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ORIGINAL ARTICLE

Binocular visual function improvement after pars plana vitrectomy for epiretinal membrane

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Abstract

Purpose: To report binocular visual function changes after pars plana vitrectomy for epiretinal membrane (ERM) and the related outcomes.

Methods: Twenty-three eyes of 23 patients operated on for ERM were included in a retrospective study. Clinical data, best-corrected visual acuity (BCVA), contrast sensitivity and binocular visual function were assessed pre- and 1 and 3 months post-operatively. Binocular visual function assessment included the evaluation of fusional amplitudes (i.e., vergences) by the synoptophore, far distance stereopsis using polarized glasses and near stereopsis using Randot and TNO tests. Central macular thickness (CMT) was measured on Spectral Domain – Optical Coherence Tomography.

Results: Mean age of the patients was 67 years. Mean BCVA and contrast sensitivity significantly improved post-operatively at one ($p=0.0006$ and $p=0.0022$, respectively) and 3 months ($p<0.0001$ and $p<0.0001$, respectively), while CMT significantly decreased after 1–3 months ($p<0.0001$ and $p<0.0001$, respectively). Fusional amplitudes improved after 3 months ($p<0.0001$). Far distance and near stereopsis significantly improved after 3 months ($p<0.0001$ and $p=0.0007$ for Randot test, and $p<0.0001$ for TNO test, respectively).

Conclusions: Pars plana vitrectomy for ERM surgery leads to an improvement of monocular and binocular visual functions (i.e., binocular fusion, near and far distance stereopsis), within 3 months post-operatively.

KEYWORDS
binocular visual function, contrast sensitivity, epiretinal membrane, far distance stereopsis, near stereopsis, pars plana vitrectomy

1 | INTRODUCTION

Epiretinal membrane (ERM) is a fibrocellular proliferation of glial tissue composed of hyalocytes, myofibroblasts and astrocytes (Abu El-Asrar et al., 2007; Foos, 1974) which extends at the surface of the retina, usually after the age of 60 (Bu et al., 2014). The origin of ERM is not fully understood. The vast majority of ERM (i.e., 80%) is considered "idiopathic" (iERM) (Dupas et al., 2015), while a minority may be consecutive to ocular trauma, retinal tears or detachment and inflammatory conditions such as uveitis, diabetic retinopathy and retinal vein occlusion (Zhu et al., 2020).

The contractile properties of ERM can lead to retinal deformations, macular thickening and foveal displacement. These changes might cause visual impairments including aniseikonia (Ugarte & Williamson, 2005), metamorphopsia (Watanabe et al., 2009), decreased visual acuity (McCarty et al., 2005), contrast sensitivity reduction (Liu et al., 2018) and binocular diplopia (Veverka, Hatt, Leske, Brown, Barkmeier, et al., 2017). Rarely, binocular diplopia results from binocular misregistration of the retinal mosaics secondary to foveal displacement. In those rare cases, defect of binocular parallax can create abnormal retinal correspondence and lead to the loss of image fusion and stereopsis (De Pool et al., 2005; Veverka, Hatt, Leske, Brown, Barkmeier, et al., 2017; Veverka, Hatt, Leske, Brown, Iezzi, & Holmes, 2017).

Only a few studies have evaluated the impact of more standard iERM on binocular visual function, (i.e., fusional amplitudes, binocular fusion and stereopsis) and contrast sensitivity, either before or after surgery (Asaria et al., 2008; Khanna et al., 2022; Sugiura et al., 2014). For

a decade, the indication of vitrectomy for symptomatic iERM has extended to less symptomatic cases. Some studies have demonstrated that vitrectomy shows better results when visual acuity is barely altered (Dawson et al., 2014; Khanna et al., 2022).

The main purpose of our study was to evaluate the impact of iERM on binocular visual function pre and post-operatively. Other visual functions including best corrected visual acuity and contrast sensitivity were assessed secondarily.

