Time Course of Changes in Metamorphopsia, Visual Acuity, and OCT Parameters after Successful Epiretinal Membrane Surgery

Takamasa Kinoshita,[1,2] *Hiroko Imaizumi,*[1] *Utako Okushiba,*[1] *Hirotomo Miyamoto,*[1] *Tetsuo Ogino,*[1] *and Yoshinori Mitamura*[2]

Purpose. To follow the changes in the metamorphopsia, visual acuity, and OCT parameters after epiretinal membrane (ERM) removal.

Methods. The study included 49 eyes of 49 patients with an ERM who underwent vitrectomy and membrane peeling. The changes in the best-corrected visual acuity (BCVA), metamorphopsia, and central foveal thickness (CFT) were evaluated at baseline and 1, 3, 6, 9, and 12 months postoperatively. M-CHARTS were used to quantify metamorphopsia.

Results. The mean BCVA, metamorphopsia scores for horizontal lines (MH) and vertical lines (MV), and CFT improved significantly at 12 months after surgery ($P < 0.001$). The baseline BCVA, MH score, and MV score were significantly correlated with the corresponding BCVA, MH score, and MV score at 12 months after surgery ($P < 0.01$). The MH and MV scores at 12 months was significantly correlated with the BCVA at 12 months ($P < 0.01$), and the baseline MV score was significantly correlated with the BCVA at 12 months ($P < 0.05$). The MH score but not the MV score was significantly correlated with the CFT at baseline and 12 months ($P < 0.05$).

Conclusions. The preoperative BCVA, MH score, and MV score were prognostic factors for the corresponding postoperative BCVA, MH score, and MV score. These results suggest that surgery for ERM should be considered before severe reduction in the BCVA or the degree of metamorphopsia. In addition, the preoperative MV score was a prognostic factor for postoperative BCVA. The MH score but not the MV score was correlated with the CFT preoperatively and postoperatively. (*Invest Ophthalmol Vis Sci.* 2012;53:3592–3597) DOI:10.1167/iovs.12-9493

Patients with an idiopathic epiretinal membrane (ERM) often suffer from metamorphopsia, which impairs the quality of vision even when the conventional visual acuity is relatively good. To resolve these visual difficulties, these eyes commonly undergo vitrectomy with the removal of the ERM. Despite a successful removal of an ERM and an improvement of the visual acuity, the patient's quality of vision may not be completely normal mainly because of residual metamorphopsia. Thus, it is essential to evaluate the visual outcome in terms of the quality of vision as well as by the visual acuity. Okamoto et al.[1,2] demonstrated that the changes in metamorphopsia but not the visual acuity were significantly associated with changes in the 25-item National Eye Institute Visual Function Questionnaire composite score on the quality of vision after ERM surgery. Therefore, assessing not only the visual acuity but also the severity of metamorphopsia is important when deciding the timing of the ERM surgery and for evaluating the postoperative quality of vision.

Amsler charts have been widely used for detecting metamorphopsia,[3] but it is difficult to quantify the severity of the metamorphopsia. Some investigators have evaluated metamorphopsia by the numbers of distorted squares on the Amsler charts[4] or a laser grid generated by a scanning laser ophthalmoscope,[5] but these findings represent the range rather than the severity of the metamorphopsia. Matsumoto el al.[6,7] developed a chart that can measure the severity of metamorphopsia called M-CHARTS (Inami Co., Tokyo, Japan). The M-CHARTS have enabled clinicians to quantify the severity of metamorphopsia associated with macular diseases. Several researchers have used the M-CHARTS and have reported the changes in metamorphopsia before and after the removal of an ERM.[1,2,8,9] Others[4,5,10] have used the charts or a laser grid to follow the changes in metamorphopsia after ERM surgery. However, these studies did not follow the changes but examined the severity of metamorphopsia before and only at a fixed postoperative time.

Optical coherence tomography (OCT) is commonly used to assess the morphological changes in patients with macular diseases, and there has been great attention given to the relationship between visual acuity and OCT findings in patients with an ERM.[11–17] However, no prospective study has been done to evaluate the correlation between metamorphopsia and OCT findings before and after ERM surgery as far as we know.

Thus, the purpose of this study was to determine the course of the changes in the metamorphopsia, visual acuity, and OCT findings after vitrectomy with the removal of an ERM. We also determined the correlation among the visual acuity, metamorphopsia score, and OCT parameters before and after surgery.

Methods

The prospective, consecutive case series included 49 eyes of 49 patients who underwent vitrectomy and membrane peeling for an idiopathic ERM associated with metamorphopsia at Sapporo City General Hospital between April 2008 and May 2010. Eighty-eight

From the [1]Department of Ophthalmology, Sapporo City General Hospital, Sapporo, Japan; and [2]Department of Ophthalmology, Institute of Health Biosciences, The University of Tokushima Graduate School, Tokushima, Japan.

Submitted for publication January 13, 2012; revised March 12 and April 29, 2012; accepted April 30, 2012.

