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# Resolving Myopic Foveoretinal Detachment by Fovea-Saving Internal Limiting Membrane Peeling: A Case-Series Report

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## Abstract

**Background:** In highly myopic eyes, myopic foveoschisis (MF), the earliest stage of myopic traction maculopathy (MTM), is present in up to 34% of patients with pathologic myopia and slowly progresses to form foveoretinal detachment (FRD) or macular hole (MH) with or without macular hole retinal detachment (MHRD) as a part of its natural history. **Aim:** To describe the microstructural and functional results in three highly myopic eyes that underwent macular surgery for early-stage MTM. The last postoperative structural findings were correlated with the final vision and macular automated microperimetry evaluation. **Methods:** We retrospectively reviewed three highly myopic eyes that underwent successful fovea-saving internal limiting membrane (FS-ILM) macular surgery for chronic FRD at Oftalmologia Integral ABC, Mexico City, Mexico. We performed postoperative multimodal microstructural and functional evaluations, including SD-OCT, SS-OCT, and microperimetric macular examinations. **Results:** There was a substantial difference between best-corrected visual acuity (BCVA) preoperatively and postoperatively in all three cases. Postoperative surgery was associated with significant improvement in visual acuity confirmed using a paired-sample permutation test. The mean presurgical BCVA value (LogMAR; mean ± SE) was ~0.83 ± 0.15, and the postsurgical value was ~0.43 ± 0.52 (P = 0.00065). The myopic foveoretinal detachment evaluation was ~7.3 ± 3.5 months, with a mean postoperative follow-up time of ~14 ± 4.08 months. Furthermore, postoperative multimodal imaging tests demonstrated an abnormal micro-

structural foveal SS-OCT pattern without evidence of macular hole (MH) development at the postoperative follow-up. Macular microperimetry confirmed a subclinical reduced macula threshold sensitivity with an anomalous retinal sensitivity analysis map and a stable central foveal fixation site. **Conclusions:** Even with the successful microstructural disappearance of myopic macular detachment, the last multidisciplinary functional and structural assessments demonstrated different subclinical macular alterations.

## Keywords

Automated Microperimetry, Myopic Foveoretinal Detachment, Myopic Foveoschisis, Myopic Macular Hole, Myopic Traction Maculopathy, Posterior Staphyloma

## 1. Introduction

It is estimated that 50% of the world's population will develop myopia by 2050 (~10% high myopia) [1] [2]. High myopia, a common cause of visual loss, can lead to blindness. High myopia is associated with pathological myopia (PM), which is defined as the progressive deterioration of chorioretinal tissue owing to scleral elongation and posterior staphyloma (PS) development. These pathologic myopic signs are consistent with chorioretinal atrophy, choroidal neovascularization, and slow progressive vitreomacular tractional schisis-like foveomacular thickening [1] [3].

Currently, an anterior-posterior axial length of 26.5 mm or more is considered high myopia. There are other macular changes associated with highly myopic eyes (MEs), such as ruptures in Bruch's membrane and macular atrophy with the absence of macular pigment. PM can be complicated by PS [1]. Earliest-stage myopic traction maculopathy (MTM) has been recently reported as the elongation of Henle's fiber layer, also known as myopic foveoschisis (MF), which remains connected by Muller cells rather than splitting the retina layers [2] (indicated with white asterisks in **Figures 1(a)-(c)**), has a thin foveal center inner wall (roof) (**Figure 1(a)**, white arrow), and involves structural schisis-like thickening formation around the inner and outer layers of the retina (**Figure 1(a)** and **Figure 1(c)**, red arrows). The vitreoretinal relationship is shown in **Figure 1(c)** with green arrows. This phenomenon has a 66.12% prevalence in women [4] [5]. Reduced thickness of individual collagen fibers, scleral thinning, and localized ectasia have been observed in postmortem MEs [6]. This entity was described by Panozzo and Mercanti in 2004 [4] as MTM, and optical coherence tomography (OCT), a noninvasive optical imaging technique, was used to characterize elusive macular changes, including: 1) vitreomacular traction or epiretinal membrane (ERM), 2) retinal thickening, 3) retinoschisis (RS), and 4) partial- or full-thickness macular hole (MH) in the presence or absence of retinal detachment (RD). Recently, posterior cortex remnants, rigidity of retinal vessels,

