Original Article

Visual outcomes of monocular idiopathic epiretinal membrane removal: a prospective follow-up study

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ABSTRACT

Background: Surgical intervention for an idiopathic epiretinal membrane (iERM) could alleviate metamorphopsia or improve vision. We evaluated changes in vision in patients undergoing treatment for monocular iERMs during a 6-month period. We investigated the rate of posterior vitreous detachment (PVD) using optical coherence tomography (OCT) imaging in eyes with iERM and in normal fellow eyes. We also examined the intraoperative rate of PVD in iERM eyes following the administration of triamcinolone acetonide (TA).

Methods: This prospective interventional case series recruited all eligible individuals with treatment-naive monocular iERM who were scheduled for pars plana vitrectomy (PPV) due to reduced best-corrected distance visual acuity (BCDVA) or metamorphopsia. OCT at baseline was used to determine the presence and stage of PVD in the eyes with iERM and the normal fellow eyes. Intraoperative TA-based PVD staging was performed for affected eyes.

Results: Participants comprised 32 cases, with 32 eyes with iERM and 32 normal fellow eyes. The mean (standard deviation [SD]) age was 60.9 (9.7) years, and the majority were men (n = 18, 56.2%). The baseline mean (SD) of BCDVA in affected eyes was 0.50 (0.21) logarithm of the minimum angle of resolution (logMAR), which improved to 0.34 (0.20) logMAR at the 1-month visit, representing a significant mean difference of 0.15 (0.20) logMAR ($P < 0.001$). At the 6-months visit, the mean (SD) BCDVA had further improved to 0.26 (0.19) logMAR, representing a significant mean difference of 0.23 (0.26) logMAR ($P < 0.001$) from the baseline value. The mean (SD) visual improvement between the 1- and 6-months follow-ups was 0.07 (0.14) logMAR, which was statistically significantly ($P < 0.05$). The mean changes in BCDVA were more pronounced in patients aged < 60 years than in those aged ≥ 60 years. The proportion of eyes at each stage of PVD detected by preoperative OCT in eyes with iERM differed from that detected by intraoperative TA staining. By both methods, the stages advanced significantly with increasing age (both $P < 0.001$). Similarly, the proportion of eyes at each stage of PVD detected by preoperative OCT in the normal fellow eyes was also higher and advanced significantly with increasing age ($P < 0.001$).

Conclusions: Continuous visual improvement is anticipated up to 6 months after surgery in eyes with iERM, and this improvement is likely to be more significant in younger individuals. The incidences of each PVD stage varies depending on the use of preoperative OCT or intraoperative TA in these cases. A higher rate of PVD observed in fellow eyes may suggest that PVD progresses through its stages simultaneously and without complications in normal eyes. Further studies are needed to validate our preliminary results and confirm these conclusions.

KEYWORDS

posterior vitreous detachment, epiretinal membranes, vitrectomies, optical coherence tomography, metamorphopsia, visual acuities

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INTRODUCTION

The epiretinal membrane (ERM) is a semi-transparent, fibrocellular layer that forms on the inner surface of the retina, specifically along the internal limiting membrane (ILM) [1]. Its development could be idiopathic (iERM), following a disruption of the vitreoretinal interface that is associated with posterior vitreous detachment (PVD) [1], which is observed in 95%–100% of iERM cases [2]. Alternatively, ERM develops secondary to various causes, such as vascular occlusion, uveitis, trauma, intraocular surgery, diabetic retinopathy, or retinal breaks [2, 3]. Structural optical coherence tomography (OCT) has significantly improved the characterization of iERM [4, 5].

While relatively common, iERM has no gender predilection [6, 7], and according to autopsy findings appears in 2% and 20% of individuals over the age of 50 and 75 years, respectively [8]. ERM is bilateral in only 10%–20% of cases, indicating a high degree of asymmetry [6]. The most consistent risk factor for ERM development is increasing age. The majority of patients presenting with ERMs are aged over 50 years, with the highest prevalence observed in individuals in their seventies [2, 3, 9].