Disclosure: **T. Kinoshita**, None; **H. Imaizumi**, None; **U. Okushiba**, None; **H. Miyamoto**, None; **T. Ogino**, None; **Y. Mitamura**, None

Corresponding author: Takamasa Kinoshita, Department of Ophthalmology, Sapporo City General Hospital, Sapporo, Japan, 1-1, N-11, W-13, Chuoku, Sapporo, 060-8604, Japan; Takamasa.kinoshita@doc.city.sapporo.jp.

Investigative Ophthalmology & Visual Science, June 2012, Vol. 53, No. 7

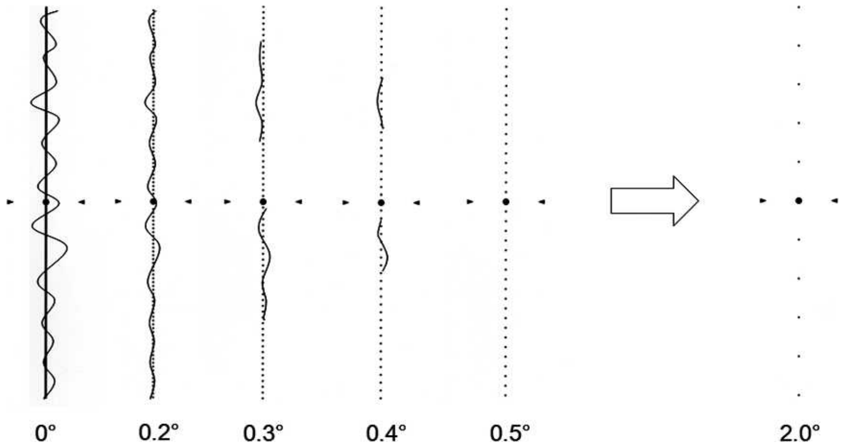

FIGURE 1. Method of determining the metamorphopsia score using M-CHARTS. The minimum angle of the dots in the line that appeared straight was taken to be the metamorphopsia score. In this case, metamorphopsia for vertical line is determined as 0.5.

consecutive eyes of 85 patients underwent ERM surgery during the periods by a single surgeon (T.K.). Thirty-nine eyes were excluded from the study. Exclusion criteria included (1) absence of preoperative metamorphopsia detected by M-CHARTS, which means both the preoperative metamorphopsia scores for horizontal lines and for vertical lines were 0 (8 eyes); (2) secondary ERM due to retinal tears, retinal detachment, retinal vascular diseases, and uveitis (16 eyes); (3) other macular diseases, including age-related macular degeneration or central serous chorioretinopathy (4 eyes); (4) BCVA of worse than 1.0 logMAR unit at baseline (2 eyes); (5) previous intraocular surgery except for uncomplicated cataract surgery (6 eyes); and (6) moderate or severe cataract that affected visual acuity (2 eyes). In a patient who underwent vitrectomy for bilateral idiopathic ERM, only one eye was chosen randomly and included in this study. In the end, 49 eyes of 49 patients were enrolled in this study.

The procedures used conformed to the tenets of the Declaration of Helsinki, and an informed consent was obtained from all of the subjects after the intent of the study had been fully explained. An approval was obtained from the Institutional Review Board of Sapporo City General Hospital to perform this study.

The preoperative duration of the symptoms was estimated from the patient's oral report. Ophthalmic examinations including measurement of the BCVA, applanation tonometry, slit-lamp biomicroscopy, indirect ophthalmoscopy, fundus photography, spectral-domain OCT (SD-OCT; 3D OCT 1000; Topcon Co., Tokyo, Japan), and severity of the metamorphopsia were determined before and at 1, 3, 6, 9, and 12 months after surgery. The BCVA was measured with a standard Japanese Landolt visual acuity chart, and the decimal visual acuity was converted to the logarithm of the minimal angle resolution (logMAR) units for statistical analyses. The potential effects of the ERM on visual function were graded from 0 to 2 by examining the fundus photographs in a masked fashion according to the Gass classification.[18] All baseline data were obtained within 2 months before surgery.

The severity of the metamorphopsia was assessed with M-CHARTS (Fig. 1). The M-CHARTS consist of 19 dotted lines with the dot intervals ranging from 0.2° to 2.0° of visual angle. In patients with metamorphopsia, a straight solid line projected onto the retina is generally reported to be curved or irregular. If the solid line is replaced by a dotted line and the dot interval is changed from fine to coarse, the curvature of the line decreases with increasing dot interval, until the dotted line appears straight. The minimum angle of the dots in the line that appeared straight was taken to be the metamorphopsia score.[6,7] The metamorphopsia scores for horizontal lines (MH) and vertical lines (MV) were measured. Both MH and MV in normal eyes are 0. The examinations were repeated three times for each subject to evaluate the reproducibility of the test. The examiners administrating the M-CHARTS tests were experienced orthoptists and were masked to the fundus findings in the patients. We used a value of 2.0 for a metamorphopsia score in cases when the metamorphopsia score was higher than 2.0.