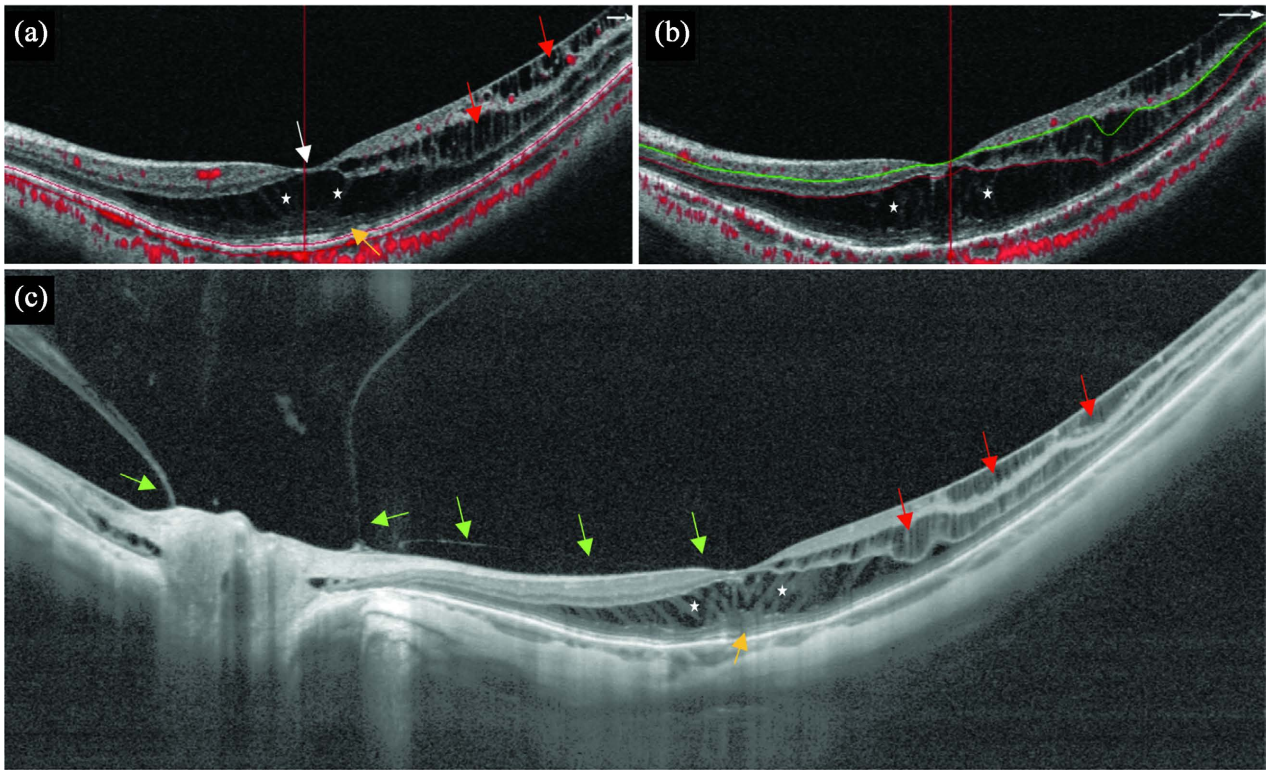


**Figure 1.** Myopic foveoschisis in a highly myopic eye. (a) High-definition (HD) image showing a 9 mm horizontal B-scan of myopic foveoschisis (MF) and a very thin foveal roof (white arrow). Inner and outer macular schisis-like thickening temporal to the fovea (red arrows), tractional elongation of Henle's fiber layer (white asterisks). Subfoveal outer retina layer biomarkers show discontinuities and reflectance alterations (dark yellow arrow), and the red dots indicate the corresponding choroidal and retinal vessels. (b) Panel with image of the same MF with tractional elongation of Henle's fiber layer (white asterisks); inner and outer schisis-like thickening sublayers are well identified by the segmentation red and green lines, and red dots correspond to choroidal vessels. (c) Enhanced HD Line 12 mm image of a very elevated stage 1 myopic foveoschisis-related myopic traction maculopathy (white asterisks). Inner and outer retina layer macular foveoschisis (red arrows) is clearly shown temporal to the central thin fovea. Posterior cortical hyaloidal condensation is seen nasally and running toward the fovea, still attached to the peripapillary region (green arrows); the subfoveal outer retina layer shows ellipsoid zone discontinuities and hyporeflectance alterations (dark yellow arrow).

and choroidal thinning have been identified as contributors to traction and degenerative changes, respectively [2]. Although the cause of foveoschisis is not completely understood, tractional forces might play a crucial role in its pathogenesis, particularly when combined with progressive development of PS and subsequent stretching of the posterior retina [7] [8].

Shimada *et al.* [9] classified and structurally defined MF with SD-OCT. The slow evolution of MF progresses to foveoretinal detachment (FRD) and an MH with or without RD in more severe cases, resulting in vision reduction. MF can be detected in up to 34% of eyes with PS and PM [2] [4] [5] [6] [8]-[14].

Pathologic scleral thinning [15] combined with subsequent progressive scleral ectasia formation contributes to stretching of critical retinal tissue on the macula [13] [14] [15]. There are few long-term functional results for foveoschisis; therefore, we mainly used visual insight to evaluate the changes in post-surgery vision. Furthermore, vision quality is also affected by central retinal sensitivity, *i.e.*,

we intended to determine the structural SS-OCT and functional outcomes in FRD that was successfully surgically treated with the fovea-saving internal limiting membrane (FS-ILM) technique.

## 2. Case-Series Report/Case Presentation

### 2.1. Examination

Patients (n = 3, age = 52.3 ± 11 years) with significant vision loss were all evaluated by an ophthalmologist and underwent preoperative examinations. No preoperative microperimetry was conducted because of the presence of submacular fluid in these symptomatic myopic FRD patients. Preoperative horizontal microstructural imaging evaluation of the macular region was accomplished with spectral-domain optical coherence tomography (SD-OCT) equipment (Ret-vue-3.4 OCT, Optovue Inc., Fremont, CA). Coherence laser interferometry was used to measure the axial lengths (Zeiss IOL Master 700; Carl Zeiss Meditec, AG, Oberkochen, Germany). We used ultrasonography (A and B Ultrasound Unit, Quantel Medical, Du Bois Loli, Auvergne, France) to perform scleral and vitreoretinal relationship mapping to confirm the PS diagnosis in all eyes. SD-OCT (Spectralis OCT, Heidelberg Engineering, Heidelberg, Germany) equipment and SS-OCT Triton equipment (Topcon Medical Systems, Inc., Oakland, NJ 07436) were employed to perform a postoperative microstructural evaluation.

