MULTIFOCAL ELECTRORETINOGRAPHY AND SPECTRAL-DOMAIN OPTICAL COHERENCE TOMOGRAPHY IN MACULA-OFF RHEGMATOGENOUS RETINAL DETACHMENT

A Prospective Cohort Study

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Purpose: To analyze the temporal trends in structural changes using spectral-domain optical coherence tomography and functional changes using multifocal electroretinogram after rhegmatogenous retinal detachment surgery.

Methods: This prospective cohort study enrolled 69 patients with macula-off rhegmatogenous retinal detachment who underwent successful surgery. Early Treatment Diabetic Retinopathy Study visual acuity, multifocal electroretinogram evaluation of the central 5°, and spectral–domain optical coherence tomography were recorded at 1, 3, 6, and 12 months (M) after surgery. The fellow eye served as the control group for multifocal electroretinogram parameters.

Results: Between M1 and M12, visual acuity improved from 64 to 75 letters ($P = 0.001$) and implicit time of N1 decreased from 27.8 to 25.2 milliseconds ($P = 0.001$), whereas the other parameters did not vary significantly. Amplitude and implicit time values did not reach normal values at M12. Alterations of the ellipsoid zone and the external limiting membrane decreased over time ($P = 0.001$). P1 implicit time correlated independently with the alteration of the external limiting membrane ($P = 0.007$).

Conclusion: Foveal wave amplitudes remain lower than normal values after successful surgery of rhegmatogenous retinal detachment, whereas anatomical improvement was found for outer retinal abnormalities and subretinal edema fluid. Retinal recovery improves N1 implicit time over time. Disruption of external limiting membrane seems to be predictive of increased P1 implicit time.

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Rhegmatogenous retinal detachment (RRD) is a fairly common sight-threatening disease, especially if the macula is detached, leading to final vision of 20/40 or better in only 37% to 71% of cases.[1] Previous studies with spectral-domain optical coherence tomography (SD-OCT) performed after successful retinal reattachment have reported poor visual outcome associated with epiretinal membranes (ERMs), cystoid macular edema (CME), macular hole, and/or disruption of the external limiting membrane (ELM),[2] ellipsoid (EZ),[3–6] or the cone interdigitation zone (CIZ).[7,8]

Retinal function after RRD has been evaluated in many studies using best-corrected visual acuity (BCVA),[1] contrast sensitivity,[9] visual field,[10] microperimetry, full-field electroretinogram (ERG),[8,11–13] and multifocal ERG (mfERG).[14–17] The correlation between retinal function and SD-OCT abnormalities has been previously reported using microperimetry, a subjective technique.[2,3,18]

Multifocal ERG is a noninvasive method detecting functional changes in the central retina up to 20 to 25 degrees of eccentricity.[19] Multifocal ERG has been evaluated after macula-off RRD surgery in studies of relatively limited sample size.[14–17] Previous studies have suggested that foveal amplitudes (AMP) improved significantly in the postoperative period.[15,17,20] To our knowledge, mfERG evaluation of RRD patients over the long term is currently lacking. Combining a functional (mfERG) and an anatomical (SD-OCT) test would provide a unique opportunity to improve our understanding of the recovery of RRD after surgery.

The aim of this prospective cohort study was to investigate the temporal trends of mfERG and SD-OCT parameters in successful macula-off RRD within a 12-month period.

Material and Methods

Study Design

We conducted a prospective study with 12 months of follow-up at the Grenoble Alpes University Hospital, France. All participants provided written informed consent. This study complied with the Declaration of Helsinki and was approved by the local institutional review board (IRB00010311).

Participants

Between April 1, 2013, and April 30, 2014, consecutive adult (age ≥18) patients with macula-off RRD were assessed for eligibility and enrolled by a physician in our institution in case of anatomical success 1 month after surgery. Patients with a history of ocular disease, amblyopia, grade C proliferative vitreoretinopathy, and/or who needed a silicone tamponade or were taking medications susceptible to change retinal function (phenothiazine, quinine sulfate, thioridazine, clofazimine, chlorpromazine, deferoxamine, hydroxychloroquine and chloroquine, cisplatin, and carmustine) were excluded. Patients with retinal redetachment within the follow-up period were excluded from the analysis.

