Effect of Foveal Pit Restoration in Foveal Avascular Zone After Surgery for idiopathic Epiretinal Membrane

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ABSTRACT

Purpose: To investigate the relationship between ophthalmic parameters—including optical coherence tomography (OCT) and optical coherence tomography angiography (OCTA) findings—and foveal pit restoration in eyes that had undergone vitrectomy for idiopathic epiretinal membrane (iERM) removal.

Methods: This study retrospectively analyzed data of patients who underwent pars planar vitrectomy (PPV) for the removal of ERM. Only eyes with iERM above stage 2 with a follow-up over 6 months were included. Baseline data and changes in ophthalmic parameters were analyzed from 3 months before to 12 months after surgery. Additionally, we stratified iERM patients into two groups (foveal pit restoration and no restoration group). Longitudinal comparison analyses between the two groups were done in best-corrected visual acuity (BCVA), central foveal thickness (CFT) and foveal avascular zone (FAZ) areas measurements using swept-source OCT and OCTA.

Results: Forty-three patients with a mean age of 75 ± 5 years were enrolled. After surgery, BCVA, FAZ, and CFT showed improvements over time (all p-value < 0.002). Thirty-one patients were designated into the foveal pit restoration (R) group and 12 patients into the no restoration (NR) group. Differences in BCVA and FAZ area in both groups existed up to 6 months. However, BCVA improved and FAZ expanded (R: 0.20 ± 0.05 vs. NR: 0.18 ± 0.04) in both groups showing no statistical difference 12 months post-surgery. The CFT decreased in both groups, but the R group was thinner at every point compared to the NR group (all p-values < 0.05).

Conclusions: The removal of ERM in PPV significantly improves BCVA, decreases the CFT and expands the FAZ. Foveal pit restoration improves BCVA, CFT and FAZ area possibly at a faster rate in the early months but long-term improvements could be achieved regardless of the status of foveal pit restoration.

Keywords: Foveal avascular zone, Foveal pit, Idiopathic epiretinal membrane, OCT angiography, Pars planar vitrectomy
Introduction

Idiopathic macular epiretinal membrane (iERM) is one of the most common retinal diseases in older adults, characterized by proliferation of fibrocellular tissues over the internal limiting membrane (ILM) [1-3]. Traction forces caused on the retinal surface by the ERM results in the loss of foveal depression, disturbance of the inner and outer layers of the retina as well as retinal vessel movements [4-6]. These anatomic changes may cause decreased vision, metamorphopsia, and aniseikonia [1,4,5].

According to previous studies, the integrity of the ellipsoid zone is a prognostic factor in the visual acuity of patients with iERM [7]. The inner-retinal irregularity index has been suggested as a prognostic factor for iERM [8], but it could be difficult to measure in low-resolution optical coherence tomography (OCT) images, including time-domain OCT demanding a multi-step process in obtaining its value [8]. Thus, it might be complicated and time-consuming to use intuitively in real-world clinics.

Alternatively, anatomical recovery is the most intuitive hallmark of success in ERM surgery. However, despite successful ERM removal not all eyes regain foveal depression. Few studies exist on the recovery of foveal depression and surgical functional outcome. Mathews et al. reported that in many of the patients (83%) loss of foveal depression persists after surgery [2]. Twenty-seven out of forty-three eyes did not recover foveal contour after surgery in a study done by Lim et al [9]. Controversies exist in whether such foveal morphology has an impact on functional improvement. Some observed a faster visual acuity improvement in the anatomic recovery group, while others claim that an absence of foveal depression does not necessarily mean compromised visual acuity [2,9].

With the recent advancement of optical coherence tomography angiography (OCTA), a noninvasive imaging technique that allows acquisition of high-resolution depth-resolved images of the retinal vascular layers [10], further investigation beyond the anatomic change is available. Studies on retinal diseases are being conducted based on the parameters of OCTA, which can clearly describe the complexities of the vessels at the edge of the foveal avascular zone (FAZ) [11]. In cases of patients with ERM, FAZ should be analyzed carefully, as ERM may disrupt the layered structure of the retina and distort FAZ owing to the architectural changes in the perifoveal capillary network [11]. Although there have been studies analyzing OCTA features after iERM surgery, few have studied OCTA features between different anatomic recovery groups (restoration vs. no restoration) to the best of our knowledge. Therefore, in this study we investigated the relationship between ophthalmic
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parameters—including OCT and OCTA findings—and anatomic recovery in eyes that had undergone vitrectomy for idiopathic ERM removal.