SD-OCT was performed at each visit in all cases. Cross-sectional scan images of 6-mm length through the fovea were obtained for each eye. Foveal thickness was measured manually on the horizontal and vertical scan images by placing calibrated calipers at the vitreoretinal interface and anterior surface of the retinal pigment epithelium. Central foveal thickness (CFT) was determined as the average of those two values obtained from the horizontal and vertical scans. The three-dimensional scan protocol, which was a raster scan composed of 256 × 256 axial scans covering a 6 × 6-mm macular region, was also used. It provides the automated macular map analysis composed of nine Early Treatment of Diabetic Retinopathy Study sectorial thickness and volume measurements in three concentric circles with diameters of 1, 3, and 6 mm. The center volume (CV, area within a 1-mm-diameter circle) was analyzed at baseline and 12 months after surgery. Status of the junction between inner and outer segments of the photoreceptors (IS/OS) in the fovea was evaluated by two authors (H.I. and U.O.) in a masked fashion and divided into two groups: eyes with continuous IS/OS line and eyes with discontinuous or missing IS/OS line. Presence of foveal pit and cystoid change were also evaluated.

Surgeries were performed by a single surgeon (T.K.) using 25-gauge transconjunctival pars plana vitrectomy with membrane peeling. Phacoemulsification and intraocular lens implantation were performed on all phakic cases, and the vitreoretinal procedures followed the implantation of the IOL. Six cases were already pseudophakic. After successful peeling of the ERM, the internal limiting membrane was removed with the assistance of triamcinolone acetonide in all cases. No other dye was used. In six cases with severe distortion of the retina, air-fluid exchange and postoperative facedown positioning for half-a-day were performed. An iatrogenic retinal tear was found intraoperatively in one eye and was successfully treated with endolaser photocoagulation. The indication of ERM surgery was the presence of a patient's visual disability because of decrease in visual acuity or metamorphopsia.

We followed the course of the BCVA, metamorphopsia scores, and OCT parameters including CFT and CV, and investigated the correlations among them before and after surgery.

Statistical analyses were carried out with the StateMate III (ATMS, Tokyo, Japan) and SPSS statistics version 19 (IBM, Armonk, NY). The significance of differences in the BCVA, MH scores, and MV scores at two visits was determined with the Wilcoxon signed-ranks tests. The MH and MV scores at the same visit were also compared by Wilcoxon signed-ranks tests. The significance of the differences in the MH and MV scores before surgery among the grades of the ERM was determined by Mann-Whitney *U* test. The correlation between any two of the following variables was analyzed using Pearson's correlation coefficient test: the baseline BCVA, BCVA at 12 months, changes in the BCVA, the baseline metamorphopsia score, metamorphopsia score at

Table 1. Baseline Demographic Data of the 49 Eyes of 49 Patients with ERM

Sex	28 women/21 men
Age, y, mean ± SE (range)	70.2 ± 1.2 (52–84)
Duration of symptom, mo, median (range)	14 (1–120)
Grade* of ERM, no.	0 grade 0/33 grade 1/16 grade 2
Presence of macular pseudohole, *n* (%)	8 (16.3)
Preoperative BCVA (logMAR), mean ± SE	0.38 ± 0.03
Preoperative MH, mean ± SE	1.10 ± 0.10
Preoperative MV, mean ± SE	0.91 ± 0.09
CFT, mean ± SE, (μm)	418.2 ± 19.2
CV, mean ± SE, (mm^3)	0.35 ± 0.01
Continuous IS/OS line, *n* (%)	35 (71.4)
Presence of foveal pit, *n* (%)	14 (28.6)
Presence of cystoid change, *n* (%)	14 (28.6)

* Gass classification

12 months, changes in the metamorphopsia score, and preoperative and postoperative OCT parameters including CFT and CV. A two-sided *P* value of less than 0.05 was considered statistically significant.

Results

The baseline demographic data are shown in Table 1. With respect to metamorphopsia, the baseline MH score was significantly correlated with the baseline MV score ($r = 0.673$, $P < 0.001$, Pearson's correlation coefficient). The mean baseline MH score was larger than the mean baseline MV score, although the difference was not significant ($P = 0.09$, Wilcoxon signed-ranks tests). The mean baseline MH score in eyes with a grade 2 ERM (1.43 ± 0.16, mean ± SE) was significantly larger than that in eyes with a grade 1 ERM (0.95 ± 0.11) ($P < 0.05$, Mann-Whitney *U* test); however, the difference in the mean baseline BCVAs and the mean MV scores for the two grades of ERM were not significant. ($P = 0.38$, $P = 0.40$, respectively).

