Jpn J Ophthalmol 2008;52:269–276

DOI 10.1007/s10384-008-0544-8

CLINICAL INVESTIGATION

Foveal Anatomical Status and Surgical Results in Vitrectomy for Myopic Foveoschisis

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Abstract

Purpose: Myopic foveoschisis (MF), a major cause of visual loss in highly myopic patients, shows varied foveal anatomic characteristics. We determined how the foveal status is related to surgical results in MF.

Methods: Forty-four eyes underwent vitrectomy for MF, including internal limiting membrane (ILM) peeling and gas tamponade. The eyes were divided into three groups depending on the preoperative foveal anatomy: foveal detachment (FD, n = 17), retinoschisis (RS, n = 16), and macular hole (MH, n = 11). Best-corrected visual acuity (BCVA) and optical coherence tomographic findings preoperatively and 3, 6, and 12 months postoperatively were obtained and compared.

Results: BCVA improved two lines or more in 81% of the FD group, 50% of the RS group, and 45% of the MH group 12 months postoperatively. The FD group had significantly improved vision ($P < 0.01$). Visual improvement was borderline in the RS group ($P = 0.057$) and not significant in the MH group. Visual improvement was significantly better in FD eyes than in RS ($P < 0.05$) or MH ($P < 0.01$) eyes. In FD and RS eyes, the postoperative BCVA was significantly correlated with age ($P < 0.05$) and preoperative BCVA ($P < 0.01$), whereas visual improvement was correlated with symptom duration ($P < 0.05$) and preoperative BCVA ($P < 0.01$).

Conclusions: Vitrectomy including ILM peeling and gas tamponade is safe and effective for MF. Patients with FD showed the most visual improvement postoperatively and therefore can obtain the most benefit from the surgery. Surgery also benefits RS and MH patients by preserving vision. The foveal status, age, duration of symptoms, and preoperative BCVA are key factors determining postoperative visual outcome in MF. **Jpn J Ophthalmol** 2008;52:269–276 © Japanese Ophthalmological Society 2008

Key Words: high myopia, macular hole, myopic foveoschisis, vitrectomy

Introduction

Myopic foveoschisis (MF), a major cause of visual loss in highly myopic eyes,[1,2] typically occurs in patients with posterior staphyloma.[3] The pathogenesis is uncertain; however, rigidity of the internal limiting membrane (ILM) or inflexibility of the retinal vessels, or both, are thought to be major causes.[4–6] A histologic study with transmission electron microscopy revealed migration of glia-like cells and the presence of collagenous tissues on the vitreous side of the ILM.[7]

Vitrectomy, including vitreous cortex removal with or without indocyanine green (ICG) dye-assisted ILM peeling and gas tamponade, is considered effective treatment for MF, although most reports describe small numbers of patients.[8–14] However, the efficacy of vitrectomy and associated predictive factors after surgery have not been well investigated.

Received: June 6, 2007 / Accepted: February 22, 2008
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Vol 52: 269–276, 2008

MF also shows varied foveal architectural characteristics.[15] Benhamou and associates[16] reported that MF is characterized by foveal morphologic abnormalities, including foveal detachment, lamellar hole, and cystic changes in the fovea. This classification is somewhat confusing because exceptional cases that do not meet these specifications are sometimes encountered. In addition, the aforementioned criteria are based simply on foveal morphologic changes seen on optical coherence tomography (OCT) but do not contain any information related to the surgical indication (i.e., surgical outcomes).

We retrospectively reviewed records, including OCT images and fundus photographs, of patients who underwent vitrectomy for MF. On the basis of our findings, we propose a simple classification of myopic foveoschisis based on both OCT images and surgical outcomes.

Patients and Methods

Patients

We retrospectively reviewed the records of 44 eyes of 42 patients who underwent vitrectomy for MF between 2001 and 2005. Surgical indications were a best-corrected visual acuity (BCVA) of 20/40 or worse, and symptoms that included visual loss and metamorphopsia, and no major atrophic changes.

Informed consent was obtained from all patients before surgery. All surgery was performed by three of the authors (Y.I., Y.O., and M.O.). BCVA measurements, color fundus photography, and OCT were performed on all visits both preoperatively and postoperatively. Only patients with a follow-up longer than 6 months after the initial surgery were included in the study. We defined high myopia as a refractive error greater than –8.0 diopters or an axial length that exceeded 26 mm. Eyes with an apparent epiretinal membrane (ERM) in the OCT image were excluded.[15] Approval from the institutional review board was not required for this study; however, informed consent was obtained from all patients.