The standard macular integrity assessment with nonmydriatic confocal scanning laser ophthalmoscope (MAIA Confocal Microperimeter equipment from CenterVue, Fremont, Ca 94539 USA) fundus imaging exam protocol was used to perform automated microperimetry with 37 data measurement points over a 10˚ diameter area with an ~1000 apostilb maximal light stimulus (36-decibel range). Furthermore, the assessment of foveoretinal sensitivity (FRS), macular retinal sensitivity (MRS), fixation location pattern (FLP, also called preferred retinal loci (PRL)), and fixation stability pattern (FSP) was performed by tracking eye movements at 25 times/s. The eye movement distribution over the ophthalmoscope image was plotted from scanning laser vision. The overall site depicting the PRL was assigned a dot for each movement.

### 2.2. Surgical Procedures

A pars plana vitrectomy (PPV) technique was performed by an experienced retinal surgeon (MAQR) in the three eyes under local anesthesia. A cannula with silicone tape (25-gauge and 2-mm soft top) and active suction was used to remove cortical vitreous from the retinal surface with triamcinolone acetonide (Kenalog 40 mg/mL, Bristol-Myers, USA). Surgical macular evaluation was performed using an ophthalmic solution (0.15%) of trypan blue (MembraneBlue™ 0.15%, Dutch Ophthalmic, USA) and 0.10 mL of Brilliant Blue-G (BBG) at 0.25 mg/mL ($C_{47}H_{48}NaO_7S_2$) to facilitate the manipulation of the stained ILM, complemented with 25-G three-port PPV equipment (Constellation Vision System,

Alcon Laboratories, Inc., USA) with a cut rate of ~7000/CPM, fine grasping vitreoretinal Tano ILM forceps (24-G, Alcon Laboratories, Inc., USA), and a 25-G membrane scraper, assisted with a 25-G Finesse microinstrument (Grieshaber®. Alcon Laboratories, Inc., USA) with high surgical precision for manipulation of the ILM flap. At the end of the procedure, we employed a bubble of perfluoropropane gas at 15% as a long-lasting tamponade.

### 2.3. Clinical Case 1

In this case, a 65-year-old female patient suffered from aggravated symptomatic metamorphopsia, severe myopia, and progressive central vision loss in her right eye, and both eyes exhibited PS. **Figure 2a** illustrates the right eye with an axial length of ~28.92 mm, which underwent surgery due to a one-year history of structural FRD with distorted vision, depicted using yellow arrows in the figure. Her preoperative BCVA was 20/200 (1.00 logMAR). This eye underwent a 25-gauge PPV with an FS-ILM surgical technique. Using perfluoropropane (15%), tamponade fluid-air-gas exchange was performed. After 19 months, SS-OCT imaging and longitudinal follow-up indicated a flat macula without evidence of FRD, which is depicted in **Figure 2(a1)** and **Figure 2(a2)**. Recovered outer retina OCT biomarkers are depicted in **Figure 2(a1)** and **Figure 2(a2)** using a dark yellow arrow, and some superficial retinal dimpling superior and temporal to the fovea are depicted in **Figure 2(a1)** and **Figure 2(a2)**, respectively, using white arrows. The thin RPE over the macula did not suffer any postoperative deterioration on the autofluorescence examination (**Figure 2(a3)**). The microperimetry control examination images are depicted in **Figure 3(control)**, **Figure 3(a)** and **Figure 3(b)**. The microperimetry examination showed a stable FSP, and the FLP was documented as foveocentral, as depicted in **Figure 3(a1)** and **Figure 3(a2)**. The final long-term postoperative SS-OCT is depicted in **Figure 3(d)** without recurrence of the FRD or progression to MH. The postoperative BCVA was ~20/25 (0.01 logMAR).

### 2.4. Clinical Case 2

In this case, a 46-year-old woman with 3 months of persistent, disabling metamorphopsia and troublesome and high myopia underwent a standard 25-gauge three-port PPV followed by macular surgery on her phakic right eye for a very symptomatic focal and well-defined FRD, as indicated in **Figure 2(b)** using a yellow arrow, and persistent hyaloidal macular traction was observed (green arrows). The inner retinal schisis-like thickening foveoschisis is depicted in **Figure 2(b)** using a red arrow. Her outer retina layer biomarkers were distorted with localized subfoveal FRD, as depicted in **Figure 2(b)** using a yellow arrow. The patient underwent macular surgery involving a BBG dye-assisted FS-ILM surgical technique and perfluoropropane (15%) long-acting nonexpandable gas tamponade. The preoperative BCVA was 20/100 (0.7 logMAR), with a shallow PS (data not shown) and an axial length of ~27.7 mm. The ultimate postoperative

