ± 0.07[c,d]	0.34 ± 0.10[a,c,d]	0.40 ± 0.15[a,b,c,d]	12.596	<0.001
6 months after surgery	0.22 ± 0.08[c,d]	0.29 ± 0.09[a,c,d]	0.36 ± 0.12[a,b,c,d]	15.240	<0.001
Time effect				91.054	< 0.001
Group effect				53.987	< 0.001
Time × group interaction				2.754	0.019

Notes: [a] $p < 0.05$ vs. Stage I; [b] $p < 0.05$ vs. Stage II; [c] $p < 0.05$ vs. preoperative; [d] $p < 0.05$ vs. 1 month postoperative.

Table 3. Comparison of OCT parameters before and after surgery among three groups ($\bar{x} \pm s$).

Parameter	Stage I (n = 38)	Stage II (n = 52)	Stage III (n = 20)	*F*-value	*p*-value
CMT (μm)					
Before surgery	508.17 ± 43.43	539.71 ± 24.06[a]	556.40 ± 52.44[a]	12.909	<0.001
1 month after surgery	332.18 ± 41.58[c]	379.54 ± 27.98[a,c]	406.35 ± 38.38[a,b,c]	34.514	<0.001
3 months after surgery	280.99 ± 26.85[c,d]	342.87 ± 22.16[a,c,d]	367.66 ± 35.97[a,b,c,d]	88.680	<0.001
6 months after surgery	275.76 ± 23.35[c,d]	325.46 ± 28.61[a,c,d]	351.05 ± 40.96[a,b,c,d]	51.191	<0.001
Time effect				914.280	< 0.001
Group effect				141.562	< 0.001
Time × group interaction				2.334	0.032
SFCT (μm)					
Before surgery	403.63 ± 36.30	427.04 ± 35.83[a]	452.05 ± 38.03[a,b]	12.064	<0.001
1 month after surgery	323.61 ± 33.34[c]	363.92 ± 30.97[a,c]	403.40 ± 35.75[a,b,c]	41.145	<0.001
3 months after surgery	286.16 ± 35.86[c,d]	317.81 ± 39.00[a,c,d]	341.65 ± 37.21[a,b,c,d]	15.770	<0.001
6 months after surgery	276.74 ± 36.97[c,d]	312.15 ± 34.77[a,c,d]	328.45 ± 30.55[a,c,d]	17.918	<0.001
Time effect				240.157	< 0.001
Group effect				72.828	< 0.001
Time × group interaction				1.314	0.250
NFCT (μm)					
Before surgery	387.74 ± 25.12	395.62 ± 40.15	423.40 ± 34.53[a,b]	7.178	0.001
1 month after surgery	341.39 ± 39.26[c]	362.25 ± 26.29[a,c]	368.70 ± 28.00[a,c]	6.668	0.002
3 months after surgery	314.00 ± 34.25[c,d]	329.54 ± 27.65[a,c,d]	344.05 ± 17.29[a,c,d]	7.633	<0.001
6 months after surgery	301.11 ± 44.01[c,d]	320.56 ± 27.30[a,c,d]	332.17 ± 23.23[a,c,d]	6.575	0.002
Time effect				130.265	< 0.001
Group effect				24.693	< 0.001
Time × group interaction				0.722	0.632
TFCT (μm)					
Before surgery	326.66 ± 24.67	359.68 ± 28.75[a]	383.75 ± 43.22[a,b]	25.419	<0.001
1 month after surgery	285.11 ± 24.62[c]	337.75 ± 31.08[a,c]	362.35 ± 24.76[a,b,c]	62.090	<0.001
3 months after surgery	270.11 ± 38.42[c,d]	305.02 ± 17.71[a,c,d]	322.40 ± 19.75[a,b,c,d]	29.928	<0.001
6 months after surgery	265.47 ± 35.86[c,d]	294.98 ± 31.65[a,c,d]	314.15 ± 29.93[a,b,c,d]	16.407	<0.001
Time effect				92.494	< 0.001
Group effect				130.494	< 0.001
Time × group interaction				1.752	0.109

Abbreviations: OCT, optical coherence tomography; CMT, central macular thickness; SFCT, subfoveal choroidal thickness; NFCT, choroidal thickness at 1000 μm from the nasal side of the macular fovea; TFCT, choroidal thickness at 1000 μm from the temporal side of the macular fovea. Notes: [a] $p < 0.05$ vs. Stage I; [b] $p < 0.05$ vs. Stage II; [c] $p < 0.05$ vs. preoperative; [d] $p < 0.05$ vs. 1 month postoperative.

Table 4. Comparison of clinical characteristics and OCT parameters between prognostic groups.