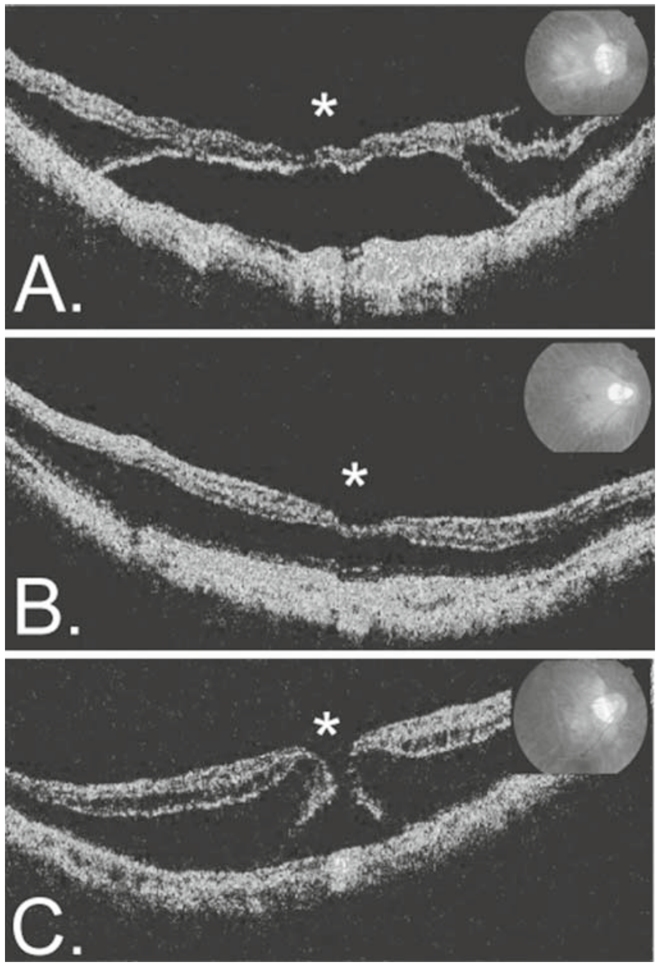

Figure 1A–C. Typical optical coherence tomographic images of the foveal detachment (FD) (**A**), retinoschisis (RS) (**B**), and macular hole (MH) (**C**) types of myopic foveoschisis. FD shows foveal detachment from the retinal pigment epithelium (RPE), while with RS there is no detachment from the RPE at the fovea. MH is a full-thickness macular hole at the fovea. *Location of the fovea.

Classification

The eyes were divided into three groups based on the foveal appearance on OCT. The foveal detachment (FD) group was characterized by photoreceptor detachment from the retinal pigment epithelium (RPE) at the fovea (Fig. 1A); the retinoschisis (RS) group was characterized by foveal retinoschisis in which the photoreceptors remained attached to the pigment epithelial cells (Fig. 1B); and macular hole (MH) group had a full-thickness macular hole at the fovea with retinoschisis in the surrounding retina but without any fluid cuff (Fig. 1C). Eight eyes in the MH group had been reported previously.[17] We compared the patient demographic data and surgical results among the three groups.

Surgical Techniques

Cataract surgery was performed on all 29 phakic eyes. A three-port conventional 20-gauge vitrectomy was carried out, as previously described.[11] Triamcinolone acetonide (TA) (0.2 ml of 20 mg/ml) was firstly injected into the vitreous cavity to visualize the vitreous. The vitreous cortex adhering to the inner retinal surface was removed gently with a diamond-dusted membrane scraper. Then, 0.5 ml of 0.5% ICG was sprayed onto the posterior retina to stain the ILM. The ILM of two to three disc diameters was peeled with intraocular forceps. Finally, fluid was exchanged with an air and gas tamponade using either 20% sulfur hexafluoride or 16% perfluoropropane. Following surgery, the patients were instructed to remain prone for at least 2 weeks.