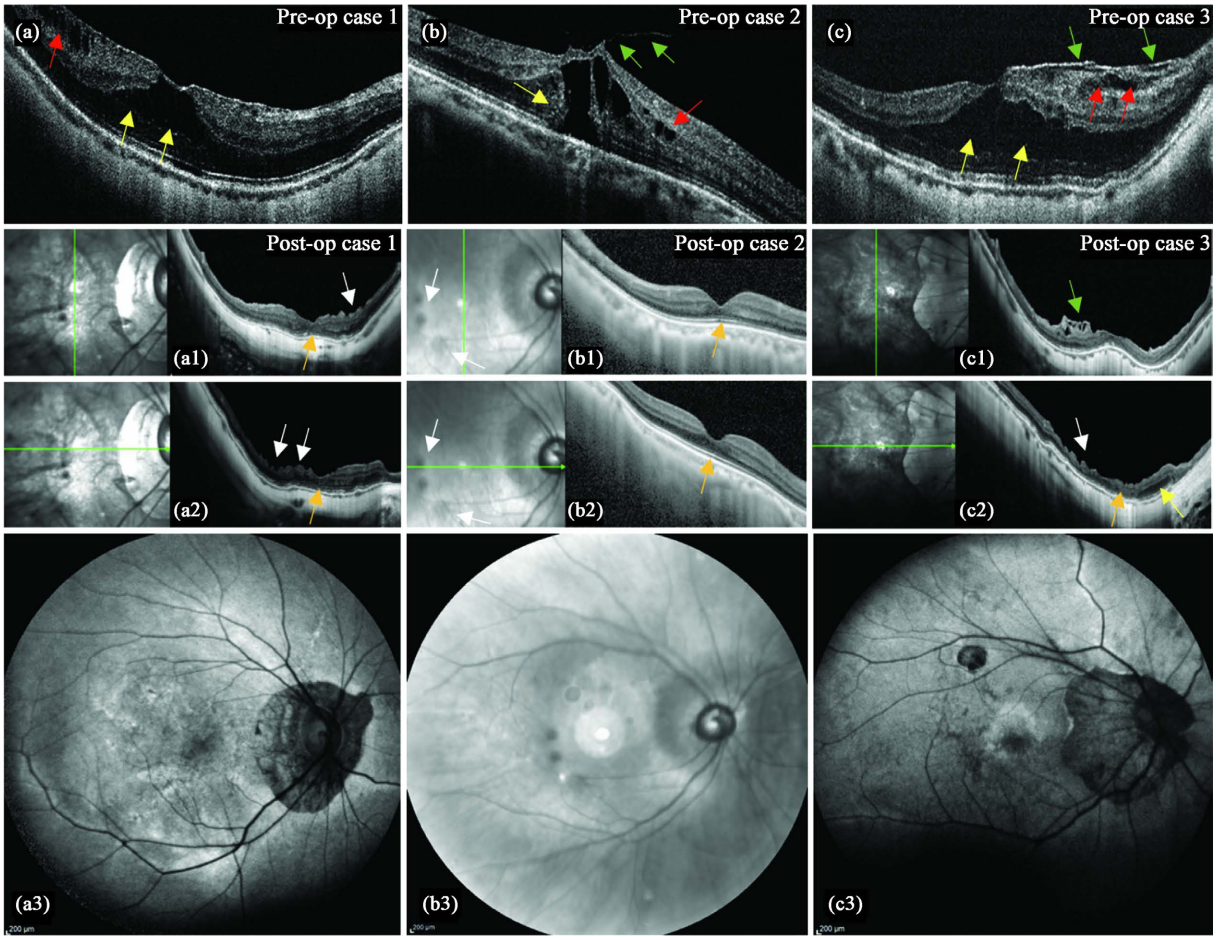


**Figure 2.** Comparative preoperative and postoperative structural findings. The upper row shows the preoperative microstructural findings on the magnified SD-OCT horizontal B-scan image evaluation of the three highly myopic eyes. (a) Case 1 shows diffuse schisis-like inner retinal thickening (red arrow). There is some schisis-like outer retinal thickening nasally with extensive foveoretinal detachment (FRD) beneath the thinned fovea (yellow arrows) and a disrupted subfoveal EZ. (b) Case 2 shows vitreomacular traction (green arrows), schisis-like inner and outer foveal thickening of the fovea (red arrow), and localized tractional FRD with a disrupted subfoveal EZ (yellow arrow). A very shallow posterior staphyloma (PS) was detected in this patient's eye (not shown). (c) Case 3 shows an epiretinal macular membrane (ERM) (green arrows), with internal schisis-like thickening (red arrows), thinning of the foveal tissue, and deep foveoretinal detachment (FRD) (yellow arrows). A disrupted ellipsoid zone (EZ) as well as a deep and irregular PS were detected in this case (partially shown). The postoperative swept-source OCT (SS-OCT) vertical and horizontal B-scans are displayed in the vertical columns. *The left vertical column depicts Case 1.* (a1) The vertical B-scan through the fovea (green vertical line) depicts a recovered foveal contour, normal subfoveal EZ, thinning of the inferior retina, and localized DONFL defects superior to the fovea (white arrow). (a2) The horizontal B-scan (green horizontal line) depicts a residual ERM and localized DONFL defects temporal to the fovea (white arrows); the subfoveal EZ is preserved (dark yellow arrow). (a3) This panel image depicts a very mild central hypoautofluorescence due to thin RPE over the macula. *The central vertical column depicts Case 2.* ((b1), (b2)) Crossline vertical and horizontal SS-OCT B-scans depicting a normal foveal contour, normal thickness of the sensorial macula, well-defined EZ, and some superficial retinal dimpling on the en face image (white arrow). (b3) The autofluorescence in this phakic eye shows only mild peripapillary pigment atrophy without evidence of foveal RPE alteration. *The right column depicts Case 3.* (c1) The vertical B-scan depicts an irregular foveal contour, mild epiretinal membrane (ERM), and hyaloid remnants inferior to the fovea (green arrow) with a well-preserved EZ. (c2) The horizontal B-scan depicts an irregular foveal contour, residual schisis-like thickening nasal to the fovea (yellow arrow), mild ERM with a well-preserved EZ (dark yellow arrow), and localized DONFL defects temporal to the fovea (white arrow). (c3) This image depicts extrafoveal areas of well-defined hypoautofluorescence and mild foveal hypoautofluorescence with a mild surrounding halo of hyperautofluorescence**.** The images in this modified multipanel figure were originally published in Int J Ophthalmol Clin Res 8:132 and used under the Creative Commons Attribution 4.0 International License (https://creativecommons.org/b/4.0).