Variable	Favorable group (n = 71)	Unfavorable group (n = 39)	$t/\chi^2/Z$	*p*-value
Age (years, $\bar{x} \pm s$)	63.76 ± 6.86	65.15 ± 5.90	1.069	0.287
Gender (n, %)			0.692	0.405
Male	36 (50.70)	23 (58.97)		
Female	35 (49.30)	16 (41.03)		
Affected eyes (n, %)			2.226	0.136
Left	36 (50.70)	14 (35.90)		
Right	35 (49.30)	25 (64.10)		
Disease course (months, $\bar{x} \pm s$)	4.28 ± 1.45	4.59 ± 1.75	0.969	0.335
Baseline BVCA (logMAR, $\bar{x} \pm s$)	0.50 (0.42, 0.57)	0.53 (0.42, 0.76)	1.450	0.147
Lens status (n, %)			0.051	0.822
Transparent lens	66 (92.96)	35 (89.74)		
Mild lens opacification	5 (7.04)	4 (10.26)		
Gas tamponade (n, %)			0.159	0.690
Pure C_3F_8	6 (8.45)	5 (12.82)		
C_3F_8 + Air	65 (91.55)	34 (87.18)		
OCT stage (n, %)			12.474	0.002
I	31 (43.66)	7 (17.95)		
II	33 (46.48)	19 (48.72)		
III	7 (9.86)	13 (33.33)		
1 month after surgery				
CMT (μm)	356.43 ± 43.20	399.21 ± 39.50	6.314	<0.001
SFCT (μm)	347.83 ± 41.15	384.18 ± 41.76	4.409	<0.001
NFCT (μm)	354.14 ± 34.08	360.00 ± 31.77	0.883	0.379
TFCT (μm)	317.30 ± 41.43	336.31 ± 36.58	2.397	0.018
3 months after surgery				
CMT (μm)	317.31 ± 40.62	341.80 ± 43.59	2.947	0.004
SFCT (μm)	305.25 ± 42.13	322.05 ± 41.27	2.015	0.046
NFCT (μm)	323.61 ± 32.13	332.64 ± 26.32	1.500	0.136
TFCT (μm)	292.69 ± 31.68	302.36 ± 35.93	1.459	0.147

icantly associated with favorable visual outcomes (OR = 0.98, 95% CI: 0.97–0.99, $p < 0.05$).

Discussion

By retrospectively analyzing the postoperative retinal structural and functional recovery trajectories of iERM patients with different OCT stages, this study demonstrated that CMT at 1 month postoperatively was significantly associated with favorable visual outcomes at 6 months, independent of baseline disease severity. After adjustment for potential confounders, multivariate logistic regression showed that lower CMT at 1 month remained significantly associated with a higher probability of a favorable visual outcome (OR = 0.98, 95% CI: 0.97–0.99, $p < 0.05$). SFCT exhibited a similar trend. However, it did not reach statistical significance in the adjusted model.

To date, it is generally accepted that the pathogenesis of iERM involves cellular proliferation and migration on the ILM, leading to mechanical traction and retinal deformation [15,16]. Vitrectomy combined with ILM and epiretinal membrane peeling relieves this traction, restores retinal anatomy [17], and improves hemodynamics [18,19,20], thereby creating favorable conditions for neural repair and visual recovery [21]. We observed significant stage-dependent differences in BCVA: patients with Stage I achieved the best visual outcomes at 6 months postoperatively, whereas those with Stage III exhibited limited recovery despite significant overall improvement. These findings are consistent with the study by Vounotrypidis et al. [22]. In their study, patients with Stage III presented with greater preoperative CMT and poorer baseline BCVA, suggesting more extensive inner retinal disorganization and potential irreversible photoreceptor damage. Even after successful traction release, the capacity for neuronal recovery may be limited, consistent with evidence that preoperative ellipsoid zone (EZ) disruption strongly predicts poor postoperative outcomes [23]. Although the present study did not directly quantify the ellipsoid zone, the structural disorganization reflected by higher OCT staging may indirectly reflect a similar state of severe damage.

In terms of anatomical reduction, this study observed that CMT in all patient groups decreased rapidly during the

Table 5. Multivariate logistic regression analysis of factors associated with good visual prognosis.

Variables	β	SE	*Z* statistic	*p*-value	OR (95% CI)
CMT1	–0.02	0.01	–2.28	0.023	0.98 (0.97–0.99)
CMT3	–0.00	0.01	–0.51	0.611	1.00 (0.98–1.01)
SFCT1	–0.01	0.01	–1.12	0.264	0.99 (0.98–1.01)
SFCT3	–0.00	0.01	–0.44	0.660	1.00 (0.99–1.01)
OCT stage					
Stage I					1.00 (Reference)
Stage II	0.34	0.85	0.40	0.686	1.41 (0.27–7.38)
Stage III	–0.04	1.23	–0.03	0.977	0.97 (0.09–10.77)

CMT1, CMT at 1 month after operation; SFCT1, SFCT at 1 month after operation; CMT3, CMT at 3 months after operation; SFCT3, SFCT at 3 months after operation; OR, odds ratio; SE, Standard Error.

Table 6. Multivariate logistic regression analysis adjusted for confounding factors.