The BCVA (mean ± SE) improved significantly from 0.38 ± 0.03 logMAR units before surgery to 0.20 ± 0.03 at 1 month after surgery ($P < 0.001$, Wilcoxon signed-ranks test; Fig. 2). The mean BCVA at 12 months (0.09 ± 0.03) was significantly better than that at baseline ($P < 0.001$). The baseline BCVA was significantly correlated with the BCVA at 12 months ($r = 0.418$, $P = 0.003$, Pearson's correlation coefficient). The BCVA improved by ≥0.2 logMAR units in 33 eyes (67.3%) and remained unchanged in 16 eyes (32.7%) at 12 months. None of the eyes had a decrease in the BCVA by 0.2 or more logMAR units.

The time course of the changes in the metamorphopsia score are shown in Figure 3. The MH score (mean ± SE) improved significantly from 1.10 ± 0.10 before surgery to 0.69 ± 0.09 at 1 month after surgery ($P < 0.001$, Wilcoxon signed-ranks test). The improvement in the mean MH score continued up to 12 months after surgery until finally the MH score at 12 months was 0.27 ± 0.06, which was significantly better than that at baseline ($P < 0.001$). The mean MH score at 12 months was statistically better than that at 6 months ($P < 0.05$).

The MV score (mean ± SE) improved significantly from 0.91 ± 0.09 before surgery to 0.58 ± 0.09 at 1 month after surgery ($P < 0.001$, Wilcoxon signed-ranks test). The improvement in the mean MV score continued up to 6 months after surgery, and it reached a plateau thereafter. The MV score at 12 months was 0.39 ± 0.07, which was significantly better than that at baseline ($P < 0.001$) but was not significantly different from that at 6 months ($P = 0.40$).

The baseline MH score was significantly correlated with the MH score at 12 months, and the baseline MV score was significantly correlated with the MV score at 12 months ($r = 0.409$, $P = 0.004$ for MH; $r = 0.526$, $P = 0.0001$ for MV; Pearson's correlation coefficient; Figs. 4A, 4B). The MH score at 12 months was significantly correlated with the MV score at 12 months ($r = 0.477$, $P < 0.001$); however, the mean MV score was significantly larger than the mean MH score at 12 months ($P < 0.05$, Wilcoxon signed-ranks test). The change in the MH score, MV score, or BCVA was defined as the postoperative value at 12 months subtracted from the baseline value. The mean change in the MH score (0.83 ± 0.09) was significantly larger than that in the MV score (0.52 ± 0.08) ($P < 0.01$, Wilcoxon signed-ranks test).

There was no significant correlation between the baseline BCVA and the baseline MH or MV scores (Table 2); however, the BCVA at 12 months was significantly correlated with the MH or MV score at 12 months ($r = 0.402$, $P = 0.005$ for MH; $r = 0.448$, $P = 0.001$ for MV; Pearson's correlation coefficient test; Table 2). In addition, the baseline MV score was significantly correlated with the BCVA at 12 months and the improvement in the BCVA ($r = 0.311$, $P = 0.031$ for BCVA; $r = 0.331$, $P = 0.022$ for change in the BCVA; Pearson's correlation coefficient test; Table 2). The baseline MH score was not significantly correlated with the BCVA at 12 months or change in the BCVA ($r = 0.135$, $P = 0.359$ for BCVA; $r = 0.022$, $P = 0.884$ for change in the BCVA; Table 2).

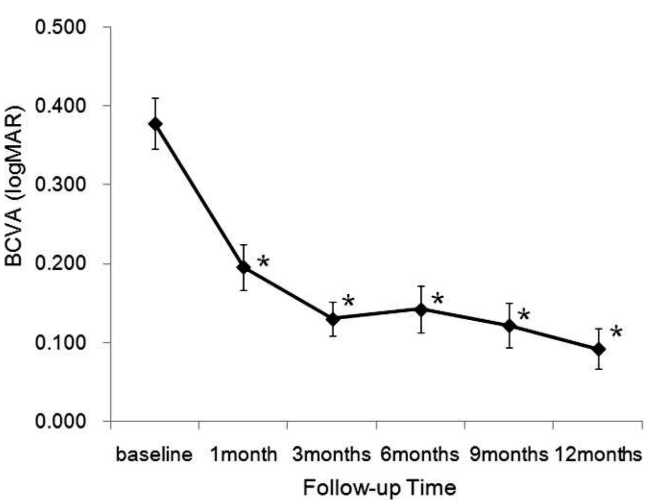

Figure 2. Time course of mean BCVA in logMAR units. Error bars indicate standard errors. *Statistically significant compared with BCVA at baseline ($P < 0.001$).

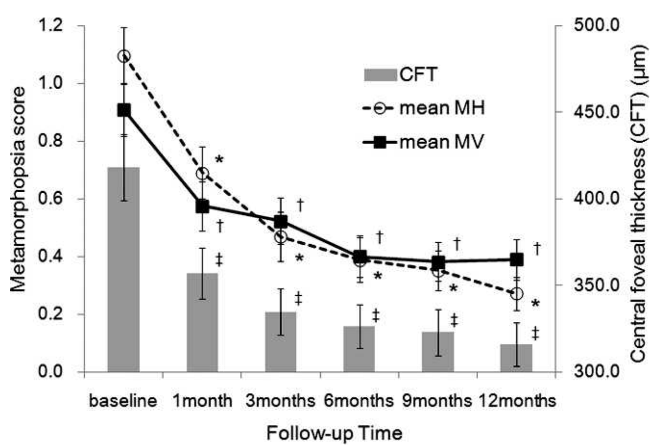

Figure 3. Time course of metamorphopsia scores and central foveal thickness (CFT). Error bars indicate standard errors. *†‡Statistically significant compared with the metamorphopsia score and CFT at baseline ($P < 0.001$).