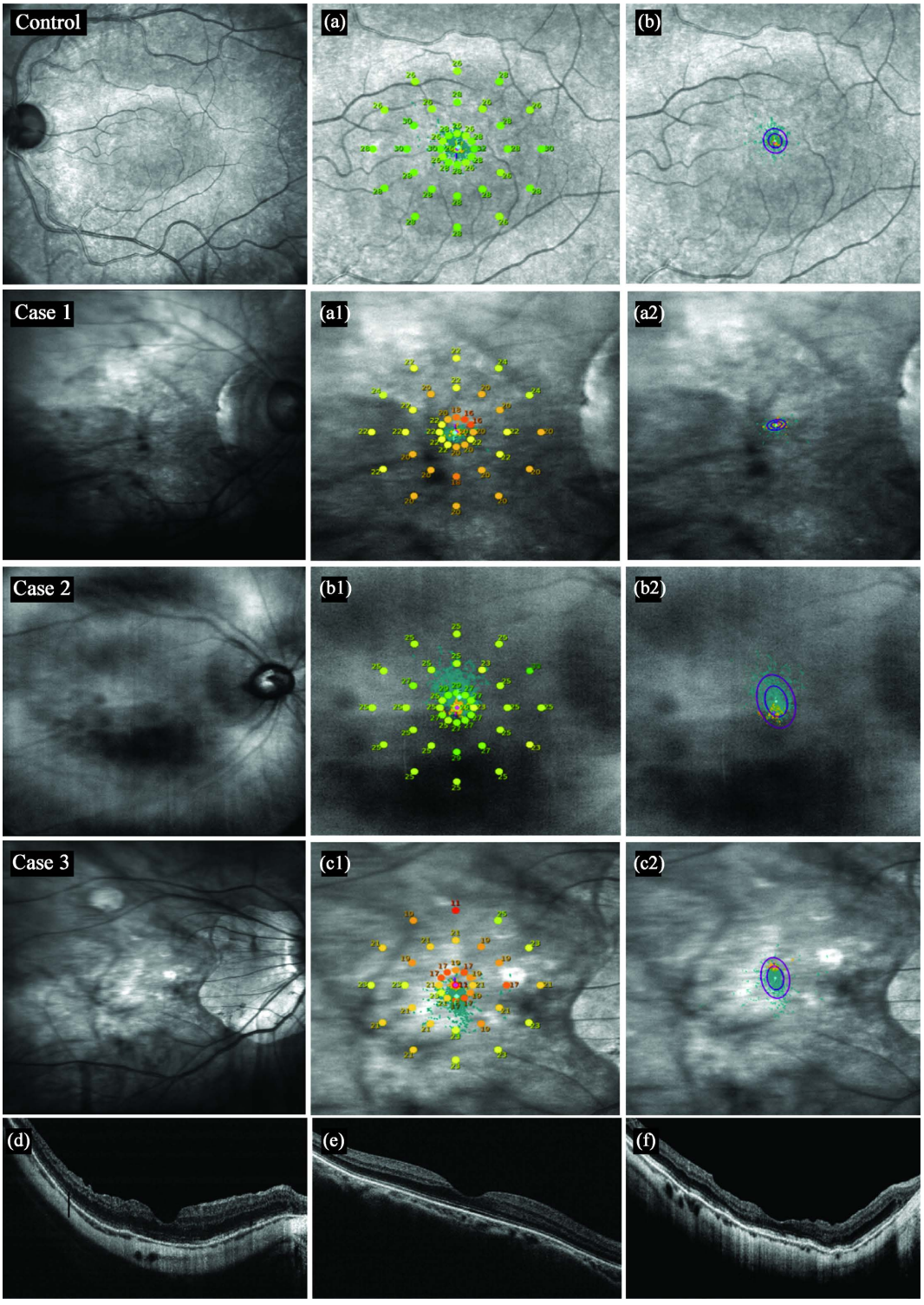


**Figure 3.** Microperimetry and corresponding SD-OCT. (control, (a) and (b)) The microperimetry images in the upper row correspond to a healthy moderate myope patient. ((a1), (b1), (c1)) The retinal sensitivity analysis map indicates ill-defined macular integrity with a low macular threshold for all three patients. ((a2), (b2), (c2)) In all three eyes, the fixation pattern was determined to be central, and the fixation stability pattern was stable. ((d)-(f)) Last SS-OCT structural evaluation of the three cases. The images in this modified multipanel figure were originally published in Int J Ophthalmol Clin Res 8: 132 and used under the Creative Commons Attribution 4.0 International License (https://creativecommons.org/b/4.0).