Data Collection

Baseline (preoperative) data included demographics, ocular history, as well as duration and extent of RRD. At 1 (M1), 3 (M3), 6 (M6), and 12 (M12) months postoperatively, the following data were recorded: BCVA measurement using the Early Treatment Diabetic Retinopathy Study chart, fundus images (TRC-NW6S; Topcon, Tokyo, Japan), mfERG (Vision Monitor, Métrovision, Pérenchies, France), and SD-OCT (Spectralis, Heidelberg Engineering, software version 5.7.5.0, Heidelberg, Germany). The SD-OCT measurement of RRD height was evaluated from the detached fovea to the anterior surface of the retinal pigment epithelium/Bruch membrane.

Procedures

All surgical procedures were performed by two experienced surgeons (C.C., K.P.). The patients underwent transconjunctival 23- or 25-G pars plana vitrectomy (with or without encircling band) or scleral buckling surgery, under general anesthesia. The indication for surgery was selected by the surgeons according to the characteristics of the retinal detachment (break location and type, proliferative vitreoretinopathy, and vitreous changes), the lens status, and/or severity of myopia. Retinopexy was performed with cryotherapy (ERBOKRYO AE, Erbe; Bron, France) or endophotocoagulation laser (Quantel Medical, VIRIDIS Twin). In case of pars plana vitrectomy, the Constellation Vitrectomy System (Alcon Laboratories, Rueil-Malmaison, France) was used with a cutting rate of 5,000/minute and a suction rate ranging between 120 and 400 mL/minute. A contact wide-angle viewing system combined with an image inverter (Resight 700 Fundus Viewing System, Zeiss, Oberkochen, Germany) or a plane-concave lens (FCI, ref. S5.7010, Paris, France) was used for fundus visualization. All vitrectomized eyes underwent complete pars plana vitrectomy, peripheral vitreous dissection under scleral depression, retinopexy (cryotherapy and/or endolaser), and then a fluid/gas exchange using 20% sulfur hexafluoride (SF_6) or 16% hexafluoroethane (C_2F_6) with drainage of subretinal edema fluid (SRF). Peeling of the internal limiting membrane was not performed.

Spectral-Domain Optical Coherence Tomography Acquisition

All OCT examinations were performed after pupillary dilation using tropicamide (Thea, Clermont-Ferrand, France) with SD-OCT. The pattern chosen for the Spectralis OCT was 20 × 20°, spaced 30 μm

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through the center of the fovea, high resolution, and 23 frames. Postoperative OCT parameters included the status (disruption or loss of integrity) of ELM, EZ, and CIZ layer in the five central degrees, presence of persistent SRF, ERM, CME and central retinal thickness (in the central 1-mm area).

Multifocal Electroretinogram

Multifocal ERG was performed according to the International Society for Clinical Electrophysiology of Vision (ISCEV) protocol, using a 61-hexagon strategy and scaled hexagons.[19] Stimulations were generated on a cathode ray tube monitor with a 120-Hz frame rate. The electrode used was the ERG-jet corneal electrode. The luminance of white hexagons was 400 cd/m^2, and the luminance of black hexagons was less than 4 cd/m.[2] Dark frames were inserted after the white frames to achieve an 18-Hz stimulus frequency. The surround luminance was set at 30 cd/m^2. The stimulus was calibrated following ISCEV guidelines. Ocular fixation was monitored continuously during the mfERG examination according to the technique of Hirschberg, which estimates the eye deviation from the position of the corneal reflection relative to the pupil. On the Metrovision equipment, for a normal eye looking at the fixation, the corneal reflection appears about 1.8 mm below the pupil center.[21] The operator can evaluate the fixation with about 5° of accuracy.

After pupil dilation using phenylephrine 5% (Europhta, Monaco, Monaco) and tropicamide (Thea), patient positioning, good fixation, best optical correction for near vision, and constant moderate room light for at least 15 minutes were ensured for each patient. Care was taken to eliminate any reflections from lens surfaces and to keep any bright light sources out of the patient's direct view. The first-order kernel mfERG responses were analyzed. Individual mfERG responses for the hexagons were grouped into five concentric rings centered on the fovea for analysis (2, 2–5, 5–10, 10–15, and beyond 15° of visual angle). The analysis focused on mfERG responses for the hexagons grouped into two concentric rings centered on the fovea for analysis (<2, 2–5° of visual angle radius).