Materials and Methods

Subjects

We reviewed the medical records of patients who underwent pars planar vitrectomy (PPV) for removal of ERM between January 2019 and December 2019 at the Veterans Health Service Medical Center. The inclusion criteria were patients who had unilateral iERM above stage 2 according to the Govetto A et al. [12]’s classification which is defined by an absence of the foveal pit and disorganization of the retinal layers in the stages beyond. Patients with at least 6 months’ follow-up, pre- and postoperative OCTA images obtained with sufficiently high quality for analysis were included. Those with recurrent ERM, diabetic retinopathy, retinal vessel occlusion, age-related macular degeneration, retinal break, or a history of vitrectomy surgery in the study eye, or any retina-associated pathology in the unaffected contralateral eye were excluded.

Surgery was performed by a single experienced vitreoretinal specialist. All patients underwent 25-gauge pars planar vitrectomy, ERM removal and ILM peeling assisted with triamcinolone staining (40mg/mL) (Constellation, Alcon Laboratories, Fort Worth, TX, USA). Phacoemulsification and posterior chamber lens implantation were performed during surgery in patients with phakic eyes.

Baseline data—age, gender, diabetes, hypertension, lens status, duration of ERM, best-corrected visual acuity (BCVA; logarithm of the minimum angle of resolution [logMAR])—were obtained. Duration of ERM was calculated as the time between the initial day of diagnosis at our clinic (if medical record did not indicate otherwise) to the day of surgery. This study adhered to the tenets of the Declaration of Helsinki and was approved by the institutional review board of the Veterans Health Service Medical Center (IRB No. 2019-02-005) in the Republic of Korea.

OCT and OCTA analysis

We used the SS-OCT and OCTA system (DRI OCT Triton, Topcon Corporation, Tokyo, Japan) for the pre- and postoperative examinations. OCT and OCTA images of both eyes were acquired at -3, 0, 1, 3, 6 and 12 months pre(-)/post-surgery. Images taken 3 months before surgery were included in the analysis to weigh the effects of progression of retinal wrinkling causing potential OCTA segmentation errors.
OCT images were obtained as a three-dimensional macular (7mm x 7mm) scan, scan size 512 x 256. For CFT, the distance between the inner limiting membrane and the inner surface of the retinal pigment epithelium on the central fovea was manually measured on the horizontal cross-sectional image, using the built-in scale of the OCT software. In addition, ellipsoid zone (EZ) disruption and inner-retinal irregularity index [8] were examined on OCT as prognostic factors. EZ was considered as a disruption if there was a discontinuity in the horizontal and vertical foveal B-scan. The inner-retinal irregularity index is defined as the length of the inferior border of the inner plexiform layer (IPL) divided by the length of the retinal pigment epithelium (RPE). It was measured using a “freehand line” tool in the Image J software (National Institutes of Health, Bethesda, Maryland, USA) within a 3000 μm Early Treatment Diabetic Retinopathy Study (ETDRS) inner circle. To reduce error, the average inner-retinal irregularity index of three measurements was taken. In the OCTA volume scans of a central 6 x 6 mm area, initial retinal vasculature en-face image of superficial capillary layer (SCL) was obtained via automated layer segmentation. All automated segmentations were re-evaluated for any layer segmentation errors and adjusted manually if present. The superficial capillary network was determined to be between 3 μm below the ILM and to 15 μm below the inner plexiform layer. The FAZ area was defined as the central capillary-free area and measured using a “freehand selection” tool in Image J software. The FAZ area in the SCL and CFT were independently measured by two individuals (B.J.B and Y.J.C). The repeatability of the measurements between the two examiners was good for both the superficial capillary layer FAZ area (intraclass correlation coefficient [ICC] = 0.95) and CFT (ICC = 0.99).
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Defining Foveal Pit Restoration

To assess the effect of the foveal pit contour on ophthalmic parameters, subjects were divided into two groups (the foveal pit contour ‘restoration (R)’ and ‘no restoration (NR)’ groups) according to postsurgical foveal pit changes. Foveal pit contour recovery was defined as reappearance of a depression of the fovea relative to the surrounding macula with the pit reaching the inner nuclear layer level. If the foveal pit recovered at any point after the operation, it was considered a recovery. The contour on OCT was independently evaluated by two individuals (B.J.B and Y.J.C) and a third evaluator (N.K.R) adjudged when there was a discrepancy between two observers.