2 | METHODS

2.1 | Study population and data collection

This retrospective study included 23 eyes of 23 patients operated on for iERM using 25 Gauge par plana vitrectomy. ERM and internal limiting membrane peeling were achieved after intravitreal blue dye (MembraneBlue Dual®, DORC) injection. Patients were consecutive and surgery was performed between August 2017 and April 2018 at the Strasbourg University Hospital by one experienced surgeon (D.G.). None of the patient presented with post-operative complications. Clinical data, best corrected visual acuity (BCVA), contrast sensitivity and binocular visual function evaluation were reviewed together with data from Spectral Domain – Optical Coherence Tomography (SD-OCT) (Spectralis) for each patient. Data from pre-operative visit and from 1 to 3 months post-operative visits were collected.

Patients presenting with other disorders potentially responsible for binocular vision impairment were excluded. This concerned the presence of clinically significant glaucoma, uveitis, high myopia, strabismus, microstrabismus (diagnosed by the synoptophore and, in any doubt, by the four dioptres prism test), amblyopia and any other retinal or ocular disease on the studied eyes.

Written informed consent was obtained from all patients. The procedures used in this study adhered to the tenets of the declaration of Helsinki.

2.2 | Patient and public involvement

Patients or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

2.3 | BCVA and contrast sensitivity

BCVA was assessed using Early Treatment Diabetic Retinopathy Study (ETDRS) charts. Contrast sensitivity was measured using the monocular static contrast sensitivity test (MonPackOne [Metrovision]). Contrast sensitivity was tested at six spatial frequencies (i.e., 0.8, 1.7, 3.5, 7, 14 and 28 cycles-per-degree) with 100% contrast level. Values of contrast sensitivity results for each frequency were averaged for each patient pre-operatively and at 1 and 3 months post-operatively for statistical analysis.

2.4 | Binocular visual function assessment

A simple cover–uncover test was realized to evaluate near and far distance phoria. Ocular motility was assessed using Hess-chart test. Fusional amplitudes (i.e., vergences) were tested with the synoptophore with third-degree sights in convergence and divergence. Stereopsis was assessed in arc seconds (“). Far distance stereopsis was evaluated at 5 m using wall-projected patterns observed through polarized glasses. This allowed to measure stereopsis between 60″ and 600″. Near stereopsis was evaluated at 40 cm using Randot test (with polarized spectacles) and TNO test (with red-green spectacles), measuring stereopsis from 400″ to 20″ and 400″ to 15″, respectively. If the patient failed the TNO test, a Wirt Fly test (or Titmus test), using polarized spectacles, was realized to attest gross stereopsis (3000″). Similarly, if patients failed the far distance stereopsis test, 3000″ value was considered for statistical analysis.

2.5 | OCT examination

Central macular thickness (CMT) was assessed on SD-OCT using the automated software evaluation of the Heidelberg device (macular mapping 25 lines 30° ART) at each time point visit. Foveal displacement was assessed on SD-OCT using *en face* images.

2.6 | Statistical analysis

Parametric tests were used when Gaussian conditions were respected and nonparametric tests in other conditions. Significance was considered for P values inferior to 0.05. All statistical analyses were realized using Graph-Pad InStat 3.10 (2009) and Statview 5.0 (SAS Institute).

3 | RESULTS

3.1 | Baseline characteristics

Mean age of the 23 patients was 66.61 ± 7.37 years. There were 8 women and 15 men. All underwent unilateral surgery. ERM, 56.52% were operated on the right eye and 43.48% on the left eye (Table 1). All participants were followed up for 3 months after surgery.

Pre-operatively, mean BCVA (ETDRS) of the eye presenting with iERM was significantly lower compared to the fellow unaffected eye (66.35 ± 7.58 vs. 77.48 ± 7.38; $p = 0.0002$). Similarly, contrast sensitivity was significantly lower on the affected eye (13.51 ± 1.74 dB vs. 16.5 ± 2.0 dB; $p = 0.0003$) while CMT was significantly higher (482.99 ± 65.95 µm vs. 314.52 ± 49.60 µm; $p < 0.0001$).

3.2 | BCVA and contrast sensitivity

Post-operatively, BCVA and contrast sensitivity significantly improved at 1 and 3 months, while CMT

TABLE 1 Baseline characteristics before epiretinal membrane surgery.