Asymptomatic ERMs should be monitored as they often worsen, which may occur shortly after detection [10]. Mild cases do not require treatment, and in rare instances, the ERM may resolve spontaneously [11], leading to an improvement in symptoms. Indications for treatment include reduced vision or significant visual distortion. The goal of surgical intervention is to alleviate metamorphopsia or to improve vision [12].

Herein, we evaluated changes in vision during a short-term follow-up in patients undergoing treatment for monocular iERMs. Additionally, we used OCT to investigate the rate of PVD in eyes with iERM and normal fellow eyes. We also examined the intraoperative rate of PVD in iERM eyes following the administration of triamcinolone acetonide (TA).

METHODS

This prospective interventional case series recruited all eligible individuals with treatment naive monocular iERM who were scheduled for pars plana vitrectomy (PPV) by a single vitreoretinal surgeon (M.B.) at Imam Khomeini Ophthalmology Center of Kermanshah, Iran, from September 2019 to September 2022. The study protocol was approved by the local Ethics Committee of Kermanshah University of Medical Sciences and adhered to the principles of the Declaration of Helsinki. Informed consent was obtained from all participants.

All eligible patients diagnosed with treatment-requiring monocular iERMs [2, 4], who had a reduced best-corrected distance visual acuity (BCDVA) of 20/50 or worse or had intolerable metamorphopsia, were included. Patients diagnosed with secondary ERM or bilateral iERM; with vitreoretinal diseases or media opacities; with a history of any intraocular surgery; and lactating or pregnant women were excluded.

Baseline clinical and demographic characteristics of the patients, including age, sex, and laterality of the affected eye, duration of symptoms, main surgery indication (reduced vision or metamorphopsia), systemic comorbidities, and history of smoking, were recorded. Participants underwent thorough ophthalmological examinations. These included BCDVA measurement with a Snellen visual acuity chart (Nikon Chart Projector NP-3S; Nikon Inc, Melville, NY, USA) and recorded in logarithm of the minimum angle of resolution (logMAR) notation. Additionally, slit-lamp biomicroscopy examination of the anterior and posterior segments (Photo-Slit-Lamp BX 900; Haag-Streit, Koeniz, Switzerland), and detailed posterior segment examination with indirect ophthalmoscopy (Heine Omega Indirect ophthalmoscope; Heine Optotechnik GmbH, Gilching, Germany) were performed using a 20-diopter condensing lens (Volk Optical, Inc., Mentor, OH, USA). Moreover, intraocular pressure was measured with Goldmann applanation tonometry (AT900, Haag-Streit, Koeniz, Switzerland).

The diagnosis of ERM was made based on fundus examination by an expert medical and surgical retina subspecialist (B.M.) and was confirmed by OCT angiography (OCT-A; RTVue XR Avanti, OptoVue, Inc., Fremont, CA, USA) [4, 5]. All eyes were dilated with 1% tropicamide eye drops (Mydrax 1%, Sina Daru, Tehran, Iran) before acquiring OCT-A scanning. Furthermore, baseline OCT-A imaging was used to determine the presence and stage of the PVD in eyes with iERM and in the normal fellow eyes [13, 14]. Stage 0 of PVD indicates an absence of PVD. Stage 1 involves focal perifoveal PVD, with persistent attachment to the fovea, optic nerve head, and mid-peripheral retina. Stage 2 involves macular PVD, where attachment to the optic disc persists, but adhesion to the fovea is absent. In stage 3, PVD is nearly complete, with adhesion only at the vitreopapillary junction. Finally, stage 4 represents complete PVD [15, 16].