Statistical analysis

The Wilcoxon signed-rank test and paired t-test were used to compare the preoperative characteristics between the operative and contralateral fellow eyes. Two-sample t-tests and Mann-Whitney U tests were used to compare the baseline characteristics, including BCVA, FAZ, CFT, EZ disruption, and inner-retinal irregularity index between foveal pit restoration and no-restoration group. Changes in BCVA, FAZ, and CFT over time were analyzed using a repeated-measures analysis of variance. Multiple linear regression analysis was performed with preoperative parameters to determine the factors associated with the postoperative FAZ area, CFT, and BCVA. All statistical analysis was performed using SPSS statistical software for Windows, version 21.0 (SPSS Inc. Chicago, IL, USA). For all tests, a $p$-value < 0.05 was used to reject the null hypothesis.

Results

Of the 149 patients who underwent vitrectomy for iERM removal, 48 patients were excluded due to previously diagnosed retinal diseases either in the surgical or contralateral eye, and the other 58 patients were excluded because of a poor OCT/OCTA quality or an insufficient follow-up period. As a result, 43 patients with iERM were enrolled. Table 1 shows the baseline characteristics and comparison between the operative and contralateral eyes. The mean age of the patients were 75.07 ± 4.80 yrs. The mean period of ERM duration was 344.05 ± 238.72 days. The mean BCVA was worse in the iERM eyes (0.38 ± 0.31) than in the contralateral eyes (0.16 ± 0.14; $p < 0.001$). The mean preoperative FAZ area was smaller (0.10 ± 0.05 mm$^2$ vs. 0.32 ± 0.07 mm$^2$; $p < 0.001$) and mean preoperative CFT thicker (445.88 ± 49.94 μm vs. 220.81 ± 50.93 μm; $p < 0.001$) in the eyes with iERM than that in the contralateral unaffected eyes.
During the preop 3 months period, BCVA and FAZ slightly decreased and CFT increased in eyes with iERM (Supplementary Table 1). However, after surgery, BCVA (preop 0.38 ± 0.31 to postop 0.12 ± 0.10), FAZ (0.10 ± 0.05 to 0.19 ± 0.05 mm²) and CFT (445.88 ± 49.94 to 369.73 ± 71.25 μm) showed statistically significant improvements over time (p = 0.002, p < 0.001, p < 0.001, respectively; Supplementary Table 1). Pearson correlation analysis was performed to detect any association between pre- and postoperative FAZ and CFT at 1, 3, and 6 months (Fig. 1). Pre- and postoperative FAZ areas (Fig. 1A-1C) and CFT (Fig. 1D-1F) had a positive association (p < 0.05). Preoperative FAZ was negatively correlated with postoperative CFT (Fig. 1G-1I). The degree of correlation shown as r (correlation coefficient) on the plot decreases as time progresses after surgery. Additionally, the association between the FAZ and the BCVA was statistically significant only in the preoperative FAZ area and preoperative BCVA (Fig. 1J-1K, p-values = 0.013).

According to postsurgical foveal pit changes, subjects were divided into two groups (the foveal pit contour ‘restoration (R)’ and ‘no restoration (NR)’ groups) (Fig. 2-3). Among the 43 patients, thirty-one showed foveal pit restoration and 12 remained as no restoration (Table 2). In addition, 31 patients in the foveal pit restoration group were analyzed separately according to the time of restoration. Based on the time of initial recovery, 23 patients recovered one month after surgery. There were 3, 4, and 1 patient who first recovered at 3, 6, and 12 months after surgery, respectively. When comparing the ophthalmic parameters, including BCVA and FAZ areas, between the early foveal pit restoration group (within 1 month of surgery) and the late restoration group (at least 1 month after surgery) no statistically significant difference existed between the two groups (data not shown).

Baseline characteristics, such as age, diabetes, and hypertension, exhibited no significant differences in the foveal pit restoration and no restoration groups. Preoperative BCVA, FAZ area, contralateral FAZ area, contralateral CFT, preoperative EZ disruption, and inner-retinal irregularity index also had no significant difference. However, the mean preoperative CFT was thinner in the restoration group (429.55 ± 34.78 μm) than the no restoration group (485.33 ± 59.92 μm; p = 0.003). Duration of ERM was longer in the restoration group than the no restoration group (373.26 ± 243.79 days vs. 268.58 ± 216.49 days, respectively; p = 0.034) with marginal significance.