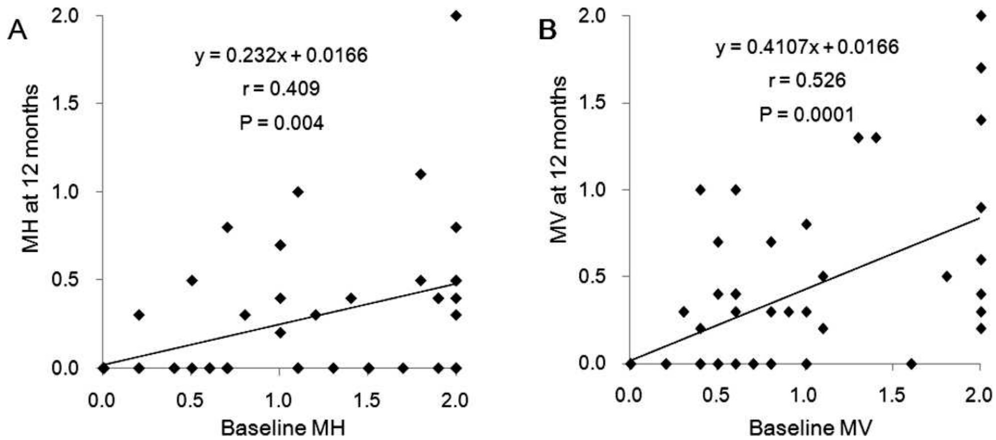

FIGURE 4. Correlation between the preoperative and postoperative metamorphopsia scores. The preoperative metamorphopsia scores both for horizontal (**A**) and vertical (**B**) lines are correlated with the corresponding metamorphopsia scores at 12 months.

With respect to OCT parameters, the mean CFT or CV at 12 months was significantly decreased from that of the baseline ($P < 0.001$, Wilcoxon signed-ranks test; Fig. 3). The correlation of metamorphopsia score with CFT or CV is shown in Table 3. The baseline MH score was significantly correlated with the baseline CFT or CV ($r = 0.300$, $P = 0.038$ for CFT; $r = 0.461$, $P = 0.004$ for CV; Pearson's correlation coefficient test). The MH score at 12 months was significantly correlated with the CFT or CV at 12 months ($r = 0.399$, $P = 0.005$ for CFT; $r = 0.337$, $P = 0.039$ for CV; Pearson's correlation coefficient test). However, there were no significant correlations between the MV score and CFT or CV at baseline and 12 months.

There was no significant correlation between the MH or MV score and the presence of foveal pit or the status of IS/OS line at baseline and 12 months; however, the MH score at 12 months was significantly larger in eyes with cystoid change at 12 months than in eyes without it ($P < 0.01$, Mann-Whitney U test). There was no relationship between the MV score and the presence of cystoid change.

The baseline BCVA was significantly correlated with the baseline CFT or CV ($r = 0.416$, $P < 0.01$ for CFT; $r = 0.486$, $P < 0.01$ for CV; Pearson's correlation coefficient test). The BCVA at 12 months was significantly correlated with baseline CFT ($r = 0.406$, $P < 0.01$; Pearson's correlation coefficient test).

The BCVA at 12 months was better in the eyes with continuous IS/OS line in the fovea at baseline than in the eyes with discontinuous or missing IS/OS line, although the difference was not significant ($P = 0.095$, Mann-Whitney U test). Similarly, the BCVA at 12 months was significantly better in the eyes with continuous IS/OS line in the fovea at 12 months than in the eyes with discontinuous or missing IS/OS line ($P = 0.014$, Mann-Whitney U test).

DISCUSSION

Our results showed that the mean BCVA improved significantly at 12 months after the removal of an ERM, and the MH and MV scores improved significantly at 12 months after surgery. Although the improvement in the mean MH score continued to improve up to 12 months after surgery, the mean MV score reached a plateau at 6 months after surgery.

We excluded eight cases that did not have preoperative metamorphopsia detected by M-CHARTS. Matsumoto et al.[6] reported that the sensitivity and specificity of the M-CHARTS in detecting metamorphopsia were 97.3% and 100.0%, respectively, using the results of Amsler charts as a standard. Therefore, the effect of excluding these cases most likely did not exclude cases with mild metamorphopsia. In fact, no case with preoperative subjective symptoms of metamorphopsia was excluded. In eight cases without preoperative metamorphopsia, the metamorphopsia score did not increase after surgery.