Mathematically, the first-order kernel was obtained by adding all the records that followed the presentation of a white hexagon (luminance, 400 cd/m^2) and subtracting all the records that followed a black hexagon. Spatial averaging is not used in the software. The following data were collected: the RMS (root-mean-square values), implicit time (IT), and AMPs of N1 and P1 waves. The N1 response was measured from the starting baseline to the base of the N1 trough; the P1 response AMP was measured from the N1 trough to the P1 peak. Implicit time was measured from the start of the line to the trough or peak. The RMS analysis calculates the root mean square of the signal calculated for each element. It represents the "power" of the signal. For each ring, the RMS of the response was calculated with the following formula where is the sample index i of the response and are the first and last indexes of the time window. Root-mean-square R was calculated between 25 and 80 milliseconds (ms) and gives an estimation of the MfERG response (+noise). Root-mean-square N was calculated between 200 and 290 ms and gives an estimation of the noise level. During the ring analysis, a graphic display of RMSr and RMSn for each ring allows for an easy evaluation of the presence of MfERG responses. Reliability was based on the noise level (RMS value < 5 μV), a low fixation error level (<10%), stability of the global signal, and average RMS AMP values. Normative data using the Vision Monitor device are (mean ± SD) as follows: −915 ±260 nV for N1 AMP, 1,633 ±395 NV for P1 AMP, 23.2 ±1.3 msec for N1 IT, and 42.2 ±1.6 msec for P1 IT.

Data from the normal fellow eye, analyzed using the same protocol, served as the control eye. MfERG were done at the M1 visit using the same recording procedure.

Statistical Analysis

The main outcome measure was mfERG parameters of the operated eye. Secondary outcomes included OCT parameters and visual acuity.

Categorical data were reported as numbers and percentages and continuous variables and were summarized with mean and SD or median and 25th–75th percentiles, where appropriate. We compared AMP and ITs between control and affected eyes using the Student *t*-test for paired samples.

To account for observations clustering within patients (i.e., correlation of repeated multifocal ERG measures for the same eye followed over time), temporal trends in parameters were modeled using generalized estimated equations for continuous or binary dependent variables. In univariate analysis, we investigated the associations between each mfERG parameter (i.e., N1 IT, N1 AMP, P1 IT, P1 AMP, and RMS) and BVCA; outer retinal abnormalities, ERM, SRF, and CME were entered as independent variables. We assessed the linearity assumption for continuous independent variables using fractional polynomial functions. First-order interactions involving time to follow-up and independent variables were systematically tested for statistical significance. If a significant interaction was found, coefficient estimates were reported for each time to follow-up strata, separately. In multivariate analysis, we evaluated the independent associations of mfERG parameters with ELM, EZ, and CIZ alterations after adjusting for SRF, CME, and ERM.

Regression coefficient point estimates were reported along with 95% confidence intervals (CIs). Regression coefficients represent the difference in predicted mfERG parameter values for each one-unit difference in the covariate value. Two-sided P values of <0.05 were considered statistically significant. All analyses were performed using Stata Special Edition version 14.0 (Stata Corporation, College Station, TX).

Results

Ninety-one patients were enrolled in the study. Of these, 22 patients were excluded because of redetachment (n = 16) or lost to follow-up early (n = 6). Finally, our analytical sample comprised 69 participants (69 eyes).

Participant Characteristics

The mean age for all patients was 61 years (SD, 12.5), 53.6% were pseudophakic, and the median duration of visual loss was 5 days at baseline (Table 1). Missing data or ungradable data were reported for 13 patients for the following reasons: SD-OCT data (n= 4 at M1; n= 1 at M3; n= 1 at M6), mfERG data (n= 1 at M1; n= 3 at M6; n= 1 at M12), and loss of follow-up at M12 (n= 3). Overall, 65 patients (94%) were analyzable for both OCT and mfERG at M1, 68 (99%) at M3, 66 (96%) at M6, and 65 (94%) at M12.