Longitudinal changes of BCVA, FAZ, and CFT after ERM surgery up to one year were compared between the restoration and no restoration groups (Table 3). The BCVA significantly improved in both the restoration and no restoration group over time (p = 0.003, p = 0.014, respectively;
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Table 3). No difference in the degree of improvement in BCVA existed between the two groups \( (p = 0.619; \text{Table 3}) \). The mean BCVA was better in the restoration group at 1 month and 6 months postoperatively \( (p = 0.004 \text{ and } p = 0.02, \text{respectively}; \text{Table 3}) \). However, BCVA recovered to 0.12 ± 0.11 in the restoration group and 0.12 ± 0.07 in the non-restoration group showing no statistical difference at 12 months. The FAZ area also significantly increased over time in both the restoration and no restoration group \( (p < 0.001 \text{ and } p < 0.001, \text{respectively}) \). There was no difference in the increment of FAZ area between the two groups \( (p = 0.139; \text{Table 3}) \). Differences in the FAZ area was significant between the two groups up to 6 months postoperatively \( (p = 0.019) \), however insignificant at 12 months \( (p = 0.158; \text{Table 3}) \). The CFT was thinner in the restoration group at every point compared to the no restoration group \( (\text{all } p\text{-values} < 0.05; \text{Table 3}) \). The restoration group showed statistically significant improvement in CFT over time \( (p = 0.002; \text{Table 3}) \). The CFT also continuously decreased in the no restoration group—from preop 485.33 ± 59.92 μm to 416.71 ± 43.05 μm at 12 months—with marginal significance \( (p = 0.053; \text{Table 3}) \). However, the decrement of CFT between the two groups was not statistically different \( (p = 0.378; \text{Table 3}) \).

In addition, preoperative EZ disruption was significantly associated with worse BCVA at 1, 3, 6, and 12 months postoperatively \( (p = 0.023, p = 0.03, p = 0.001, \text{and } p = 0.019, \text{respectively}) \). Postoperative EZ disruption was also significantly correlated with worse BCVA at 1, 3, and 6 months postoperatively \( (p = 0.019, p = 0.025, \text{and } p = 0.011, \text{respectively}) \), whereas pre- and postoperative EZ disruptions were not correlated with foveal pit restoration \( (p = 0.41 \text{ and } p = 0.367, \text{respectively}) \). Alternatively, 6 months postoperative inner-retinal irregularity index was significantly associated with foveal pit restoration \( (R \text{ group } 1.030 \pm 0.008 \text{ vs. } NR \text{ group } 1.040 \pm 0.010; p = 0.001) \). Furthermore, BCVA was significantly better in the restoration group than the no restoration group \( (R \text{ group } 0.14 \pm 0.14 \text{ vs. } NR \text{ group } 0.25 \pm 0.17; p = 0.02) \). However, preoperative inner-retinal irregularity index was not correlated with foveal pit restoration \( (R \text{ group } 1.139 \pm 0.19 \text{ vs. } NR \text{ group } 1.165 \pm 0.029; p = 0.243) \). Likewise, postoperative 12 months inner-retinal irregularity index was not correlated with foveal pit restoration \( (R \text{ group } 1.017 \pm 0.006 \text{ vs. } NR \text{ group } 1.017 \pm 0.019; p = 0.618) \). Its BCVA was not associated with foveal pit restoration \( (R \text{ group } 0.12 \pm 0.11 \text{ vs. } NR \text{ group } 0.12 \pm 0.07; p = 0.576) \).

Preoperative inner-retinal irregularity index was not correlated with postoperative BCVA \( (\text{all } p\text{-values} > 0.05) \).
Discussion

This study investigated the relationship between ophthalmic parameters—such as BCVA, CFT, FAZ area, EZ disruption, and inner-retinal irregularity index—and anatomic recovery in eyes that had undergone vitrectomy for idiopathic ERM removal. The primary objective was to evaluate whether postsurgical foveal pit changes had any predictive or prognostic factors.

Removal of epiretinal membrane significantly decreases the CFT and increases the superficial FAZ area. The expansion of FAZ was significant after surgery, however remained smaller than the contralateral unaffected eye. It may be possible that before ERM surgery, strong centripetal contractions act on the FAZ, and after ERM removal, centrifugal expansion occurs. In addition, the preoperative FAZ area was significantly correlated with the postoperative FAZ area. These results are consistent with previous reports [13-15].