The baseline BCVA was significantly correlated with the BCVA at 12 months, indicating that preoperative visual acuity is a prognostic factor for the postoperative visual acuity, being consistent with previous reports.[19,20]

The mean MH score improved rapidly during the first 3 months after surgery and then more slowly until 12 months. The mean MH score at 12 months was significantly smaller than that at 6 months. Therefore, observations of the MH score for longer than 12 months is needed to evaluate the time course of MH after ERM surgery. On the other hand, the mean MV score improved rapidly during the first month after surgery and then more slowly until 6 months, when it reached a plateau.

The mean baseline MH score was greater than the mean baseline MV score. One of the reasons why the mean MH score was greater than the mean MV score before surgery was that the ability to detect horizontal lines is better than that for vertical lines in humans.[6,21–23] Matsumoto et al.[6] showed that the horizontal M-CHARTS scores increased significantly more than the vertical M-CHARTS scores as the stage of the disease advanced. Another reason for the difference may be the directionality of retinal plasticity. The axons of the retinal ganglion cells course horizontally rather than vertically in the posterior pole except for the temporal raphe.[9] In addition, the

TABLE 2. Correlation of BCVA with Metamorphopsia Scores Before and After Surgery (Pearson's Correlation Coefficient Test)

	Baseline MH		MH at 12 months		Baseline MV		MV at 12 months	
	r	*P*	*r*	*P*	*r*	*P*	*r*	*P*
Baseline BCVA (logMAR)	0.094	0.527	0.084	0.569	−0.084	0.571	0.029	0.846
BCVA at 12 months (logMAR)	0.135	0.359	**0.402**	**0.005**	**0.311**	**0.031**	**0.448**	**0.001**

Values in bold indicate statistical significance ($P < 0.05$).

Table 3. Correlation of Metamorphopsia Scores with OCT Parameters Before and After Surgery (Pearson's Correlation Coefficient Test)

	Baseline MH		MH at 12months		Baseline MV		MV at 12 months	
	r	*P*	*r*	*P*	*r*	*P*	*r*	*P*
Baseline CFT	**0.300**	**0.038**	0.194	0.187	0.035	0.811	0.065	0.661
CFT at 12 months	0.208	0.156	**0.399**	**0.005**	0.143	0.331	0.111	0.452
Baseline CV	**0.461**	**0.004**	0.278	0.091	0.079	0.638	0.019	0.911
CV at 12 months	0.214	0.197	**0.337**	**0.039**	0.132	0.431	0.065	0.698

Values in bold indicate statistical significance ($P < 0.05$).

optic disc may restrict horizontal displacement of the posterior retina (Fig. 5).[6] Therefore, the vertical plasticity of the posterior retina may be greater than that for the horizontal retina. Thus, horizontal metamorphopsia may be larger than vertical metamorphopsia preoperatively because vertical retinal contraction is correlated with horizontal metamorphopsia and horizontal retinal contraction with vertical metamorphopsia.[7] Conversely, the mean MV score at 12 months was significantly larger than the mean MH score at 12 months, and the improvement in the mean MV score was significantly smaller than that of the mean MH score. Physiologic difference in perception between horizontal and vertical objects may contribute to the difference in the improvement between the MH and MV score. Vertical metamorphopsia will probably less likely increase than horizontal metamorphopsia; however, once it arises, it is also less likely to decrease than the horizontal metamorphopsia.

There was a correlation of the grade of ERM with the mean baseline MH score but not with the mean baseline MV score. In addition, the MH score but not the MV score was correlated with the CFT or CV at baseline and 12 months. There was relationship between the presence of cystoid change and the MH score but not between the cystoid change and the MV score. These results suggest that the MH score rather than the MV score may reflect the morphologic change due to ERM. The reason why there were no correlations between the MV score and the morphologic changes remains unclear, but the restriction of horizontal retinal displacements due to the optic disc (Fig. 5) may contribute this decorrelation.

The preoperative and postoperative BCVA were significantly correlated with the preoperative CFT. The postoperative BCVA was better in the eyes with preoperative or postoperative continuous IS/OS line in the fovea than those with a discontinuous or missing IS/OS line. These results were consistent with previous reports.[11–17]

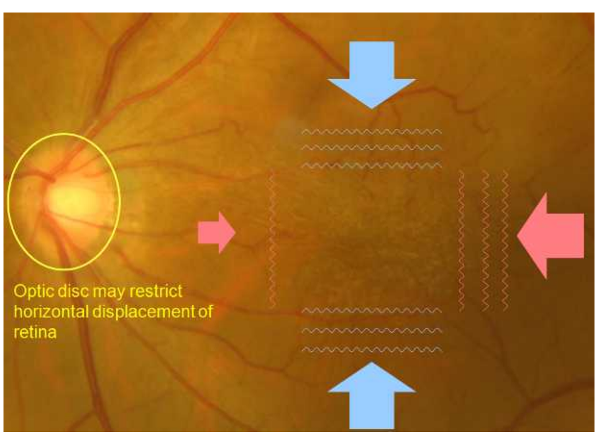

Figure 5. Illustration of displacements of the posterior retina due to ERM. *Red arrows* and *wavy lines* correspond to metamorphopsia for vertical line, and *blue arrows* and *wavy lines* to metamorphopsia for horizontal line.