Examinations

The axial length was measured by using A-mode ultrasonography. The detailed macular architecture was evaluated by using Stratus OCT (Carl Zeiss Meditec, Dublin, CA, USA). OCT images were obtained by using the default setting of the cross-hair mode (scan length, 5.65 mm). Color fundus photographs were taken with a fundus camera TRC-50 (Topcon, Tokyo, Japan). Technicians masked to the patients' diagnoses performed all the examinations.

Statistical Analysis

To evaluate the effects of surgery, factors such as sex, age, and the preoperative and postoperative BCVA were analyzed using Sigma Stat (SPSS). The BCVA was converted to logarithm of the minimum angle of resolution (logMAR) for analysis. The following tests were used: one-way analysis of variance (ANOVA), paired *t* test, Spearman's log-rank test, or the Mann-Whitney *U*. test. $P < 0.05$ was considered significant.

Results

Preoperative Factors

The preoperative patient data are shown in Table 1. There were 17 eyes with FD, 16 with RS, and 11 with MH. Patient age at surgery ranged from 43 to 79 years (63.3 ± 9.4 years, mean ± SD. The refractive error ranged from –3.0 to –25.0 diopters (D) (–10.8 ± 6.1 D, mean ± SD) in the 29 phakic eyes, the axial lengths from 24.4 to 34.6 mm (29.1 ± 1.9 mm, mean ± SD), and the duration of symptoms from 0.5 to 96 months (14.3 ± 24.3 months, mean ± SD). There was no significant difference among the three groups in age, sex, lens status, refractive error, axial length, duration of symptoms, or preoperative BCVA.

Surgical Outcome

The retinoschisis resolved in all eyes in the FD and RS patients. The macular hole closed in four (36%) of the 11 eyes in the MH group but not in the other seven (64%) eyes; two (50%) of four eyes with macular hole closures attained visual improvement of more than two lines. However, the retinoschisis resolved and the retina flattened in all eyes in the MH group.

The relationship between the preoperative and 12-month postoperative BCVA in each group is shown in Fig. 2. The postoperative BCVA and logMAR changes 3, 6, and 12 months after surgery among the groups are compared in Table 2. The mean BCVA in the FD group was 0.25 three months postoperatively and gradually increased to 12 months. The mean BCVA stayed at a similar level in the RS and MH groups during follow-up. There was no significant difference in the postoperative BCVA at any point among the three groups.

Table 1. Preoperative data for patients who underwent vitrectomy for myopic foveoschisis

Factor	Preoperative type of foveal status			*P* value (one-way ANOVA)
	FD ($n = 17$)	RS ($n = 16$)	MH ($n = 11$)	
Age (years)				
Range	43–77	54–74	49–76	
Mean ± SD	60.9 ± 10.6	65.7 ± 6.3	63.6 ± 11.0	0.347[a]
Sex, no. of eyes (%)				
Male	5 (29)	2 (13)	1 (9)	
Female	12 (71)	14 (87)	10 (91)	0.301
Lens, no. of eyes (%)				
Phakic	14 (82)	8 (50)	7 (64)	
Aphakic	0 (0)	0 (0)	0 (0)	
IOL	3 (18)	8 (50)	4 (36)	0.144[a]
Refractive error[b] (diopters)				
Range	–3.0 to –20.0	–6.3 to –15.5	–8.3 to –20.3	
Mean ± SD	–12.9 ± 4.6	–11.9 ± 3.6	–14.1 ± 3.9	0.590
Axial length (mm)				
Range	24.4–30.5	26.1–34.6	27.9–33.5	
Mean ± SD	28.5 ± 1.6	29.8 ± 2.2	28.9 ± 1.2	0.236
Duration of symptoms (months)				
Range	2–96	0.5–90	1–12	
Mean ± SD	12.3 ± 24.2	23.2 ± 30.0	4.4 ± 3.5	0.105
Preoperative BCVA				
Range	0.02–0.3	0.01–0.5	0.01–0.4	
Mean BCVA	0.12	0.11	0.11	0.668

BCVA, best-corrected visual acuity; IOL, intraocular lens; FD, foveal detachment type; RS, retinoschisis type; MH, macular hole type; ANOVA, analysis of variance.

[a] χ-squared test.

[b] Only phakic eyes.