In normal eyes, a lower CFT is associated with a larger FAZ area [13,16]. However, in this study, preoperative CFT and FAZ areas were not correlated ($p > 0.05$, data not shown), while the postoperative CFT and FAZ areas were significantly associated by Pearson correlation analysis at any point. This is probably because, before ERM surgery, the strong afferent contraction of the ERM and anteroposterior traction by the vitreous act on the FAZ, disrupting the normal FAZ morphology. The preoperative FAZ area showed negative correlation with postoperative CFT at 1, 3, and 6 months (all $p$-values $< 0.05$). Yoon et. al. [14] also reported this negative correlation between superficial FAZ area and CFT.

This study verified that the preoperative FAZ area was negatively correlated with preoperative BCVA ($p$-values $= 0.013$). A smaller FAZ may have more severe ERM contraction and foveal retinal structure abnormalities than a larger FAZ [17]. Therefore, preoperative BCVA could be worse in ERM with a smaller preoperative FAZ area. This result is consistent with the findings of Yoshida et al. [18].

Pre- and postoperative EZ disruption were significantly correlated with worse BCVA after surgery, which is consistent with the previous reports [7,8]. Moreover, the inner-retinal irregularity index was significantly lower in the restoration group than the no restoration group 6 months after surgery, and its BCVA was significantly better in the restoration group than the no restoration group. However, there was no significant difference in the inner-retinal irregularity index or BCVA between the two groups 12 months after surgery. The conflicting results between the two time points could be...
explained as follows: the inner nuclear layer, which plays an important role in the visual prognosis of the ERM [8], can be restored by removing the tangential traction after ERM surgery. Meanwhile, there might be a difference in the recovery velocity of the inner nuclear layer between the restoration and no restoration groups, which possibly affected the visual acuity at 6 months postoperatively. Subsequently, with a gradual decrease in the velocity effect, there was no difference in the visual acuity between the two groups at 12 months postoperatively.

Few studies exist which analyze the effect of the postsurgical foveal pit restoration in eyes with iERM. In our study, the BCVA was significantly better in the restoration group than in the no restoration group 1 month postoperatively ($p = 0.004$); however, after 12 months, the BCVA in both groups improved compared to the preoperative BCVA without a significant difference ($p = 0.576$). This means that even if the foveal pit contour does not recover, long-term visual acuity improvement can be achieved, which supports the finding of a previous study that the absence of postoperative foveal depression does not imply failure to improve the BCVA [2]. Additionally, majority of the restoration group recovered within one month of surgery (23 out of 31). We also found that this early foveal pit restoration group within 1 month of surgery did not exert any benefit in visual acuity improvement than the late restoration group. According to a previous study by Lim JH et al. [9], unlike our study, the degree of BCVA improvement was greater in patients who showed rapid foveal pit recovery within 1 month after surgery than in patients who did not show foveal pit recovery after surgery. However, although the recovery group showed faster BCVA improvement after surgery than the non-recovery group, there was no significant difference in the BCVA between the two groups 12 months postoperatively, as in our study.

No significant differences existed in the preoperative FAZ area in both the restoration and no restoration group. However, after vitrectomy, FAZ area increased and differences between the two groups were evident at 3 and 6 months. Unlike continuous and immediate improvement of CFT, it is thought that superficial FAZ is more exposed to traction and mechanical stress caused by ERM, which delays its restoration after surgery [14]. Dubis et al. [19] reported that in normal eyes the degree of foveal depression may be positively correlated with the size of FAZ. We can speculate that since most of our restoration group recovered within 1 month the degree of foveal depression increased and the FAZ expanded in a delayed manner during the following months resulting in such significant difference up to 6 months. However, as FAZ genuinely enlarges after epiretinal membrane removal regardless of
the state of foveal depression, the velocity-effect wears off and the difference becomes insignificant at 12 months.

Epiretinal membrane tends to aggravate with time [1,9]. However, unlike our expectation, the duration of ERM does not seem to have an impact on anatomic restoration. When compared between the restoration and non-restoration group, the duration of ERM was longer in the restoration group. Nonetheless, since duration of ERM could only be estimated with medical record based on the time of presentation of the patient to the clinic and not the generation of ERM itself, careful interpretation is required.