The correlations between the preoperative and postoperative values in the MH and MV scores indicate that the preoperative metamorphopsia score is a prognostic factor for the postoperative metamorphopsia score. Thus, surgery for ERM should be considered before severe worsening of metamorphopsia because the preoperative severe metamorphopsia may not be completely resolved. Arimura et al.[23] reported that 41.1% of ERM patients with a metamorphopsia score less than 0.5 had no distorted vision in their daily life and that only 15.0% of ERM patients with a metamorphopsia score of 0.5 or higher had no distorted vision. In our case series, all cases with a metamorphopsia score of 0.5 or higher had subjective metamorphopsia in their daily life before and after surgery (data not shown). If the postoperative metamorphopsia score less than 0.5 is pursued, vitrectomy should be performed when the preoperative metamorphopsia score is less than 1.72 for MH and 0.93 for MV, according to the regression lines of Figures 4A and 4B. Thus, a preoperative MH score of 0.5 to 1.7 or a preoperative MV score of 0.5 to 0.9 may be one of the surgical indications for satisfactory postoperative outcome regarding metamorphopsia.

There was no significant correlation between the preoperative BCVA and the preoperative MH or MV scores as previously reported[6]; however, significant correlations were found between the postoperative BCVA and postoperative MH or MV scores at 12 months. Ooto et al.[24] showed that mean cone density in patients with ERM did not differ from that in healthy subjects. Therefore, the possible causes for visual disturbance in patients with ERM may be a veiling effect of the membrane, or dysfunction of the inner retinal neurons or photoreceptors due to retinal distortion. Thus, we assumed that the BCVA and metamorphopsia scores were significantly correlated when the veiling effect disappeared after the ERM surgery.

The preoperative MV score was significantly correlated with the BCVA at 12 months and the BCVA change, whereas the preoperative MH score showed no association. The reason for this discrepancy between the MH and MV scores remains unclear; however, we speculate that a similar pattern of time course in MV score and BCVA may contribute to the association between preoperative MV score and BCVA change. The mean MV score improved during the first 6 months after surgery and reached a plateau thereafter. Similarly, the BCVA improved during the first 3 months, and the improvement rapidly slowed down thereafter. On the other hand, the mean MH score continued to improve throughout the 12 months after surgery.

Table 4 shows the summary of correlation of metamorphopsia scores with BCVA, CFT, and CV. The horizontal but not the vertical metamorphopsia score was correlated with CFT and CV preoperatively and postoperatively. The postoperative metamorphopsia scores both for horizontal and vertical lines were correlated with postoperative BCVA. The preoperative vertical metamorphopsia score, but not the preoperative

Table 4. Summary of Correlation of Metamorphopsia Scores with BCVA, CFT, and CV

	Preoperative			Postoperative		
	BCVA	**CFT**	**CV**	**BCVA**	**CFT**	**CV**
Preoperative horizontal metamorphposia score	X	**O**	**O**	X	X	X
Preoperative vertical metamorphopsia score	X	X	X	**O**	X	X
Postoperative horizontal metamorphopsia score	X	X	X	**O**	**O**	**O**
Postoperative vertical metamorphopsia score	X	X	X	**O**	X	X

O, correlation was found between two variables; X, correlation was not found between two variables.

horizontal metamorphopsia score, was correlated with postoperative BCVA.

In conclusion, we demonstrated the time course of metamorphopsia, visual acuity, and OCT parameters after vitrectomy and ERM peeling. The preoperative BCVA, horizontal metamorphopsia score, and vertical metamorphopsia score are prognostic factors for the postoperative BCVA, horizontal metamorphopsia score, and vertical metamorphopsia score respectively. In addition, the preoperative vertical metamorphopsia score is a prognostic factor for the postoperative BCVA. The horizontal, but not the vertical, metamorphopsia score was correlated with the CFT preoperatively and postoperatively. Further studies of the correlation between metamorphopsia scores and subjective perception of metamorphopsia or OCT findings before and after surgery would be of value for a better understanding and surgical indications for ERMs.