			Central macular thickness (μm)		Visual acuity (ETDRS)			Near stereopsis (arc seconds)		Fusional amplitudes (dioptres)		Contrast sensitivity (dB)	
Patient	Sex	Age	Operated eye	Contralateral eye	Operated eye	Contralateral eye	Far distance stereopsis (arc seconds)	Randot	TNO	Convergence	Divergence	Operated eye	Contralateral eye
1	F	50	424	511	54	70	3000	3000	3000	4	2	10	14
2	M	72	425	292	78	73	120	100	240	32	4	13	17
3	F	72	432	336	82	77	240	70	3000	12	4	14	13
4	M	70	545	312	67	81	240	70	480	6	2	14	17
5	M	73	408	404	67	67	3000	3000	3000	0	0	15	13
6	M	72	414	261	58	50	3000	3000	3000	20	4	9	17
7	M	53	480	291	75	87	60	30	120	9	6	12	13
8	M	63	367	265	63	55	120	400	3000	14	6	11	13
9	M	70	595	262	63	79	3000	3000	3000	15	4	14	18
10	F	70	544	289	70	82	240	40	3000	8	4	15	13
11	M	78	499	440	60	68	240	100	3000	24	4	13	16
12	M	54	657	256	29	78	3000	800	3000	0	0	17	21
13	M	73	568	283	57	84	3000	3000	3000	20	4	12	17
14	M	67	420	302	76	90	60	25	480	21	6	21	24
15	F	62	601	267	66	87	3000	3000	3000	0	0	12	17
16	M	67	481	254	74	79	600	100	3000	22	3	14	17
17	M	59	477	304	60	79	3000	200	3000	12	3	12	16
18	F	75	405	302	71	81	3000	3000	3000	0	0	13	17
19	M	65	430	452	78	79	3000	400	240	20	4	15	16
20	F	61	535	287	69	75	60	200	3000	7	3	14	19
21	M	68	546	277	67	90	3000	3000	3000	0	0	12	20
22	F	65	498	278	70	86	240	70	3000	19	2	15	18
23	F	73	357	309	72	85	3000	3000	3000	0	0	13	17

Abbreviations: dB, decibels; ETDRS, Early Treatment Diabetic Retinopathy Study.

TABLE 2 Statistical comparisons between pre and postoperative data at 1–3 months (M1 and M3, respectively) after epiretinal membrane surgery.

	T0	M1	M3	*p* T0 vs. M1	*p* T0 vs. M3
BCVA (ETDRS), mean ± SD	66.35 ± 10.95	74 ± 7.46	77.39 ± 6.58	0.0006	<0.0001
Far distance stereopsis (arc seconds), mean ± SD	1661.7 ± 1433	1653.9 ± 1444.6	383.48 ± 840.34	0.367	<0.0001
Near stereopsis (arc seconds), mean ± SD					
Randot	1287.2 ± 1413.9	675.87 ± 1104.8	210 ± 613.12	0.06	0.0007
TNO	2415.7 ± 1135.7	1919.6 ± 1382.5	911.74 ± 1271.7	0.02	<0.0001
Fusional amplitudes (diopters), mean ± SD					
Convergence	11.52 ± 9.5	14.56 ± 9.8	24.39 ± 8.56	0.098	<0.0001
Divergence	2.83 ± 2.03	3 ± 1.76	3.22 ± 1.28	0.758	0.440
Central macular thickness (μm), mean ± SD	482.96 ± 79.99	406.78 ± 78.14	386.39 ± 61.36	<0.0001	<0.0001
Contrast sensitivity (dB), mean ± SD	13.51 ± 2.47	15.93 ± 2.57	16.57 ± 2.3	0.0022	<0.0001

Abbreviations: dB, decibels; BCVA, Best Corrected Visual Acuity; ETDRS, Early Treatment Diabetic Retinopathy Study; SD, Standard Deviation.

significantly decreased during the same period (Table 2, Figures 1 and 2). Contrast sensitivity was especially improved for high spatial frequencies as shown in Figure 3. BCVA improvement negatively correlated with CMT reduction at 3 months (+10.5 on ETDRS chart vs. −101 μm on SD-OCT, Pearson's correlation coefficient, $R = 0.405$; $p = 0.031$). Post-operative BCVA correlated positively with contrast sensitivity ($R = 0.433$; $p = 0.02$) and negatively with TNO test ($R = 0.589$; $p = 0.004$).