An expert medical and surgical retina subspecialist (B.M.) performed all surgeries under general anesthesia, using a standard three-port, 23-gauge PPV with a non-contact binocular indirect operating microscope system (Oculus Inc., Petaluma, CA, USA). Following trocar placement in the pars plana region (4 mm from the limbus), core vitrectomy was applied, TA 10 mg/mL (Triamcinolone Acetonide, Sina Darou, Tehran, Iran) was injected into the vitreous cavity. The surgeon then determined the stage of PVD for each eye based on TA staining [14]. When PVD was absent, the posterior hyaloid membrane was detached around the optic disc using a vitrectomy probe, followed by removal of the peripheral vitreous. The ERM and ILM were stained with Trypan Blue (Vision Blue, 0.06%, DORC International BV, Zuidland, The Netherlands) and Brilliant Blue (Ocublue Plus, Brilliant Blue G solution, Aurolab, Madurai, India), respectively, before peeling. The surgery was further carried out as explained in depth elsewhere [17-20].

Postoperatively, eyes received ciprofloxacin hydrochloride 0.3% eye drops (Ciplex; Sina. Darou, Tehran, Iran) four times daily for 10 days and betamethasone 0.1% eye drops (Betasonit; Sina. Darou, Tehran, Iran) six times daily, tapered during the

4 weeks' follow-up, using an individualized approach. Patients underwent frequent detailed ophthalmological examinations at postoperative follow-ups. BCDVA was recorded at the 1- and 6-months follow-up visits.

Data were analyzed statistically using SPSS Statistics Software for Windows (version 25.0; IBM Corp., Armonk, NY, USA). The Kolmogorov–Smirnov test was used to assess the normality of data distribution. Data were summarized as mean (standard deviation [SD]) or frequency (percentage) as appropriate. The one-way analysis of variance (ANOVA), paired-samples *t*-test, and independent samples *t*-test were used for comparison when applicable. A *P*-value < 0.05 indicated statistical significance.

RESULTS

The patient group comprised 32 cases with 32 eyes diagnosed as iERM and 32 fellow normal eyes. The mean (SD) age was 60.9 (9.7) years (range: 39–80 years). Eighteen (56.2%) participants were men and 14 (43.8%) were women. In 17 (53.1%) patients, the right eye, and in 15 (46.9%) patients, the left eye had been diagnosed with iERM. The main surgery indication in 29 (90.6%) eyes was reduced BCDVA, while in three (9.4%) eyes, the indication was metamorphopsia. Twenty (62.5%) patients had no systemic comorbidities, seven (21.9%) had systemic hypertension, four (12.5%) had diabetes mellitus without clinically evident retinopathy (3 [9.4%] patients with type II diabetes mellitus and 1 [3.1%] with type I diabetes), while one patient (3.1%) had both hypertension and type II diabetes mellitus. Ten patients (31.3%) had a history of smoking (Table 1).

The mean (SD) of BCDVA at baseline in the affected eyes was 0.50 (0.21) logMAR (range: 0.15–1.0 logMAR) and improved to 0.34 (0.20) logMAR at the 1-month postoperative visit, representing a significant mean difference of 0.15 (0.20) logMAR (*P* < 0.001). At the 6-months postoperative visit, the mean (SD) BCDVA had further improved to 0.26 (0.19) logMAR, representing a significant mean difference of 0.23 (0.26) logMAR (*P* < 0.001) relative to baseline. The mean (SD) visual improvement between the 1-month and 6-months follow-ups was 0.07 (0.14) logMAR, which was statistically significant (*P* < 0.05) (Table 2). Therefore, eyes with treated iERM demonstrated continuous visual improvement during the 6 months after surgery.

In subgroup analysis, the mean changes in BCDVA were more pronounced in patients younger than 60 years than in those 60 years and older (Table 3), indicating greater visual improvement in younger patients.