Progression in Anatomical and Functional Parameters Over Time

Visual acuity statistically improved over time (mean difference between baseline and 12 months of follow-up, 49 letters, 95% CI, 45 to 53; $P <$ 0.001). N1 IT decreased by 0.23 ms each month (Figure 1B; regression coefficient, −0.23; 95% CI, −0.35 to −0.11; P = 0.001). Other mfERG responses remained unchanged from M1 to M12, including N1 AMP (Figure 1A; regression coefficient, −1.52; 95% CI, −11.2 to 8.15; P = 0.76), P1 AMP (Figure 1C; regression coefficient 3.75; 95% CI, −7.21 to 14.7; P = 0.50), P1 IT (Figure 1D; regression coefficient, −0.12; 95% CI, −0.24 to 0.01; P = 0.06), and RMS (Figure 1E; regression coefficient 3.68; 95% CI, −10.84 to 18.21; P = 0.62).

Table 1. Participant Baseline Characteristics

Characteristics	(n = 69)	
Male gender, *n* (%)	47	68
Age, mean (SD), year	61.3	12.5
Right affected eye, *n* (%)	37	54
Duration of visual loss, median (25–75th percentiles), days	5	3–11
Pseudophakic, *n* (%)	37	54
Topography of RRD, *n* (%)		
Superior		33
Inferior		22
Temporal		27
Subtotal		9
Total		9
Procedure, *n* (%)		
Pars plana vitrectomy	45	65
Scleral buckling	24	35
Axial length >26 mm, *n* (%)	9	13
Detachment macular height, median (25–75th percentiles), microns*	556	381–992
Detachment macular height >1,500 μm, *n* (%)	18	30
Preoperative BCVA, median (25–75th percentiles), No. letters	18	0–50

*SD-OCT measurement of RRD height was limited to 1,500 μm because of the Heidelberg device.

In comparison with control eyes, RRD eyes yielded decreased P1 AMP and N1 AMP values and longer P1 IT and N1 IT at each follow-up visit (Table 2).

In OCT, the odds of central retinal thickness (regression coefficient, 1.32; 95% CI, 0.14–2.5; P = 0.03) and ERM (odds ratio [OR], 1.06; 95% CI, 1.01–1.12; P = 0.02) increased significantly over time (Figure 2). This means that a 32% increase in OR of central retinal thickness and 6% in OR of ERM were noted over time. In contrast, the odds of alterations of the EZ (17% reduction in OR [OR, 0.83; 95% CI, 0.78–0.87; P = 0.001]), the ELM 12% reduction in OR (OR, 0.88; 95% CI, 0.82–0.93; P = 0.001), the CIZ (9% reduction in OR [OR, 0.91; 95% CI, 0.87–0.95; P = 0.001]), and the SRF (15% reduction in OR [OR, 0.85; 95% CI, 0.79–0.92; P = 0.001]) decreased over time (Figure 3). External limiting membrane disruption was almost always associated with EZ disruption (96% at M1, 100% at M3, 92% at M6, 100% at M12).

Structure–Function Correlations Over Time

P1 IT correlated with the alteration of the ELM period and BCVA (Table 3), over the follow-up. No other significant correlation was observed between mfERG and the OCT or BCVA parameters. In multivariable analysis, P1 IT remained associated with ELM alteration (adjusted regression coefficient, 1.97; 95% CI, 0.48–3.45; P = 0.009), after adjusting for SRF, CME, and ERM.