3.3 | Binocular functions

No significant modification of phoria or ocular alignment were found at 1 and 3 months after ERM surgery, when compared to the pre-operative assessment.

Fusional amplitudes in convergence improved post-operatively, the improvement was significant only at 3 months (Table 2).

Far-distance stereopsis did not change after 1 month but significantly improved 3 months after surgery. Concerning near vision stereopsis, TNO test significantly improved at 1 and 3 months post-operatively and the Randot test showed a global post-operative improvement, although it was only significant at 3 months.

No patients presented with diplopia. Two patients (numbers 1 and 12) presented with a foveal displacement after ERM surgery (horizontal and vertical, respectively). These two patients had the worst results for near stereopsis (3000″ and 3000″ for TNO test; 400″ and 3000″ for Randot test, respectively), far distance stereopsis (3000″ for both patients) and fusional amplitudes (8 degrees for convergence and 2 for divergence in patient 1; null for both in patient 12) after 3 months post-operatively (Figure 2).

Of the 23 operated eyes, 15 were phakic. Three underwent cataract surgery combined with ERM peeling: patients 6 and 11 showed increased BCVA post-operatively and patient 16 showed steady BCVA. Patients 6, 8 and 11 underwent cataract surgery in their fellow unaffected eye: BCVA increased in patients 6 and 8, while steady vision was observed in patient 11 (Table 1). Two patients (5 and 19) had bilateral ERM, with only one eye retained for surgery. One patient had contralateral increased CMT due to macular oedema of unknown origin. In these three patients, BCVA and CMT of the contralateral eye remained stable during the follow-up period.

4 | DISCUSSION

The present study aimed to assess whether the quality of vision (i.e., BCVA, contrast sensitivity and binocular visual function) was modified by ERM surgery.

Monocular vision improvement after ERM surgery has already been reported. While recent studies reported BCVA improvement up to 12 months after surgery (Hartmann et al., 2014; Kim et al., 2010; Kinoshita et al., 2016; Kwon et al., 2009), overall results showed that vision mostly improves 1–3 months after ERM removal. In our study, BCVA increased significantly after 1–3 months (66.35 ± 10.95 vs. 74 ± 7.46 and 77.39 ± 6.58; $p = 0.0006$ and $p < 0.0001$, respectively).

CMT was significantly reduced at both 1–3 months (from 482.96 ± 79.99 μm to 406.78 ± 78.14 μm at 1 month, $p < 0.0001$; to 386.39 ± 61.36 μm at 3 months, $p < 0.0001$) and BCVA improvement significantly and positively correlated with CMT reduction after 3 months (Pearson's correlation coefficient: $R = 0.405$; $p = 0.031$). These results are in accordance with what has been previously reported in the literature (Chen et al., 2015). In the present study, ILM peeling was performed systematically. A recent meta-analysis showed higher post-operative CMT during the first 12 months in eyes with combined ILM and ERM peeling compared to ERM peeling alone. Then, after 12 months, CMT becomes similar in both groups of patients. Thus, in our study with a 3-month follow-up period, the CMT difference between operated and non-operated eyes could have been underestimated due to systematic ILM peeling (Huang & Li, 2021).