Preoperative OCT-based staging for PVD detected two eyes with iERM at stage 0, six eyes at stage 1, five eyes at stage 2, eight eyes at stage 3, and 11 eyes at stage 4. Intraoperative TA-based PVD staging detected two eyes at stage 0, four eyes at stage 1, six eyes at stage 2, seven eyes at stage 3, and 13 eyes at stage 4. Both OCT-based preoperative and TA-based intraoperative staging of PVD in eyes with iERM demonstrated a significant advance in staging with increasing age (both *P* < 0.001) (Table 4).

Preoperative OCT-based staging for PVD in the normal fellow eye detected no eye with stage 0, three eyes at stage 1, seven eyes at stage 2, six eyes at stage 3, and 16 eyes at stage 4. OCT-based staging for PVD in normal fellow eyes advanced significantly with increasing age (*P* < 0.001) (Table 4). The rate of PVD detected by OCT was higher in the normal fellow eyes than in the iERM eyes.

No signs of recurrence were detected during clinical examinations conducted over 6-month follow-up period.

Table 1. Demographic and clinical characteristics of the study participants

Variable	Value
Age (y), Mean ± SD (Range)	60.9 ± 9.7 (39 to 80)
Sex (Men / Women), n (%)	18 (56.2) / 14 (43.8)
Laterality of iERM (OD / OS), n (%)	17 (53.1) / 15 (46.9)
Main surgery indication (Reduced vision / Metamorphopsia), n (%)	29 (90.6) / 3 (9.4)
History of smoking (Smoker/ Non-smoker), n (%)	10 (31.3) / 22 (68.7)
Systemic comorbidities	
Type I diabetes mellitus, n (%)	1 (3.1)
Type II diabetes mellitus, n (%)	3 (9.4)
Systemic hypertension, n (%)	7 (21.9)
Both hypertension and type II diabetes mellitus, n (%)	1 (3.1)
None, n (%)	20 (62.5)

Abbreviations: y, years; SD, standard deviation; n, number; %, percentage; iERM, idiopathic epiretinal membrane; OD, right eye; OS, left eye.

Table 2. Comparison of mean difference in BCDVA between follow-up visits in eyes with iERM

Changes in BCDVA (logMAR)	Mean difference ± SD	*P*-value
Between baseline and 1-month postop visit	0.15 ± 0.20	**< 0.001**
Between baseline and 6-month postop visit	0.23 ± 0.26	**< 0.001**
Between 1- and 6-month postop visit	0.07 ± 0.14	**0.007**

Abbreviations: BCDVA, best-corrected distance visual acuity; iERM, idiopathic epiretinal membrane; logMAR, logarithm of the minimum angle of resolution; SD, standard deviation; postop, postoperative. Note: *P*-value < 0.05 are shown in bold.

Table 3. Comparison of mean difference in BCDVA between follow-up visits in eyes with iERM, according to age groups

Age group	Between baseline and 1-month postop, Mean difference ± SD (logMAR)	Between baseline and 6-month postop, Mean difference ± SD (logMAR)	Between 1- and 6-month follow-ups, Mean difference ± SD (logMAR)	[1] *P*-value
< 60 y, (n =12)	0.23 ± 0.19	0.28 ± 0.26	0.05 ± 0.11	**0.023**
≥ 60 y, (n =20)	0.08 ± 0.13	0.17 ± 0.20	0.09 ± 0.15	0.219
[2] *P*-value	0.117	0.451	0.362	

Abbreviations: BCDVA, best-corrected distance visual acuity; iERM, idiopathic epiretinal membrane; y, years; n, number of patients; logMAR, logarithm of the minimum angle of resolution; SD, standard deviation. Note: *P*-value < 0.05 is shown in bold; [1] *P*-value, [1] *P*-value for comparing across follow-up visits within each age group; [2] *P*-value; [2] *P*-value for comparing between two age groups at each follow-up visit.