BCVA was 20/25 after a 14-month follow-up (0.10 logMAR). Postoperative structural OCT evaluation showed a resolved FRD, as depicted in Figure 2(b1) and Figure 2(b), released hyaloidal traction, a flat macula with a good foveal and macular profile and evidence of some superficial dimpling on the en face examination, as depicted in Figure 2(b1) and Figure 2(b2). The autofluorescence in this phakic eye shows some media lens-induced opacity and evidence of DONFL appearance induced by ILM removal; the image shows only mild peripapillary pigment atrophy without evidence of foveal RPE alteration (Figure 2(b3)). The microperimetric evaluation results were in the normal range, as depicted in Figure 3(b1) and Figure 3(b2). The final SS-OCT aspect is depicted in Figure 3(e).

### 2.5. Clinical Case 3

In this case, a 49-year-old woman presented with symptoms of aggravating symptomatic metamorphopsia in the right eye for more than seven months, accompanied by progressive vision loss. The myopic spherical equivalent was -22.90 diopters. The preoperative BCVA was ~20/120 (0.80 logMAR) with normal applanation intraocular tension (10 mmHg). An axial length of ~30.76 mm and a deep central PS were observed by fundus photography (not shown), fundoscopy, and SS-OCT evaluation. The findings of the preoperative spectral-domain (SD)-OCT are consistent with ERM proliferation (Figure 2(c) using green arrows); foveal detachment with a remarkable amount of central submacular fluid is depicted in Figure 2(c) using yellow arrows, and schisis-like macular thickening is depicted using red arrows. Macular surgery was performed using an FS-ILM surgical technique. As a result of the patient's refractory FRD and increased foveal symptomatology, a second round of surgery was performed using BBG dye guidance to distinguish epiretinal and ILM residues. Finally, air-fluid exchange with a mixture of octafluoropropane gas (15% nonexpandable concentration) was safely performed. On crossline, vertical and horizontal SS-OCT B-scan postoperative evaluations, no clinical evidence of residual macular ERM proliferation was observed on the superficial aspect of the macula (Figure 2(c1) and Figure 2(c2)). The foveomacular region remained attached at the 9-month last evaluation visit, with a BCVA of ~20/40 (0.30 logMAR). Some vitreous cortical remnants inferior to the fovea were identified (Figure 2(c1), green arrow) with localized DONFL defects temporal to the fovea (Figure 2(c2), white arrow). The autofluorescence imaging evaluation showed peripapillary and extrafoveal areas of well-defined hypoautofluorescence and faint foveal hypoautofluorescence with a mild surrounding halo of hyperautofluorescence (Figure 2(c3)). Retinal sensitivity assessment confirmed abnormal macular sensitivity, with a mild decrease in foveal threshold sensitivity, as depicted in Figure 3(c1) and Figure 3(c2). The last long-term SS-OCT structural evaluation is depicted in Figure 3(f).

Table 1 summarizes the preoperative and postoperative structural and functional findings of the three eyes.

**Table 1.** Summary of preoperative and postoperative structural and functional findings.

| Findings | Case 1 (65 F) | Case 2 (46 F) | Case 3 (49 F) | Observations |
|---|---|---|---|---|
| Evolution of FRD | 12 months | 3 months | 7 months | Mean = 7.3 months |
| Follow-up | 19 months | 14 months | 9 months | Mean = 14.0 months |
| Preoperative BCVA | LogMAR 1.00 (20/200) | LogMAR 0.70 (20/100) | LogMAR 0.80 (20/120) | |
| Postoperative BCVA | LogMAR 0.10 (20/25) | LogMAR 0.10 (20/25) | LogMAR 0.30 (20/40) | Snellen equivalent |
| Preoperative SD-OCT | FRD + ERM | FRD | FRD+ERM | |
| Axial length | 28.92 mm | 27.70 mm | 30.76 mm | Mean = 29.12 mm |
| CSFT | Less than 180 µm | Up to 220 µm | Less than 180 µm | |
| Foveal contour | Disrupted | Recovered and preserved | Disrupted | |
| ERM | No | No | Mild, inferotemporal to the fovea | |
| Residual SRF | No | No | Residual nasal to fovea | |
| Residual foveoschisis | No | No | Nasal and extrafoveal | |
| Subfoveal EZ | Mild disruption | Preserved | Moderate disruption | |
| RPE changes | Faint central atrophy | Not detected | Mild central atrophy | |
| DONFL defects (dimples) | Isolated dimples | Mild dimples on en-face OCT | Not detected | |
| MRS | Reduced | Normal | Reduced | |
| FRS | Mild reduction | Normal | Deeply reduced | |
| FSP | Stable | Stable | Stable | |
| FLP (PRL) | Foveocentral | Foveocentral | Foveocentral | |
| RSAM | Abnormal | Recovered to normal | Depressed abnormal | |

BCVA, best-corrected visual acuity; SD-OCT, spectral-domain optical coherence tomography; SRF, subretinal fluid; CSFT, central subfoveal thickness; EZ, ellipsoid zone; ERM, epiretinal membrane; DONFL, dissociated optic nerve fiber layer; FRD, foveoretinal detachment; MRS, mean retinal sensitivity; FRS, foveal retinal sensitivity; FSP, fixation stability pattern; FLP, fixation location pattern; PRL, preferred retinal loci; RSAM, retinal sensitivity analysis map.