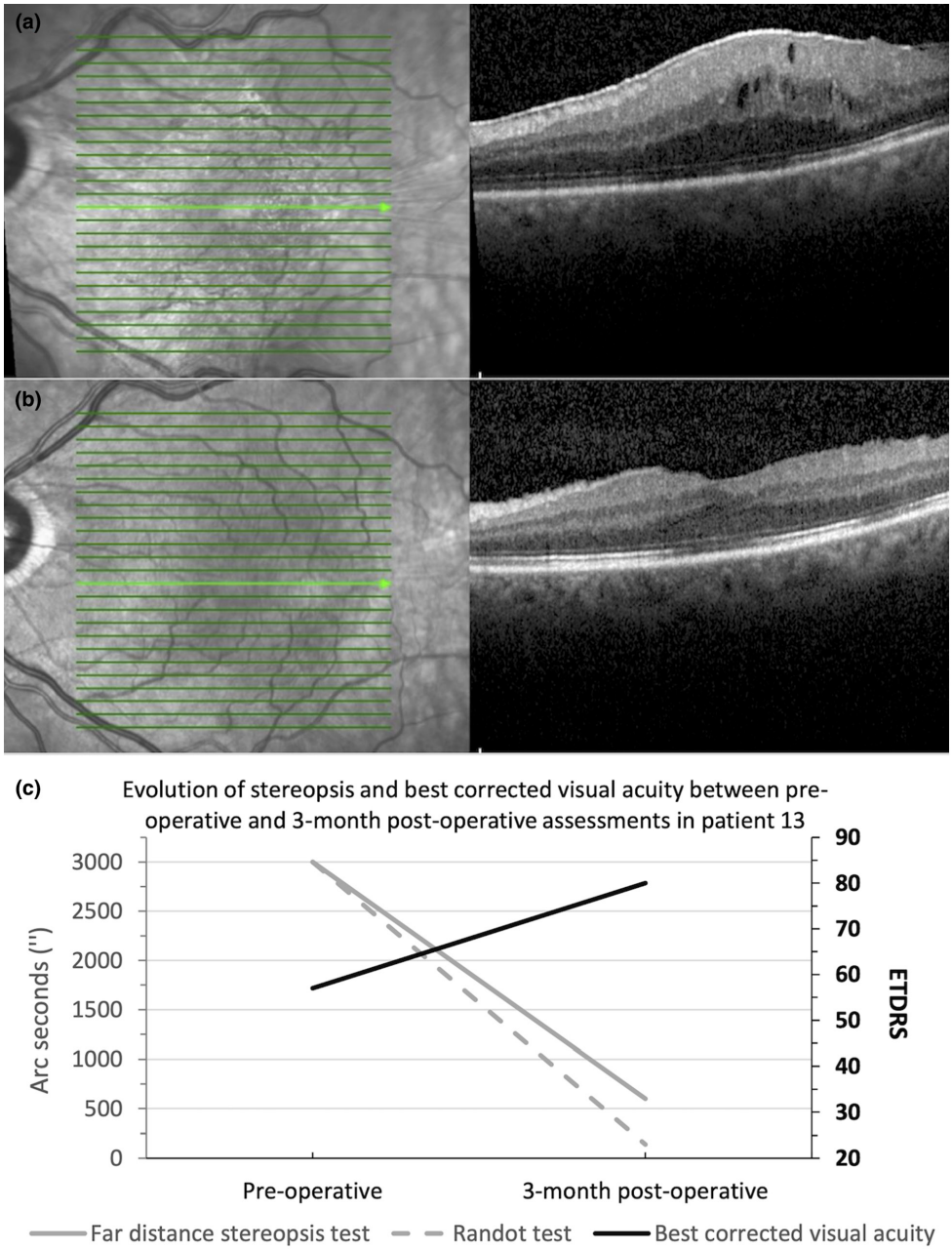

FIGURE 1 Pre-operative (a) and 3-month post-operative (b) spectral domain – optical coherence tomography of the left eye of patient 13 showing anatomical improvement of the macular profile and central macular thickness reduction after epiretinal membrane surgery. (c) Corresponding best corrected visual acuity increased from 57 to 80 on Early Treatment Diabetic Retinopathy Study (ETDRS) chart for this patient. Randot near stereopsis test improved from 3000 to 140 arc seconds (''). Far distance stereopsis test improved from 3000″ to 600″.

The main goal of our study was to analyse the impact of ERM surgery on vision quality and binocular function changes. It appeared interesting to evaluate contrast sensitivity, near and far distance stereopsis and fusional amplitudes before and after ERM surgery.