Table 2. Postoperative data from patients who underwent vitrectomy for myopic foveoschisis

Factor	Preoperative Type of Foveal status FD (n = 17)	RS (n = 16)	MH (n = 11)	P value (one-way ANOVA)
Postoperative BCVA (3 months)				
Range	0.05–0.6	0.02–0.8	0.01–0.4	
Mean BCVA	0.25	0.21	0.13	0.207
Postoperative BCVA (6 months)				
Range	0.06–0.6	0.02–0.9	0.01–0.5	
Mean BCVA	0.27	0.19	0.15	0.275
Postoperative BCVA (12 months)				
Range	0.06–0.9	0.02–0.9	0.02–0.5	
Mean BCVA	0.31	0.18	0.11	0.152
LogMAR gain (3 months)				
Mean ± SD	0.36 ± 0.25	0.24 ± 0.27	0.00 ± 0.28	0.039[b]
LogMAR gain (6 months)				
Mean ± SD	0.40 ± 0.28	0.21 ± 0.32	0.03 ± 0.27	0.054[a]
LogMAR gain (12 months)				
Mean ± SD	0.48 ± 0.27	0.18 ± 0.35	0.07 ± 0.26	0.013[b]

LogMAR, logarithm of the minimum angle of resolution.
[a]Borderline significance.
[b]Statistically significant.

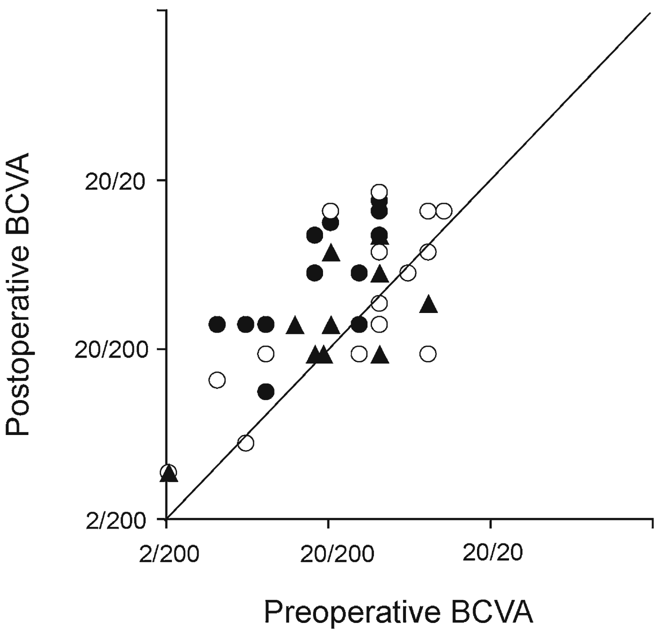

Figure 2. Preoperative versus 12-month postoperative best-corrected visual acuity (*BCVA*) of all patients who underwent vitrectomy for myopic foveoschisis. ● FD; ○ RS; ▲ MH. The preoperative and postoperative BCVA were positively correlated ($P < 0.01$).

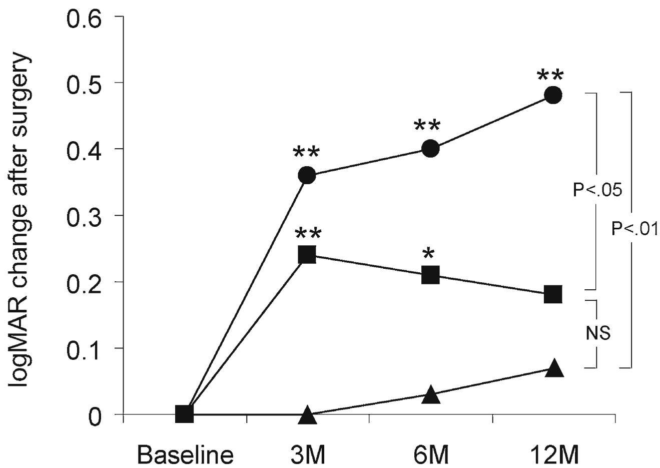

Figure 3. The mean logarithm of the minimum angle of resolution (*logMAR*) changes at different time points after vitrectomy in each group. The mean logMAR change was obtained by subtracting the postoperative logMAR value from the preoperative value. ● FD; ■ RS; ▲ MH. *$P < 0.05$, **$P < 0.01$; visual improvement from baseline by paired t test. The mean logMAR change was significantly greater in FD than in RS ($P < 0.05$) or MH ($P < 0.01$) by nonparametric statistical analysis at 12 months. *M*, months.