Table 4. Proportion of eyes with iERM and normal fellow eyes in each stage of PVD, with the corresponding mean age of participants

Variable	Mean ± SD of participants' age in years in each stage					*P*-value
	Stage 0	Stage 1	Stage 2	Stage 3	Stage 4	
OCT-based preoperative staging of PVD in eyes with iERM, n (%)	2 (6.3) 41.0 ± 2.8	6 (18.8) 51.5 ± 5.7	5 (15.6) 60.6 ± 6.7	8 (25.0) 64.5 ± 3.9	11 (34.4) 67.3 ± 7.7	**< 0.001**
Intraoperative TA-based staging of PVD in eyes with iERM, n (%)	2 (6.3) 41.0 ± 2.8	4 (12.5) 49.0 ± 4.9	6 (18.8) 58.7 ± 6.20	7 (21.9) 64.6 ± 4.2	13 (40.6) 66.8 ± 7.1	**< 0.001**
OCT-based preoperative staging of PVD in normal fellow eyes, n (%)	0 (0.0) -	3 (9.4) 43.7 ± 5.0	7 (21.9) 54.6 ± 8.4	6 (18.8) 67.3 ± 7.5	16 (50.0) 64.6 ± 5.9	**< 0.001**

Abbreviations: PVD, posterior vitreous detachment; iERM, idiopathic epiretinal membrane; OCT, optical coherence tomography; n, number of eyes; %, percentage; SD, standard deviation; TA, triamcinolone acetonide 10 mg/mL (Sina Darou, Tehran, Iran). Note: *P*-value < 0.05 are shown in bold; Stage 0, absence of PVD; Stage 1, focal perifoveal PVD, with persistent attachment to the fovea, optic nerve head, and mid-peripheral retina; Stage 2, macular PVD, with persistent attachment to the optic disc but no adhesion to the fovea; Stage 3, near-complete PVD, with adhesion only at the vitreopapillary junction; Stage 4, complete PVD [15, 16].

DISCUSSION

We studied 32 patients, each with one eye diagnosed with iERM and one fellow normal eye. Over a follow-up period of up to 6-months after surgery, eyes treated for iERM showed continuous improvement in vision. Notably, younger patients experienced greater visual improvement than did older patients. Additionally, the frequency of PVD varied between preoperative OCT-based staging and intraoperative TA-based PVD staging in eyes affected by iERM. The PVD stage advanced significantly with increasing age in both the affected and the normal fellow eyes.

iERM surgery is both safe and effective in improving vision in most cases [21, 22] and resolves subjective symptoms, particularly in patients with considerable preoperative disturbance [23]. Monocular iERM eyes that are indicated for surgery may experience significant visual improvement postoperatively [8, 22, 24-26], as reported in both iERM and secondary ERM cases at a mean postoperative follow-up of 28.95 months in patients aged < 40 years [27]. In a 10-year follow-up study of 49 patients with surgically treated iERM, Elhusseiny et al. [28] observed continuous visual improvement over the first 3 years, after which vision remained stable up to 10 years postoperatively [28]. Continuous visual improvement up to 6 months (short-term) [29] and 41.6 months (long-term) [30] postoperative follow-up of surgically treated iERM have been reported. In contrast, Kim et al. [31] found that the majority of changes in the best-corrected visual acuity (BCVA) occurred during the first 3 months after surgery, and that BCVA had stabilized by the 12-months postoperative visit [31]. However, Konstantinidis et al. found that 84% of the total improvement in BCDVA occurred within the first week after surgery [32]. In a study by Donati et al. [33], 20 eyes from 20 patients with iERM were examined. The mean (SD) visual acuity at baseline was 0.55 (0.08) logMAR, which significantly improved to 0.33 (0.05) logMAR by day 180. Their results indicated that iERM surgery leads to a continuous improvement in visual function, not only by 1-month post-surgery but also beyond 6 months [33]. The current study observed a continuous improvement in vision over 6 months after surgery in eyes treated for iERM.