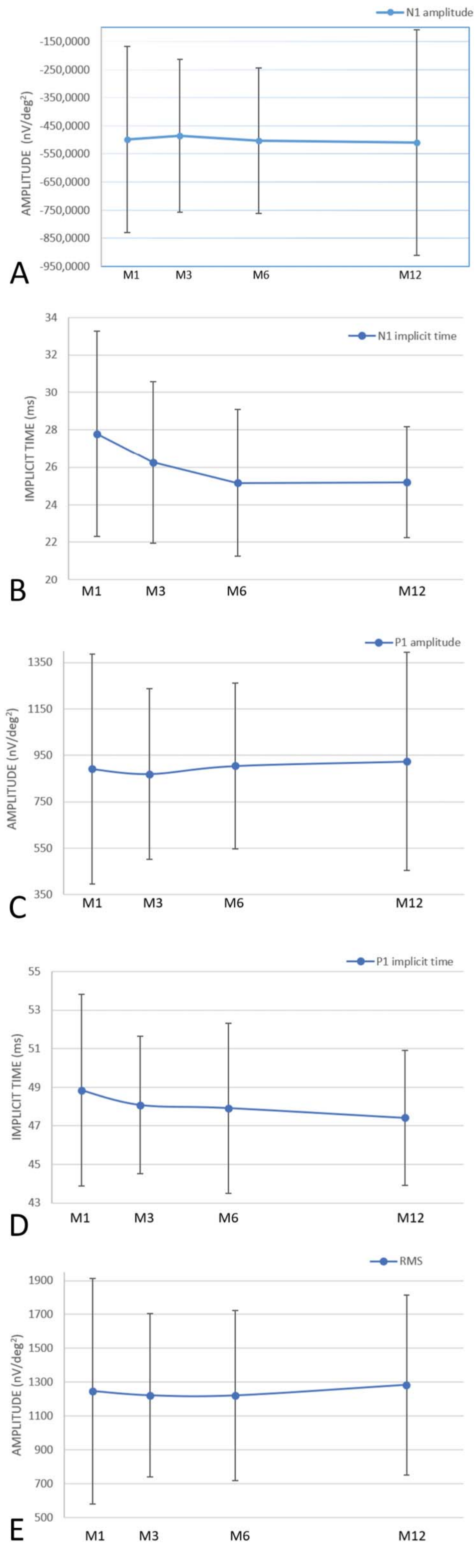

Fig. 1. Mean AMP and IT of the mfERG components over 12 months: N1 AMP (**A**) and IT (**B**); P1 AMP (**C**) and IT (**D**); RMS (**E**). Error bars indicate SD. RMS, root mean square of the signal; M1: Month 1 visit; M3: Month 3 visit; M6: Month 6 visit; M12: Month 12 visit.

Discussion

This prospective study combining SD-OCT and mfERG showed that 1) N1 IT decreased over the 12-month follow-up period, whereas other mfERG parameters remained fairly unchanged, 2) absolute values of P1 and N1 AMPs remained significantly lower by 36% and 44% in patients with RRD when compared with control eyes, respectively, up to the M12 visit, 3) central retinal thickness and the rate of ERM increased over time, whereas the rate of SRF decreased, and 4) P1 IT was independently associated with the alteration of ELM.

We found that eyes with a history of macula-off RRD exhibited a significant reduction in AMP of P1 and N1 over a 12-month follow-up when compared with control eyes (36%–45% and 44%–47%, respectively) and a significant lengthening of N1 and P1 IT (4%–13% and from 3% to 5%, respectively). The same results were found in previous studies with relatively limited sample sizes, using mfERG[14,22] and focal macular ERG.[8]

We also observed an improvement in N1 IT (i.e., a significant reduction) with no significant change in AMP over time. N1 wave abnormalities found after RRD surgery suggest the impairment of hyperpolarization of cones and loss of off-bipolar cells.[19] The results reported herein are consistent with focal macular ERG findings after RRD surgery, with lower IT of b waves between the 1-month and 6-month visits.[8] The absence of normalization of all mfERG parameters, which was previously reported in small series of patients using mfERG[15] and focal macular ERG[8] up to 6 months, contrasts with the normalization of BCVA (20/20 at M12) in 28% of the participants. Our findings of unchanged P1 wave abnormalities in the postoperative period emphasize the incomplete cellular remodeling of second-order neurons to establish contact after retinal reattachment.[23]

We found no correlation between mfERG and BCVA. This discrepancy between objective and subjective measurement of macular function was also found using focal macular ERG.[8] This is highlighted by the progressive visual improvement, mostly in the first month of follow-up, and the stability of the decreased N1 and P1 AMP values.

Evidence derived from previous SD-OCT studies suggests that microstructural changes at the fovea may explain incomplete visual recovery after successful RRD surgery. We observed a restoration of the outer

Table 2. Paired Comparisons of mfERG Parameter for Eyes After Retinal Detachment Surgery With Baseline Values of Control Eyes