References

1. Okamoto F, Okamoto Y, Hiraoka T, Oshika T. Effect of vitrectomy for epiretinal membrane on visual function and vision-related quality of life. *Am J Ophthalmol*. 2009;147:869–874.
2. Okamoto F, Okamoto Y, Fukuda S, Hiraoka T, Oshilka T. Vision-related quality of life and visual function after vitrectomy for various vitreoretinal disorders. *Invest Ophthalmol Vis Sci*. 2010;51:744–751.
3. Amsler M. Earliest symptoms of disease of macula. *Br J Ophthalmol*. 1953;37:521–537.
4. Ghazi-Nouri SM, Tranos PG, Rubin GS, Adams ZC, Charteris DG. Visual function and quality of life following vitrectomy and epiretinal membrane peel surgery. *Br J Ophthalmol*. 2006; 90:559–562.
5. Arndt C, Rebollo O, Sequinet S, Debruyne P, Caputo G. Quantification of metamorphopsia in patients with epiretinal membranes before and after surgery. *Graefes Arch Clin Exp Ophthalmol*. 2007;245:1123–1129.
6. Matsumoto C, Arimura E, Okuyama S, Tanaka S, Hashimoto S, Shimomura Y. Quantification of metamorphopsia in patients with epiretinal membranes. *Invest Ophthalmol Vis Sci*. 2003; 44:4012–4016.
7. Arimura E, Matsumoto C, Okuyama S, Takada S, Hashimoto S, Shimomura Y. Retinal contraction and metamorphopsia scores in eyes with idiopathic epiretinal membrane. *Invest Ophthalmol Vis Sci*. 2005;46:2961–2966.
8. Ueta Y, Tachi N, Kimura Y, Yoshimura K, Kurokawa Y, Hashimoto Y. Value of surgery and quantitation of metamorphopsia before and after surgery [in Japanese]. *Jpn J Clin Ophthalmol*. 2010;64:521–524.
9. Kuroyanagi K, Gunji H, Kato H, Gekka T, Arai K, Ito Y. Use of M-charts® in the evaluation of metamorphopsia after surgical removal of epiretinal membrane [in Japanese]. *Jpn J Clin Ophthalmol*. 2010;64:1551–1554.
10. Bouwens MD, Van Meurs JC. Sine Amsler Charts: a new method for the follow-up of metamorphopsia in patients undergoing macular pucker surgery. *Graefes Arch Clin Exp Ophthalmol*. 2003;241:89–93.
11. Massin P, Allouch C, Haouchine B, et al. Optical coherence tomography of idiopathic macular epiretinal membranes before and after surgery. *Am J Ophthalmol*. 2000;130:732–739.
12. Michalewski J, Michalewska Z, Cisiecki S, Nawrocki J. Morphologically functional correlations of macular pathology connected with epiretinal membrane formation in spectral optical coherence tomography (SOCT). *Graefe's Arch Clin Exp Ophthalmol*. 2007;245:1623–1631.
13. Mitamura Y, Hirano K, Baba T, Yamamoto S. Correlation of visual recovery with presence of photoreceptor inner/outer segment junction in optical coherence images after epiretinal membrane surgery. *Br J Ophthalmol*. 2009;93:171–175.
14. Kim J, Rhee KM, Woo SJ, Yu YS, Chung H, Park KH. Long-term temporal changes of macular thickness and visual outcome after vitrectomy for idiopathic epiretinal membrane. *Am J Ophthalmol*. 2010;150:701–709.
15. Arichika S, Hangai M, Yoshimura N. Correlation between thickening of the inner and outer retina and visual acuity in patients with epiretinal membrane. *Retina*. 2010;30:503–508.
16. Inoue M, Morita S, Watanabe Y, et al. Preoperative inner segment/outer segment junction in spectral-domain optical coherence tomography as a prognostic factor in epiretinal membrane surgery. *Retina*. 2011;31:1366–1372.
17. Kim JH, Kim YM, Chung EJ, Lee SY, Koh HJ. Structural and functional predictors of visual outcome of epiretinal membrane surgery. *Am J Ophthalmol*. 2012;153:103–110.
18. Gass JD. *Stereoscopic Atlas of Macular Diseases: Diagnosis and Treatment*. 4th ed. Vol. 2. St Louis: CV Mosby; 1997:938–951.
19. Pesin SR, Olk RJ, Grand MG, et al. Vitrectomy for premacular fibroplasia. Prognostic factors, long-term follow-up, and time course of visual improvement. *Ophthalmology.* 1991;98: 1109–1114.
20. Wong JG, Sachdev N, Beaumont PE, Chang AA. Visual outcomes following vitrectomy and peeling of epiretinal membrane. *Clin Experiment Ophthalmol*. 2005;33:373–378.
21. Hughe A. *The Topography of Vision in Mammals of Contrasting Life Style: Comparative Optics and Retinal Organization. Handbook of Sensory Physiology.* Berlin: Springer-Verlag; 1984:613–756.
22. Azuma N. Monocular cell biology on morphogenesis of the fovea and evolution of the central vision [in Japanese]. *Nippon Ganka Gakkai Zasshi*. 2000;104:960–985.
23. Arimura E, Matsumoto C, Nomoto H, et al. Correlations between M-CHARTS and PHP findings and subjective perception of metamorphopsia in patients with macular diseases. *Invest Ophthalmol Vis Sci*. 2011;52:128–135.
24. Ooto S, Hangai M, Takayama K, et al. High-resolution imaging of the photoreceptor layer in epiretinal membrane using adaptive optics scanning laser ophthalmoscopy. *Ophthalmology.* 2011;118:873–881.