A retrospective study of 114 patients with iERM revealed that those with preoperative inner retinal deformation had significantly improved long-term visual outcomes after iERM removal [34]. Akincioglu et al. recruited 45 eyes from 45 patients (36% men and 64% women) with a mean (SD) age of 69 (8.2) years, diagnosed with iERM, were followed for an average of 7 months. The researchers observed a continuous improvement in visual acuity, with mean (SD) BCVA at baseline and at postoperative visits at 3, 6, and 12 months of 0.58 (0.32), 0.40 (0.31), 0.33 (0.33), and 0.28 (0.34) logMAR, respectively [35]. Likewise, Jiao et al. studied 75 eyes with iERM for 12 months. The researchers observed a continuous improvement in visual acuity after surgery, with mean (SD) BCVA at baseline and at postoperative visits at 1, 3, 6, and 12 months after surgery of 0.59 (0.26), 0.63 (0.34), 0.46 (0.22), 0.45 (0.23), and 0.41 (0.23) logMAR, respectively [36].

Mao et al. [37] conducted a study involving 108 eyes from 106 patients, with a mean (SD) age of 66.87 (7.98) years, all diagnosed with iERM. Preoperatively, they categorized the patients into four stages based on the anatomical structure of the macula as observed in OCT B-scan images. They found a significant visual improvement at a minimum follow-up of 6 months as compared to baseline values [37]. Sato et al. [38] reported significant visual improvement and a decrease in the area of paravascular abnormalities at the 6-months postoperative follow-up in 28 eyes with concurrent iERM and paravascular abnormalities [38]. Haseeb et al. [39] conducted a study involving 43 patients with a mean (SD) age of 59.98 (6.1) years who were diagnosed with iERM. The mean (SD) visual acuity improved significantly from 0.59 (0.21) logMAR at baseline to 0.33 (0.21) logMAR at the final 6-months follow-up [39]. In our patients, the mean BCDVA had improved significantly by 1 and 6 months after the surgery, as compared to the preoperative stage. Comparison of findings at the 1-month and 6-months follow-up revealed a significant improvement in the patients' BCDVA, which indicates that functional improvement proceeds for months postoperatively.

Fang et al. [40] observed different clinical features of the ERMs in young patients compared with older individuals [40]. The mean baseline BCVA in young patients was 20/140 (range: 20/250–20/63) and improved significantly to 20/30 (range: 20/40–20/20) at 14.6 months (range: 6–42 months) postoperative visit [40]. Benhamou et al. [41] conducted a study involving 20 young patients, with a mean age of 16.3 years, who had either iERM or secondary ERM. They found clinical characteristics in these patients that differed from those typically seen in adults [41]. All eyes of the young patients showed a significant improvement in final BCDVA, with improvement from 20/112 to 20/50 logMAR, over a mean follow-up period of 21.2 months [41]. Follow-up at 12-months post-surgery for 44 eyes with surgically treated iERM showed that achieving a final visual acuity better than 0.5 logMAR was associated with younger age. The multifactorial analysis confirmed that age (odds ratio = 0.862, 95% confidence interval = 0.745–0.099, P = 0.048) was one of the important factors affecting the visual outcome, after adjusting for other factors [42]. In contrast, Moisseiev et al. [43] conducted a retrospective chart review of patients aged ≥ 75 years who underwent surgery for iERM and found that the postoperative visual outcomes in older patients were comparable to those previously reported for younger patients with iERM. The authors suggested that age should not be a barrier to surgery for patients with iERM who wish to improve their vision and quality of life [43]. In the current study, the mean changes in BCDVA were more pronounced in patients who were younger than 60 years than in those aged 60 years or older.