Indeed, contrast sensitivity impairment accounts for visual discomfort in patients with iERM, even when BCVA is preserved (Liu et al., 2018; Nishi et al., 2013). Retinal thickness in patients with ERM is associated with larger reductions in contrast sensitivity (Zeng et al., 2023). Clear improvement of contrast sensitivity, especially in high spatial frequencies, was observed at 1–3 months in the present study (Figure 3). Such improvement has already been observed in several studies, independently from BCVA changes (Sugiura et al., 2014). While low spatial frequencies are typically impaired by optic neuritis (Viret et al., 2013), high spatial frequencies tend to be altered by intraocular affections, including retinal diseases like age-related macular degeneration (Peyrin et al., 2017). This might support the hypothesis that ERM surgery was responsible for the contrast sensitivity improvement measured in this study. Furthermore, in this study, post-operative BCVA correlated positively with pre-operative contrast sensitivity and negatively with near stereopsis using TNO test. Assessment of these parameters pre-operatively might be relevant. Lack of correlation with other pre-operative binocular visual functions, especially far vision stereopsis and Randot test, could suggest a higher sensitivity of TNO test.

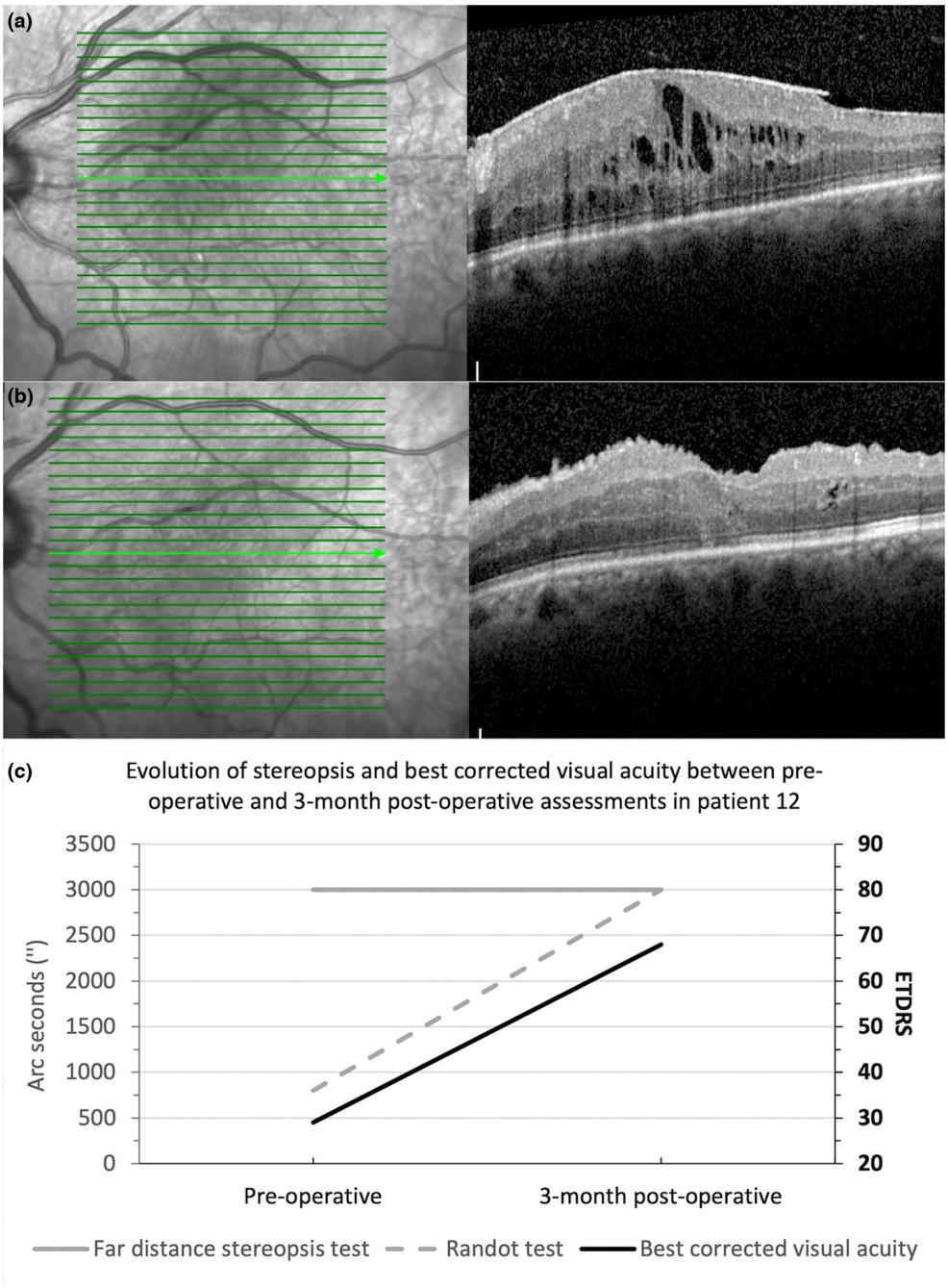

FIGURE 2 Pre-operative (a) and 3-month post-operative (b) spectral domain – optical coherence tomography of the left eye of patient 12 showing anatomical improvement of the macular profile and central macular thickness reduction after epiretinal membrane surgery. (c) Corresponding best corrected visual acuity increased from 29 to 68 on Early Treatment Diabetic Retinopathy Study (ETDRS) chart. However, near and far distance stereopsis tests did not improve in this patient post-operatively which is probably due to foveal displacement.