Variable	β	SE	*Z* statistic	*p*-value	OR (95% CI)
CMT1	–0.02	0.01	–2.31	0.021	0.98 (0.97–0.99)
SFCT1	–0.01	0.01	–1.26	0.209	0.99 (0.98–1.00)
OCT Stage					
I					1.00 (Reference)
II	0.03	0.66	0.04	0.966	1.03 (0.28–3.75)
III	–0.86	0.97	–0.89	0.374	0.42 (0.06–2.82)
Lens status					
Transparent lens					1.00 (Reference)
Mild opacification	0.49	1.25	0.39	0.694	1.63 (0.14–18.79)
Gas tamponade					
Pure C_3F_8					1.00 (Reference)
C_3F_8 + Air	–1.12	1.12	–1.00	0.319	0.33 (0.04–2.95)
Disease course	–0.12	0.15	–0.81	0.421	0.89 (0.66–1.19)
Baseline BVCA	1.00	1.04	0.96	0.339	2.72 (0.35–21.04)

first 3 months postoperatively and subsequently stabilized. This reduction exhibited a clear stage-dependent pattern: the CMT of Stage I patients at 6 months postoperatively (275.76 ± 23.35 μm) approached the normal physiological range, while that of Stage II and III patients stabilized at relatively higher levels (325.46 ± 28.61 μm and 351.05 ± 40.96 μm, respectively). These findings suggest that in advanced iERM, although surgery can effectively alleviate acute edema caused by traction, it may not fully reverse chronic thickening resulting from retinal tissue remodeling, glial proliferation, or microvascular leakage due to long-term traction.

In addition to retinal thickness, this study incorporated choroidal parameters. We observed that SFCT, NFCT, and TFCT at 1, 3, and 6 months postoperatively were reduced compared with preoperative values, and that these parameters in Stage I were significantly lower than those in Stage II and III. Furthermore, after adjustment for baseline BCVA, disease duration, OCT stage, lens status, and gas tamponade use, CMT at 1 month postoperatively remained significantly associated with visual prognosis at 6 months.

Early postoperative CMT was independently associated with mid-term visual outcomes. A rapid reduction in CMT within the first postoperative month likely reflects effective relief of traction-induced macular edema, which may facilitate restoration of retinal architecture and photoreceptor function [17,24]. Second, although not statistically significant, the association between lower SFCT showed a non-significant trend toward better visual outcomes. Although changes in choroidal thickness were observed, these measurements do not directly reflect choroidal blood flow. Therefore, we refrain from drawing mechanistic conclusions about choroidal hemodynamics based on thickness data alone.

The OCT staging system used in this study was adapted from the classification proposed by Govetto et al. [11], which is based on the presence of ectopic inner foveal layers (EIFL) and the integrity of the EZ. Although this system has demonstrated prognostic value in multiple studies [2,9], other iERM staging systems have also been reported [25,26]. Therefore, the findings of this study should be interpreted within the context of this specific staging approach, and direct comparisons with studies using different classification systems may be limited. Nevertheless, the substantial interobserver agreement observed in our study (κ = 0.839) supports the reproducibility and reliability of

this staging method in both clinical practice and research settings.

This study has several limitations. First, as a single-center retrospective study, the sample size was relatively limited, particularly for Stage III patients (n = 20), which may reduce the statistical power of subgroup analyses and compromise the robustness of advanced-stage outcomes. Second, although multiple confounders were adjusted for, residual confounding due to unmeasured variables (e.g., detailed postoperative anti-inflammatory regimens or subtle cataract progression) cannot be entirely excluded. Third, the follow-up period was limited to 6 months, and longer-term outcomes require further investigation. Fourth, the absence of external validation of the regression model may limit its generalizability. Finally, although significant changes in choroidal thickness parameters were observed, these measurements do not directly reflect choroidal blood flow.

Conclusions

In summary, postoperative visual recovery of iERM patients is stage-dependent, and both functional and anatomical recovery may be limited in advanced-stage disease. CMT at 1 month postoperatively was significantly associated with visual outcomes at 6 months. These findings highlight the importance of incorporating early postoperative OCT evaluation into prognostic assessment, providing an objective basis for individualized prognostic counseling and more refined postoperative management of iERM.

Availability of Data and Materials

The data used to support the findings of this study are available from the corresponding author upon request.

Author Contributions

WFM and XXL designed the research study. YCZ collected the clinical data. WFM and YCZ performed the research and drafted the manuscript. All authors contributed to the critical revision of the manuscript for important intellectual content. All authors read and approved the final manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

This study conforms to the Declaration of Helsinki and has been approved by the Medical Ethics Committee of the Huzhou Aier Eye Hospital (No.20250105006). The requirement for informed consent was waived by the Medical Ethics Committee of the Huzhou Aier Eye Hospital due to the retrospective nature of the study and the use of de-identified patient data, in accordance with the Declaration of Helsinki.

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Conflict of Interest

The authors declare no conflict of interest.

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