Tanikawa et al. [44] observed no significant correlation between BCDVA and the measurements of metamorphopsia and aniseikonia, taken both horizontally and vertically, in patients with treatment-naive iERM [44]. These findings suggested that metamorphopsia and aniseikonia may be independent of BCDVA in eyes with ERM. Therefore, quantitative assessments of these symptoms are necessary for a comprehensive evaluation of visual function, alongside BCDVA in patients with ERM [44]. In a prospective observational study involving 45 eyes with iERM from 45 patients, Takabatake et al. [45] reported a significant improvement in BCDVA and horizontal metamorphopsia at the 6-months postoperative visit. However, the reduction in aniseikonia was statistically significant only at the 12-months follow-up [45]. In our study, the primary indication for surgery was reduced vision, reported in 29 patients (90.6%), rather than metamorphopsia, which affected three patients (9.4%). All eyes experienced significant improvement in visual symptoms over the 6-months follow-up.

Better preoperative vision predicts better postoperative vision in eyes with symptomatic iERM [30, 46-49]. At 6 months after iERM surgery, Byon et al. [50] found that patients with good vision maintained their visual acuity after a temporary worsening, while patients with poor vision achieved significant improvement in their visual acuity [50]. We did not analyze our data in this respect.

Chang et al. [51] conducted a retrospective, consecutive, and comparative study involving 60 patients with iERM who were scheduled for one of three treatment options: traditional ERM peeling, ERM peeling combined with ILM peeling as a whole, or maculorrhexis ILM peeling. At the 12-months follow-up, the mean BCDVA in eyes treated with maculorrhexis ILM peeling was significantly better than that of the other two methods [51]. Cubuk et al. [52] compared visual outcomes of ERM peeling with or without ILM peeling over a mean follow-up of 14.1 months. They observed a significant and similar visual improvement in both groups, yet the recurrence rate was significantly higher in eyes with ERM peeling only [52].We performed Trypan Blue dye-assisted ERM removal within a fovea-centered circular area of 3 optic disc diameters, followed by Brilliant Blue dye-assisted ILM peeling from an area around the fovea with a size of 2 disc diameters. All eyes experienced significant visual improvement over the 6-months follow-up.

The frequency of PVD was significantly higher in eyes with ERM [53], presenting in up to 90% of clinically significant ERMs [10]. Partial or complete PVD is found in 80–95% of eyes with iERM [54]. Yamashita et al. [55] evaluated the intraoperative characteristics of the posterior vitreous cortex in 15 patients with iERM who showed no signs of PVD during both slit-lamp and B-scan ultrasound examinations. During vitrectomy, the surgeon observed the relationship between the posterior vitreous cortex and the ERM membrane while inducing PVD using TA. They identified three distinct patterns: 1) In seven eyes (47%), a round defect in the posterior vitreous cortex was observed after surgical PVD, while an ERM remained attached to the macula. 2) In three eyes (20%), a complete detachment of the vitreous cortex along with the ERM were noted. 3) In five eyes (33%), the posterior vitreous cortex was detached without forming a round defect, again leaving the ERM on the macula. Notably, four of these five eyes exhibited a discrete linear signal over the macular area on preoperative OCT imaging [55]. They concluded that the observation that the posterior vitreous cortex can split into lamellae during surgery supports the hypothesis that ERMs result from anomalous PVD, accompanied by vitreoschisis, which leaves the outermost layer of the posterior vitreous cortex attached to the macula [55]. In the current study, more than 93% of eyes with iERM showed some level of PVD, as detected through preoperative OCT-based and intraoperative TA-based staging. Notably, this rate reached 100% in the normal fellow eyes based on preoperative OCT imaging. This observation may be due to anomalous PVD presence in eyes with ERM. Further studies are needed to validate this justification.

During vitrectomy, an undetached posterior hyaloid membrane was observed in 82 (20.1%) of 408 eyes with iERM by Luc et al. [56]. Janknecht et al. studied the prevalence of PVD in patients with iERM during vitrectomy. They recruited 34 patients, with a mean age of 72.9 years, who had been diagnosed with iERM and underwent 20-G vitrectomy. The ERM along with any remaining vitreous was stained using Membrane Blue. They found that PVD was present in 50% of the patients, and detected no correlation between age and the prevalence of PVD. Postoperatively, an improvement in visual acuity was observed [57]. The authors noted that, contrary to earlier literature, patients with an iERM typically did not exhibit a PVD. It is particularly important to conduct this check, which can be easily performed during surgery using Membrane Blue, as achieving PVD is more challenging with a 23-G vitrectomy than with a 20-G vitrectomy [57]. The frequency of PVD in eyes with iERM in the current study was higher.