This study is unique in that we analyzed all features not only immediate to the operation day, but 3 months prior to the surgery. OCTA image quality tends to be inaccurate in patients with severe retinal degeneration due to ERM [6], and ERM may disrupt the retina’s layered structure; hence segmentation errors may exist in FAZ analysis [18]. According to Bontzos et al. [20], the iERM period is significantly related to segmentation errors in OCTA. As such, there may be increased measurement errors in the OCTA image immediate to surgery; therefore, in this study, to overcome the inherent limitation of OCTA analysis, OCTA images taken 3 months before surgery, expecting relatively little disruption of the retinal layer, were also analyzed. However, there were no significant differences between the two image measurements (p = 0.90). In other words, as long as manual adjustment is applied for segmentation errors, FAZ area may be reliable without significant discrepancy at any point before surgery.

Although studies exist which evaluates the OCTA features after vitrectomy in iERM, this study is the first, within our knowledge, to investigate OCTA features between different anatomic recovery groups (restoration vs. no restoration). However, the retrospective nature and small sample size remain as a limitation of this study. Future studies with larger sample size, and longer follow-up period may be beneficial.

In conclusion, the removal of epiretinal membrane in PPV significantly decreases the CFT and expands the superficial FAZ and improves BCVA. Foveal pit restoration improves BCVA, CFT and FAZ area possibly at a faster rate in the early months but the change becomes insignificant at 12 months and long-term improvement could be achieved regardless of the status of foveal pit restoration.

Conflict of Interest
The authors have no potential conflicts of interest to declare relevant to this article.

**Acknowledgments**

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REFERENCES


Table 1. Preoperative baseline characteristics between the operative and contralateral eyes

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Operative eye (n = 43)</th>
<th>Contralateral eye (n = 43)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>75.07 ± 4.80</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sex (Male:Female)</td>
<td>36:7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DM</td>
<td>15 (34.88 %)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HTN</td>
<td>33 (76.74 %)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pseudophakia</td>
<td>9 (20.93 %)</td>
<td>11 (25.58 %)</td>
<td></td>
</tr>
<tr>
<td>Duration of ERM (days)</td>
<td>344.05 ± 238.72</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BCVA (logMAR)</td>
<td>0.38 ± 0.31</td>
<td>0.16 ± 0.14</td>
<td>&lt; 0.001†</td>
</tr>
<tr>
<td>FAZ (mm²)</td>
<td>0.10 ± 0.05</td>
<td>0.32 ± 0.07</td>
<td>&lt; 0.001†</td>
</tr>
<tr>
<td>CFT (μm)</td>
<td>445.88 ± 49.94</td>
<td>220.81 ± 50.93</td>
<td>&lt; 0.001†</td>
</tr>
</tbody>
</table>

Values are presented as mean ± standard deviation or number (%).

DM = diabetes mellitus; HTN = hypertension; BCVA = best-corrected visual acuity; logMAR = logarithm of the minimal angle of resolution; FAZ = foveal avascular zone; CFT = central foveal thickness

* Wilcoxon signed-rank test; † paired t-test
Table 2. Preoperative baseline characteristics between the restoration and no restoration groups

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>R. Group (n=31)</th>
<th>NR. Group (n = 12)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>74.52 ± 4.43</td>
<td>76.50 ± 5.58</td>
<td>0.219</td>
</tr>
<tr>
<td>Sex (M:F)</td>
<td>(26:5)</td>
<td>(10:2)</td>
<td></td>
</tr>
<tr>
<td>DM</td>
<td>12 (38.71 %)</td>
<td>3 (25 %)</td>
<td>0.492 *</td>
</tr>
<tr>
<td>HTN</td>
<td>6 (66.67 %)</td>
<td>26 (78.79 %)</td>
<td>0.698 *</td>
</tr>
<tr>
<td>Pseudophakia</td>
<td>6 (19.35 %)</td>
<td>4 (33.33 %)</td>
<td>0.427 *</td>
</tr>
<tr>
<td>Duration of ERM (days)</td>
<td>373.26 ± 243.79</td>
<td>268.58 ± 216.49</td>
<td>0.034 *</td>
</tr>
<tr>
<td>BCVA (logMAR)</td>
<td>0.34 ± 0.30</td>
<td>0.47 ± 0.34</td>
<td>0.228 *</td>
</tr>
<tr>
<td>FAZ (mm²)</td>
<td>0.11 ± 0.05</td>
<td>0.09 ± 0.03</td>
<td>0.144</td>
</tr>
<tr>
<td>CFT (μm)</td>
<td>429.55 ± 34.78</td>
<td>485.33 ± 59.92</td>
<td>0.009 †</td>
</tr>
<tr>
<td>Contralateral FAZ (mm²)</td>
<td>0.32 ± 0.07</td>
<td>0.29 ± 0.05</td>
<td>0.243 †</td>
</tr>
<tr>
<td>Contralateral CFT (μm)</td>
<td>221.93 ± 55.83</td>
<td>218.00 ± 37.94</td>
<td>0.477 †</td>
</tr>
</tbody>
</table>

Values are presented as mean ± standard deviation or number (%).