	AMP, nV/Deg²						Implicit Time, ms					
	P1		*P*	N1		*P*	P1		*P*	N1		*P*
Control eye at baseline, m (SD)	1,262	436	—	—	289	—	46	—	—	24	2	—
Difference (95% CI)*												
1-month FU visit	399	258 to 539	<0.001	−263	−372 to −153	<0.001	−3.0	−4.4 to −1.6	<0.001	−3.8	−5.2 to −2.3	<0.001
3-month FU visit	390	276 to 503	<0.001	−287	−383 to −192	<0.001	−2.0	−3.1 to −0.8	0.001	−2.0	−3.2 to −0.8	0.001
6-month FU visit	305	193 to 418	<0.001	−207	−301 to −114	<0.001	−1.8	−3.1 to −0.4	0.01	−0.9	−2.0 to 0.2	0.12
12-month FU visit	326	195 to 456	<0.001	−229	−366 to −92	0.002	−1.2	−2.3 to −0.1	0.03	−1.0	−1.9 to −0.1	0.04

*Values are point estimates (along with 95% CI) for the differences in mfERG parameters between RRD eye at follow-up and baseline control eye values.
FU, follow-up visit; m, mean.

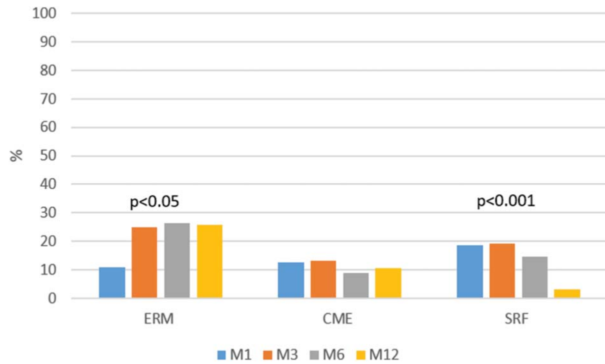

Fig. 2. Temporal trends in percentages of ERM, CME, and SRF in the five central degrees. M1: Month 1 visit; M3: Month 3 visit; M6: Month 6 visit; M12: Month 12 visit.

retina layer at the fovea after macula-off RRD surgery, with EZ restoration in 50% of the cases (from 68% disruption at M1 to 18% at M12), ELM restoration in 22% (from 31% disruption at M1 to 9% at M12), and CIZ restoration in 27% (from 69% disruption at M1 to 42% at M12). Previous studies using SD-OCT showed that ELM disruption was reported in 3% to 30% of eyes at M1[8,24,25] and 18% at M12,[26] EZ in 21% at M1 and 7% to 60% at M6,[8,27] and CIZ disruption in 83% at M1[8] and 68 to 82% at M6.[8,27] All these data suggest a considerable potential for tissue regeneration.

Only one recent publication[8] reported the correlation between OCT and electroretinographic function and suggested that a restoration of EZ accompanied by restoration of the CIZ was essential for the recovery of focal macular ERG. Experimental detachment in the ground squirrel showed significant correlations between outer nuclear cell counts and ERG flicker for the cone responses.[23] In the present study, P1 IT was the only mfERG parameter correlated with OCT, especially the alteration of the ELM over the follow-up period. Changes in ELM, which represent the Müller cell junctional complexes, is associated with the morphological changes in the photoreceptor cell bodies. Primate studies have shown that both rods and cones recovered less than 50% of their length after 30 days of reattachment, with many of the cones reaching about two thirds of their length. Previous studies showed that combined disruption of EZ and ELM carried a poorer visual prognosis than EZ alone. External limiting membrane disruption is almost always associated with EZ disruption, as illustrated in our study. Many studies suggested that the restoration of the outer retinal layer in the postoperative period depends on the state of ELM.[28] The effect of ELM disruption was highlighted in the present study by its relationship with higher IT values of the P1 response and was consistent with the fact that IT P1 is known to

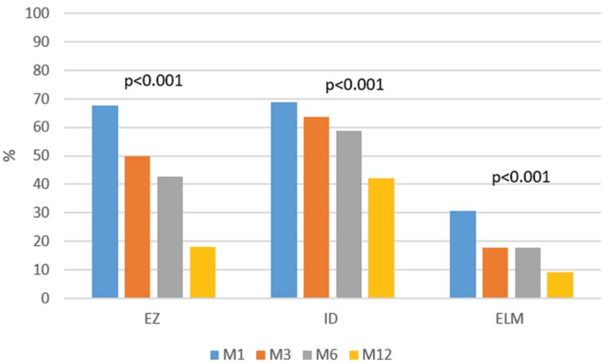

Fig. 3. Temporal trends in SD-OCT retinal layer alteration in the five central degrees. M1: Month 1 visit; M3: Month 3 visit; M6: Month 6 visit; M12: Month 12 visit; ID, interdigitation.