Binocular visual function after ERM peeling has been poorly studied. Fusional amplitudes (i.e., vergences), assessed by the synoptophore, is the second grade of binocular visual function, the first being simultaneous perception. Stereopsis is considered as the third, higher, grade of binocular visual function.

Fusional amplitudes in convergence were significantly and spontaneously (i.e., without any training) improved 3 months after ERM surgery in our study.

Near vision stereopsis significantly improved after ERM surgery, as already reported by Okamoto et al. (2015). In our study, some patients even recovered a normal near stereopsis. While most studies about ERM surgery focused on near vision stereopsis evaluation (Asaria et al., 2008; Okamoto et al., 2015), we also evaluated pre- and post-operative far-distance stereopsis. Far-distance stereopsis is interesting to evaluate. It results, like near stereopsis, from binocular fusion (i.e., the second grade of binocular function). However, it might be preserved in case of near stereopsis impairment (Han et al., 2016). Far-distance stereopsis was assessed using polarized glasses, while several other methods are available (Distance Randot, Frisby-Davis 2). However, there is no gold standard defined for far-distance stereopsis evaluation and its precise impact on vision quality still needs to be determined (Zhao et al., 2020).

It is interesting to note that in this study, none of the patients presented with pre-operative or post-operative diplopia. Diplopia, in eyes presenting with iERM, might be related to associated treatable conditions such as