## 3. Discussion

We performed vitrectomy with an FS-ILM removal technique in three consecutive, symptomatic, and high MEs with FRD, and postoperative structural and functional evaluations were performed in the three cases. Although none of the patients developed MH, one demonstrated evidence of mild extrafoveal epiretinal membrane reproliferation regardless of ILM removal in an updated manner. Evidence of a significant reduction in macular sensitivity was demonstrated by the results of functional evaluations. Microperimetry showed stable fixation patterns and central location patterns in the three eyes. Two eyes showed subclinical evidence of reduced retinal sensitivity and a very abnormal retinal sensitivity in the analysis map that correlated with the postoperative BCVA.

Panozzo and Mercanti [4] concluded that the reflattening of the macula can

be facilitated by releasing the epimacular and vitreous traction at the early stages of MTM, which prevents the development of an MH or RD.

Shimada *et al.* [12] prospectively reported progressive macular thickening as a sign of progression to foveomacular retinoschisis and FRD. Although the progression of foveomacular retinoschisis to MH formation has been reported recently, the myriad pathogenic properties, especially at the early stages of MTM, are still not well understood; therefore, we speculated that early-stage detection of structural signs of the disorder in symptomatic eyes may improve the surgical outcomes. Patients with early-stage MTM, particularly MF, are among the least symptomatic when presented to retina specialists. This kind of early stage might persist for a long time with chronic subclinical progression before macular function is substantially impaired [11]. This observation confirms the proposals by Takano and Kishi in their classical study [10] and others [14] [16] regarding MF occurrence at an earlier stage or as a direct precursor lesion followed by development into FRD. Moreover, Uchida *et al.* [13] showed that during the follow-up, 80% of eyes (n = 10) progressed to FRD, followed by developing a partial- or full-thickness MH. Hayashi *et al.* [17] evaluated 806 eyes in 429 patients (~34% male and ~66% female). It was confirmed that the progression of foveomacular retinoschisis to FRD occurred in approximately 41.0% of eyes, and progression to partial-thickness MH in ~20.70% of eyes. It has been reported that initial findings such as thickening of the outer retina layers with tissue irregularities were associated with the development of a partial-thickness macular defect associated with shallow, focal FRD; the partial-thickness defect elevates the upper edge of the macula, leading to enlargement of the localized FRD [16] [17].

Baba *et al.* [18] found an incidence of up to 9% of eyes with high myopia and PS that eventually developed FRD. According to previous studies, these maladies could be treated with vitrectomy, posterior hyaloidal removal, different ILM stripping techniques and gas tamponade [11] [14] [19] [20] [21].

Currently, revised techniques, such as long-term gas with the FS-ILM surgical technique, are accessible for both primary and refractory cases, subsequently resulting in foveal reattachment and offering substantial visual improvement [22]. However, there are inherent risks associated with ILM removal, including: 1) thinning of superficial retinal layers, 2) superficial retinal tiny holes, 3) dissociated optic nerve fiber layer (DONFL) defects and 4) partial- or full-thickness MH formation. Shimada *et al.* [23] attempted to avoid these risks in eyes with an FRD by using a modified technique called the foveal-sparing technique. They found that no eyes developed MH with this technique. Up to ~16.7% of eyes progressed and finally developed a full-thickness MH subsequent to total classical removal or nonsparing ILM removal [23] [24]. In this way, progression to FRD may be indicative of a poor prognosis leading to MH formation [11] [16] [19] [22] [24] [25].

Herein, we report a case series of three eyes showing symptomatic FRD. The best postoperative final logMAR vision was found using long-acting gas with the

FS-ILM technique, with no observed MH development during the follow-up. An almost normal postoperative SS-OCT pattern was noticed in only one eye, and the observed postoperative visual improvement in these three FRD eyes was significant. One limitation of this report is that no standardization and correlation of the most important OCT biomarkers in this entity with the functional results were available, and there was a lack of postoperative multifocal electroretinography (mfERG) evaluation. Therefore, this study can only be empirically used to correlate functional results until an international and standardized SD-OCT biomarker classification is established. At present, these described biomarkers suggest that defects, including an unusual foveal contour, ELM line disruptions, segmented RPE, DONFL defects seen on en face imaging, and subfoveal EZ disruptions, may be tomographic indicators of vision. However, the effect of these tomographic microstructures, their reactive recovery to surgical procedures, and their potential correlation with the final postoperative BCVA are unknown.

The appearance of DONFL defects may be a result of ILM removal, and these observations were discussed by Alkabes *et al.* [26]. However, in comparison with automated microperimetry and mfERG, its effect on macular function remains debated. Huang *et al.* [27] considered myopic FRD as one of the most crucial postsurgery risk factors for developing MHRD in MTM, and in contrast to their findings, Al-Badawi *et al.* [25] recently reported a prospective study where there was no difference in the development of MHRD when the ILM was completely removed with a total classical technique, which was comparable to the results of the FS-ILM technique [14] [23] [24] [27].