be a very sensitive measurement of outer retinal function.[19]

Subretinal edema fluid was observed in 18% of eyes at M1 and for the most part resolved at M12 (3%), consistent with previously reported frequencies: from 10% to 81% of cases at M1[25,29–31] resolved in 4% to 33% of the cases at 6 months.[17,27,30,31]

The strengths of this study include its prospective design, the relatively high number of patients, the long duration of follow-up, and the use of an objective technique for visual function such as mfERG. Furthermore, we used the contralateral normal eye as control, as gender and age being considered as potential factor affecting mfERG measurements. Data from contralateral eyes were in the normal range using the Vision Monitor device. Yet, this study has limitations that deserve mention: 1) the assessment of the outer retina was qualitative, without quantitative measurements of ELM, EZ, CIZ, and left eye length; 2) mfERG analysis was limited to the fovea responses (Rings 1 and 2 because the other ring areas could be variably involved by the RRD according to the different topographies of RRD); 3) our results are not directly comparable with those of previous series because of the difference in ERG devices and the different rings studied. Pattern focal ERG, which also allows for the assessment of macular function, was not used in this study. We focused on mfERG responses for the hexagons grouped into two concentric rings centered on the fovea (<2, 2–5° of visual angle radius) because we initially aimed to correlate mfERG results with macular OCT in patients with macular detachment at baseline; 4) we did not evaluate the effect of treatment techniques (scleral buckling vs. vitrectomy) because the choice of the surgical technique depends on different clinical factors. The study aimed to report associations between functional and anatomical changes, independently from the surgical technique; 5) we did not use mfERG before surgery because the

Table 3. Univariable Associations Between mfERG Parameters and BCVA and OCT Parameters During Follow-up*

	RMS		*P*	N1 AMP		*P*	N1 Implicit Time		*P*	P1 AMP		*P*	P1 Implicit Time		*P*
BCVA	−0.8	−6.3 to 4.8	0.78	−0.9	−4.3 to 2.4	0.58	−0.03	−0.1 to 0.02	0.27	1.7	−2.9 to 6.2	0.47	−0.05	−0.1 to −0.01	0.008
OCT parameters															
EZ alteration	13.4	−142.8 to 169.6	0.87	16.0	−83.2 to 115.2	0.75	−0.04	−1.4 to 1.3	0.95	1.3	−124.9 to 127.6	0.98	0.5	−0.7 to 1.7	0.44
ELM alteration	−42.9	−239.7 to 153.6	0.67	8.35	−114.1 to 130.9	0.89	0.49	−1.1 to 2.1	0.56	−51.2	−210.2 to 107.7	0.53	1.9	0.5 to 3.4	0.007
CIZ alteration	−24.2	−174 to 125.6	0.75	17.9	−77.1 to 112.9	0.71	−0.07	−1.3 to 1.2	0.92	−20.9	−142 to 100.2	0.73	0.3	−0.8 to 1.5	0.56

*Values are unadjusted β regression coefficient point estimates (along with 95% CI) derived from univariable generalized estimated equations for continuous dependent variables. Regression coefficients represent the difference in mfERG parameter values for one-unit difference in BCVA or for OCT parameter alteration, respectively.

fixation is often reduced in macula offretinal detachment, with acquisition of low-quality recordings; and 6) given the limitation of 1,500 μm using HRA spectralis OCT, we could not recode all height ofretinal detachment. This was the case for 25 eyes out of 69 (36%). Therefore, we decided to exclude this variable from the analysis. Finally, some of the observed associations might be spurious, reflecting inflated Type-I error because of multiple statistical comparisons. Hence, our findings need to be replicated in an independent sample.

In conclusion, this prospective mfERG study shows that foveal wave AMPs remain lower than normal values 12 months after successful RRD surgery, whereas anatomical improvement was found for outer retinal abnormalities and SRF. Retinal regeneration was assessed with an improvement of IT N1 over the long term. Disruption of ELM was the only OCT abnormality found to be associated with increased IT P1.

Key words: ellipsoid, external limiting membrane, multifocal electroretinogram, spectral-domain optical coherence tomography, outer retina, retinal detachment.

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