The study by Luc et al. also revealed that iERM can occur without preexisting PVD [56]. Thus, the induction of PVD is necessary to reach the surgical endpoint. This information is crucial, as the peeling of iERM can pose risks when the posterior hyaloid membrane is still attached [56]. In the present study, all patients had advanced stage ERM, requiring surgical intervention. However, the observed rate of PVD in eyes with iERM was lower than that in the normal fellow eyes. The frequency of preoperative PVD observed by OCT in each stage was different from that determined using TA during surgery in eyes with iERM. This observed discrepancy may have several explanations. First, the accuracy of preoperative OCT imaging for diagnosing PVD has a lower sensitivity and specificity than that of intraoperative TA staining [14]. Moreover, the diagnosis of complete PVD using macular OCT is less accurate and often requires the use of ultrasound for confirmation [13]. Additionally, the interval between diagnostic imaging and surgery could allow for PVD to develop. Lastly, PVD could possibly have been induced in the early stages of surgery after the core vitrectomy, since staining with TA is performed after core vitrectomy. Further studies are needed to verify these justifications.

A deep-learning model, trained on preoperative OCT images—comprising 1392 images from 696 eyes with iERM—demonstrated a high level of effectiveness in predicting the outcomes of iERM surgery. It also helped to clarify the structural mechanisms observed in the OCT images [58]. Among the tested models, ResNet-101 achieved the best overall performance, as indicated by various metrics: recall, specificity, precision, F1-score, accuracy, and the area under the receiver operating characteristic curve, all of which were greater than or equal to 0.90. This model outperformed general ophthalmologists and non-retina specialists, and it slightly surpassed the performance of retina specialists [58]. Jin et al. [1] developed and tested an integrated deep-learning model for iERM, using 4547 OCT B-scans collected from four different commercial OCT devices across nine international medical centers. This integrated network effectively improved grading performance by 1–5.9% as compared to traditional classification deep-learning models. It achieved high accuracy scores of 82.9%, 87.0%, and 79.4% in the internal test dataset and two external test datasets, respectively. These results were comparable to those of retinal specialists, whose average accuracy scores were 87.8% and 79.4% in the two external test datasets [1]. Although, we did not test a deep-learning model in the current study, further studies using big data and a deep-learning method could help to develop an optimal model for predicting functional and anatomical outcomes of iERM after surgery.

The current study observed continued visual improvement in eyes that had been surgically treated for iERM, with greater enhancement noted in individuals younger than 60 years. Additionally, the rate of PVD identified in preoperative OCT was higher in the normal fellow eyes than in those affected by iERM. However, the study's short follow-up period, small sample size, and the absence of diagnostic accuracy tests to confirm the effectiveness of OCT-based and TA-based PVD staging may limit the generalizability of our findings. Therefore, further studies that focus on diagnostic accuracy are necessary to provide more conclusive results.

CONCLUSIONS

Continuous visual improvement can be anticipated in the short-term after surgery for eyes with iERM. This improvement is likely to be more significant in younger individuals. The rate of detection of different PVD stages varies depending on whether preoperative OCT or intraoperative TA staining is used. The higher rate of PVD observed in fellow eyes may suggest that PVD progresses through its stages in the fellow eye simultaneous with the iERM eye without conversion to anomalous PVD. Further studies are needed to validate these findings and confirm this hypothesis.

ETHICAL DECLARATIONS

Ethical approval: The study protocol was approved by the local Ethics Committee of Kermanshah University of Medical Sciences and adhered to the principles of the Declaration of Helsinki. Informed consent was obtained from all participants.

Conflict of interests: None.

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