The FS-ILM technique inhibits the proliferation of epiretinal macular membranes and hypothetically halts the progression of RS and FRD to MH by reducing ILM rigidity [23] [24] [27]; however, some other complications, such as macular atrophy, lamellar hole (partial-thickness MH), and thinning of the inner layers of the retina, have been previously described [27]. It is worth noting that the preoperative presence of FRD constitutes a risk factor for the development of MHRD [27], but a timely and uneventful surgical technique resolved macular traction, flattening the FRD without progression, as described in this report. Likewise, many novel surgical methods have been recently proposed for the unexpected complication of a postoperative MH, including autologous neurosensory retinal free patch transplantation [28], lens capsular flap transplantation [29], ILM repositioning with autologous blood [30] and inverted ILM insertion [31].

In this report, despite surgical reattachment of the FRD within the first months, chronic separation of the photoreceptors and presence of stagnant SRF in contact with the RPE were considered the causes of photoreceptor damage. As shown in two eyes, abnormal structural SD-OCT findings correlated with macular regions that were abnormal on automated microperimetry. The retinal origin of the defect is thus highly certain. Eye movements and changes in retinal fixation can be overcome with microperimetry, which provides accurate retina-related sensitivity data. The strength of this study is that it is among the first studies to evaluate the functional and anatomical results in a series of three patients with

high MEs who underwent FS-ILM using the best-known biomarkers to correlate functional results. However, this study presents some limitations because the only functional evaluations available preoperatively were BCVA and the Amsler test. Additionally, when FRD patients had profound vision loss and/or no clear central vision, preoperative microperimetry testing showed only false functional traces with no preoperative clinical relevance. Nevertheless, thorough microperimetry was performed during the final postoperative visit.

In summary, in the early stages of MTM, there are four major sources of traction on the retinal surface: adherent vitreous cortex, vitreomacular traction, epiretinal membrane presence, and ILM [32]. ILM inflexibility is considered a major cause of this maculopathy. Furthermore, ILM peeling reduces the rigidity that allows the retina to better conform to PS [33]. In FS-ILM, the fovea is reattached in a manner comparable to that of classical total ILM removal. This suggests that tangential traction is likely released by FS-ILM similar to the classical technique. In terms of visual prognosis, both the FS-ILM and classical total ILM removal techniques showed BCVA improvement after surgery. Such visual improvement by both types of surgical techniques might be attributed to foveoschisis restoration and the low occurrence of macular holes [22] [23] [24] [25]. However, according to one meta-analysis [34], the FS-ILM eye group achieved a better postoperative BCVA than the classical total ILM removal group.

In this case-series report, the anatomic outcomes were similar, with no evidence of residual RS or progression to MH or MHRD in either eye. The results favored the FS-ILM technique after assessing the structural results and the change in BCVA from baseline. This result indicates that the FS-ILM technique achieved acceptable outcomes in terms of functional postoperative vision. Randomized clinical trials or MTM full-spectrum systematic reviews with meta-analyses should be conducted to investigate the best surgical approach in the different MTM stages and to investigate the rates at which postoperative MH and MHRD occur. We consider that a better pathogenic classification of MTM stages is an outcome of the broad application of OCT and vitrectomy [35], since the full spectrum of MTM is increasingly being considered as a single clinical disorder with a wide range of clinical phenotypes ranging from RS to MH, followed by FRD and RD [36].

## 4. Conclusion

In conclusion, to minimize damage to photoreceptors and the RPE, MTM-induced FRD should be treated as soon as possible. It is unclear whether the observed functional changes are associated with prolonged exposure to subretinal fluid or secondary to mechanisms related to photoreceptor perfusion alterations that in turn are due to surgical maneuvers or to ILM surgical removal. Only subclinical damage permits successful early foveomacular anatomical reattachment. In this way, certain highly myopic eyes with PM, abnormal premacular tissues, and PS are at risk of developing MTM that in early stages should be periodically moni-

tored, and if progression is suspected, a timely, well-planned surgical intervention should be performed.

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## List of Abbreviations (Acronyms)

3-D, three-dimensional; ATN, classification system for myopic maculopathy including atrophic (A), tractional (T) and neovascular (N) components; BBG, Brilliant Blue G; BCVA, best-corrected visual acuity; ELM, external limiting membrane; ERM, epiretinal membrane; FRD, foveoretinal detachment; ILM, internal limiting membrane; logMAR, logarithm of the minimum angle of resolution; ME, myopic eye; MF, myopic foveoschisis; MH, macular holes; MTM, myopic traction maculopathy; OCT, optical coherence tomography; PM, pathological myopia; PS, posterior staphyloma; RPE, retinal pigment epithelial; RS, retinoschisis; SD, spectral domain; SS, swept-source.

## Statement of Ethics

The protocol for this study was approved by the Institutional Review Board (IRB) of Oftalmologia Integral ABC on May 10, 2022. All protocols adhered to the criteria of the Declaration of Helsinki of the World Medical Association. All three patients gave informed consent to the publication of this case report and any accompanying images. According to the Declaration of Helsinki, this report does not contain any personal information that could identify patients.

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## Author Contributions

Quiroz-Reyes MA conceptualized this work and drafted and reviewed the manuscript, Quiroz-Gonzalez EA was responsible for statistics and table generation, Quiroz-Gonzalez MA was responsible for figures and artwork, and Lima-Gomez V performed the final revision.

## Data Availability Statement

All the data generated or analyzed during this study are included in this article. Further inquiries can be directed to the corresponding author.

## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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