DM = diabetes mellitus; HTN = hypertension; ERM = epiretinal membrane; BCVA = best-corrected visual acuity; logMAR = logarithm of the minimal angle of resolution; FAZ = foveal avascular zone; CFT = central foveal thickness, NR = no restoration; R = restoration

* Mann-Whitney U test; † two-sample t-test
Table 3. BCVA, FAZ area, and CFT after ERM surgery according to foveal pit restoration

<table>
<thead>
<tr>
<th>Time after ERM surgery</th>
<th>Preop. 3 mo</th>
<th>Preop. 0 mo</th>
<th>1 mo</th>
<th>3 mo</th>
<th>6 mo</th>
<th>12 mo</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BCVA (logMAR)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R group</td>
<td>0.33 ± 0.29</td>
<td>0.34 ± 0.30</td>
<td>0.17 ± 0.16</td>
<td>0.16 ± 0.17</td>
<td>0.14 ± 0.14</td>
<td>0.12 ± 0.11</td>
</tr>
<tr>
<td>NR group</td>
<td>0.42 ± 0.26</td>
<td>0.47 ± 0.34</td>
<td>0.33 ± 0.18</td>
<td>0.23 ± 0.15</td>
<td>0.25 ± 0.17</td>
<td>0.12 ± 0.07</td>
</tr>
<tr>
<td>p - value†</td>
<td>0.151</td>
<td>0.228</td>
<td>0.004†</td>
<td>0.076</td>
<td>0.02†</td>
<td>0.576</td>
</tr>
<tr>
<td><strong>FAZ (mm²)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R group</td>
<td>0.11 ± 0.05</td>
<td>0.11 ± 0.05</td>
<td>0.14 ± 0.06</td>
<td>0.17 ± 0.06</td>
<td>0.19 ± 0.06</td>
<td>0.20 ± 0.05</td>
</tr>
<tr>
<td>NR group</td>
<td>0.10 ± 0.04</td>
<td>0.09 ± 0.03</td>
<td>0.11 ± 0.04</td>
<td>0.13 ± 0.05</td>
<td>0.15 ± 0.04</td>
<td>0.18 ± 0.04</td>
</tr>
<tr>
<td>p - value†</td>
<td>0.697</td>
<td>0.144</td>
<td>0.097</td>
<td>0.023†</td>
<td>0.019†</td>
<td>0.158</td>
</tr>
<tr>
<td><strong>CFT (μm)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R group</td>
<td>422.19 ± 37.92</td>
<td>429.55 ± 34.78</td>
<td>365.19 ± 95.57</td>
<td>355.82 ± 92.87</td>
<td>345.52 ± 88.60</td>
<td>355.43 ± 72.60</td>
</tr>
<tr>
<td>NR group</td>
<td>494.67 ± 58.57</td>
<td>485.33 ± 59.92</td>
<td>471.00 ± 50.16</td>
<td>457.27 ± 45.71</td>
<td>446.58 ± 49.88</td>
<td>416.71 ± 43.05</td>
</tr>
<tr>
<td>p - value†</td>
<td>0.002†</td>
<td>0.003†</td>
<td>&lt; 0.001†</td>
<td>0.001†</td>
<td>&lt; 0.001†</td>
<td>0.031†</td>
</tr>
</tbody>
</table>

BCVA = best-corrected visual acuity; logMAR = logarithm of the minimal angle of resolution; FAZ = foveal avascular zone; CFT = central foveal thickness; Preop. = Preoperative; mo = months; R group = restoration group; NR Group = no restoration group.

†Repeated measures ANOVA p-value; † Mann-Whitney U test; ‡ statistically significant.