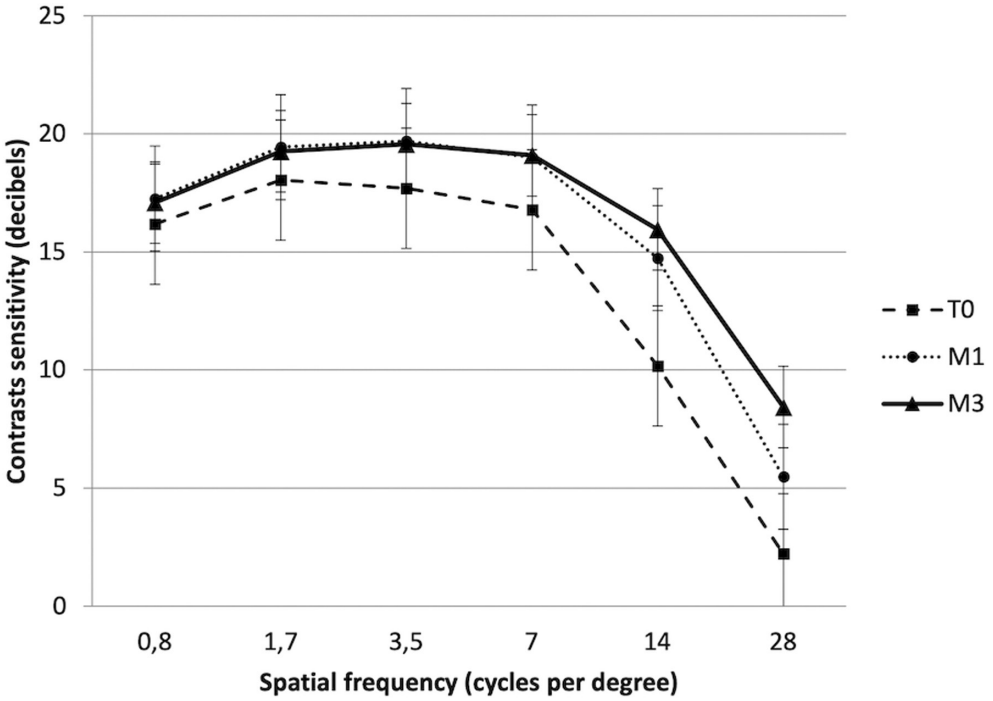

FIGURE 3 Pre-operative (T0) and post-operative contrast sensitivity changes at 1–3 months (M1 and M3, respectively) in patients operated on for epiretinal membrane, as a function of spatial frequency. Contrast sensitivity improved post-operatively, especially in high spatial frequencies.

strabismus (28%) (Veverka, Hatt, Leske, Brown, Iezzi, & Holmes, 2017), which were excluded in the present study. New-onset diplopia after ERM surgery has been reported in one recent study (19%) (Hatt et al., 2019). However, binocular functions are rarely evaluated before surgery, which may lead to over-diagnosed post-operative heterophoria decompensation in case of diplopia.

Finally, there was no case of dragged-fovea diplopia syndrome in the present work. While two patients suffered from the foveal displacement after surgery, with bad binocular recovery on fusional amplitudes and far-distance and near stereopsis assessments. In these cases, binocular visual function impairment was not associated with binocular central diplopia.

Quality of life (QOF), assessed by a subjective visual function composite score, improves after ERM surgery (Ghazi-Nouri et al., 2006; Khanna et al., 2022). However, the causative factor for such improvement is not clearly identified: neither BCVA change nor metamorphopsia decrease correlates with subjective visual function improvement. According to one recent study, QOF improvement would precede near stereopsis improvement (Khanna et al., 2022). One might wonder if another binocular visual function (like fusional amplitudes or far-distance stereopsis) could be responsible for early QOF improvement after ERM peeling. Indeed, while metamorphopsia changes have been widely studied, their eventual link with binocular function recovery remains unknown (Ghazi-Nouri et al., 2006; Kinoshita et al., 2016).

QOF assessment could include symptoms related to binocular visual function alteration (depth of focus impairment, altered distance measurement, aniseikonia). Ocular dominance could also play a role in patients' post-operative visual comfort. Its correlation to post-operative BCVA and binocular visual function should also be assessed. Reading speed assessment might also be another parameter to consider.

Further studies might be needed to evaluate whether patients' post-operative satisfaction or QOF improvement correlates with binocular function changes. Indeed, BCVA or macular anatomical improvement observed on OCT is surprisingly not always associated with patients' satisfaction.

Some limitations of this study include the small number of patients studied and its retrospective character. Due to this retrospective status, three patients who presented with cataract were operated during the membrane peeling surgery. In those patients, the presence of cataract may have influenced the pre-operative binocular vision tests, although none of them presented with monocular diplopia. Another patient presented with macular oedema on the contralateral eye without a clear aetiology. However, BCVA was conserved and stable during the study in this eye and macular oedema did probably not influence binocular vision.

5 | CONCLUSION

Our study shows a significant improvement of monocular and binocular visual functions (i.e., fusional amplitudes, far-distance and near stereopsis), together with central macular thickness decrease, 3 months after vitrectomy for ERM surgery. Far distance stereopsis is rarely assessed although its post-operative recovery might be associated with a certain level of vision quality improvement. Post-operative diplopia seems to be a rare complication when binocular visual function is assessed before surgery. While BCVA and contrast sensitivity

improvement is known to enhance visual comfort, further studies are still needed to assess the impact of binocular visual function improvement on patients' quality of life.

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