Supplementary Table 1. BCVA, FAZ area, and CFT of the operative eye after ERM surgery

<table>
<thead>
<tr>
<th>Time after ERM surgery</th>
<th>Preop. 3 mo</th>
<th>Preop. 0 mo</th>
<th>1 mo</th>
<th>3 mo</th>
<th>6 mo</th>
<th>12 mo</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BCVA (logMAR)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R group</td>
<td>0.36 ± 0.28</td>
<td>0.38 ± 0.31</td>
<td>0.22 ± 0.18</td>
<td>0.18 ± 0.16</td>
<td>0.18 ± 0.16</td>
<td>0.12 ± 0.10</td>
</tr>
<tr>
<td>NR group</td>
<td>0.11 ± 0.05</td>
<td>0.10 ± 0.05</td>
<td>0.13 ± 0.05</td>
<td>0.16 ± 0.06</td>
<td>0.18 ± 0.06</td>
<td>0.19 ± 0.05</td>
</tr>
</tbody>
</table>

Supplementary Table 1. BCVA, FAZ area, and CFT of the operative eye after ERM surgery
Effect of Foveal pit restoration after ERM surgery

Values are presented as mean ± standard deviation.

Preop. = preoperative; mo = months; BCVA = best-corrected visual acuity; logMAR = logarithm of the minimal angle of resolution; FAZ = foveal avascular zone; CFT = central foveal thickness.

Revised measures ANOVA *p*-value.

<table>
<thead>
<tr>
<th>CFT (μm)</th>
<th>438.50 ± 52.43</th>
<th>445.88 ± 49.94</th>
<th>397.74 ± 97.09</th>
<th>384.44 ± 93.90</th>
<th>378.30 ± 91.07</th>
<th>369.73 ± 71.25</th>
<th>&lt; 0.001</th>
</tr>
</thead>
</table>
[Figure Legends]

Fig. 1. Pearson correlation analysis between pre- and postoperative parameters. (A-C) pre- and postoperative FAZ areas, (D-F) pre- and postoperative CFT and (G-I) preoperative FAZ area and CFT at 1, 3, and 6 months after surgery were significantly correlated. (J-K) Pre- and postoperative FAZ area and pre- and postoperative BCVA (logMAR) were significantly associated only in the preoperative FAZ area and preoperative BCVA ($p$-values = 0.013).

$r$ = correlation coefficient; FAZ = foveal avascular zone; CFT = central foveal thickness; BCVA = best-corrected visual acuity; logMAR = logarithm of the minimal angle of resolution.

Fig. 2. Representative OCTA and OCT images of the foveal pit “Restoration (R)” group. (A) Preoperative OCTA image of the restoration group. The BCVA is 0.22. The superficial FAZ area is 0.09 mm$^2$ and shown in white. (B) Postoperative OCTA image of the superficial layer: The BCVA and the FAZ area are 0.05 and 0.20 mm$^2$, respectively. (C, G) Preoperative OCT: absence of the foveal pit noted (D, H) Postoperative OCT: the foveal pit is restored (E) Preoperative OCTA image of the superficial layer in the restoration group: The BCVA and the FAZ area are 0.22 and 0.09 mm$^2$, respectively. (F) Postoperative OCTA image of FAZ area in the restoration group: The BCVA and the FAZ area are 0.05 and 0.13 mm$^2$, respectively.

OCTA = optical coherence tomography angiography; OCT = optical coherence tomography; BCVA = best-corrected visual acuity; FAZ = foveal avascular zone; ERM = epiretinal membrane.

Fig. 3. Representative OCTA and OCT images of the foveal pit “No Restoration (NR)” groups. (I) Preoperative OCTA image of the no restoration group. The BCVA is 0.10. The superficial FAZ area is 0.09 mm$^2$ and shown in white. (J) Postoperative OCTA image of the superficial layer: The BCVA and the FAZ area are 0.05 and 0.13 mm$^2$, respectively. (K, O) Preoperative OCT: absence of the foveal pit noted (L, P) Postoperative OCT: no restoration of the foveal pit is detected. (M) Preoperative OCTA image of the superficial layer in the no restoration group: The BCVA and the FAZ area are 0.40 and 0.06 mm$^2$, respectively. (N) Postoperative OCTA image of FAZ area in the no restoration group: The BCVA and the FAZ area are 0.05 and 0.11 mm$^2$, respectively.

OCTA = optical coherence tomography angiography; OCT = optical coherence tomography; BCVA = best-corrected visual acuity; FAZ = foveal avascular zone; ERM = epiretinal membrane.