However, there were statistically significant differences in logMAR changes 3 months after surgery. This trend continued to the end of follow-up at 12 months. To understand this better, we displayed the data as a graph (Fig. 3). The postoperative mean BCVA improved significantly from baseline to 3 months postoperatively ($P < 0.01$) in the FD group and continued to improve throughout the follow-up. At the end of follow-up, the change in this group remained significant. The BCVA improved significantly in the RS group at 3 months ($P < 0.01$); however, the mean BCVA then decreased gradually, and the improvement was no longer significant at 12 months. The MH group did not show any significant visual improvement. The BCVA was somewhat better than baseline at 6 and 12 months, postoperatively, but the difference did not reach significance.

The visual changes in each group are profiled in Fig. 4. Three months after surgery, the BCVA improved by more than two lines in 27 eyes (61%), was unchanged in 14 (32%), and worsened by more than two lines in three (7%). Twelve months postoperatively, the BCVA improved in 25 eyes (60%), was unchanged in 14 (33%), and worsened by more than two lines in three (7%). In the FD group, the VA

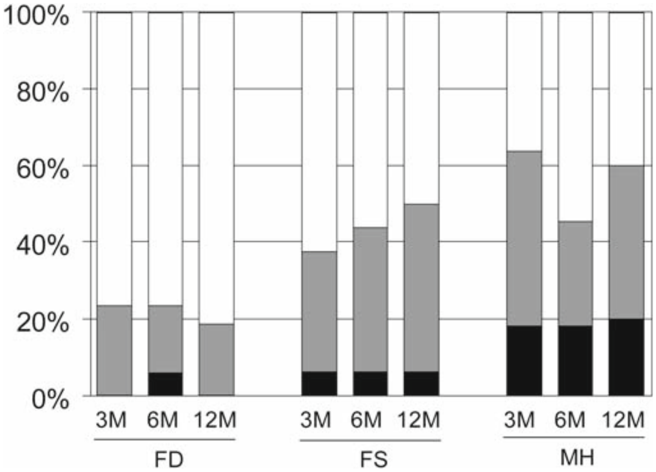

Figure 4. The rate of visual improvement, no change, or worsening after surgery in all groups. □, visual improvement of two or more lines; ■, worsening of two or more lines; ▨, unchanged vision. Almost 80% of eyes with FD had visual improvement 3 months after surgery, and the rate was stable until 12 months. Over 60% of the eyes with RS had visual improvement 3 months postoperatively; however, this rate gradually decreased. About 50% of the eyes with MH had visual improvement. Less than 10% of the eyes with FD or RS showed visual worsening; however, about 20% of the eyes with MH had visual worsening.

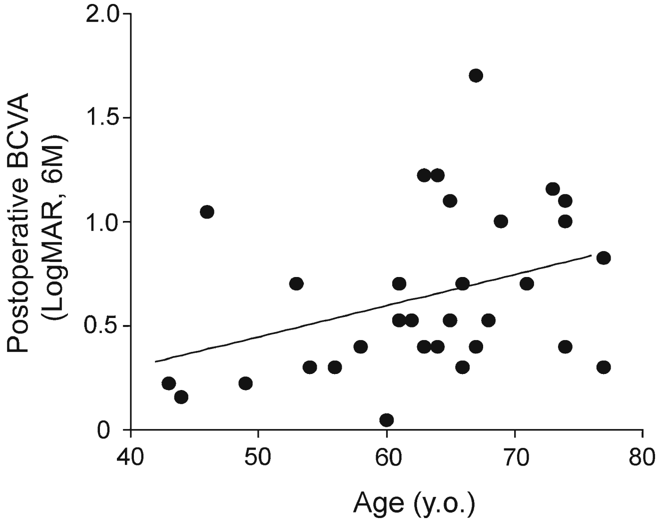

Figure 5. The 6-month postoperative BCVA after vitrectomy to treat the FD or RS type of myopic foveoschisis was significantly correlated with the age of the patient at surgery ($r^2 = 0.12$, $P < 0.05$). y.o., years old.

improved by more than two lines in 13 eyes (76%), was unchanged in three eyes (24%), and worsened in none (0%) at 3 months. The rate of visual improvement was similar up to 12 months, when the rate was 81%. In the RS group, the BCVA improved in ten eyes (63%), which was a somewhat lower rate than that in the FD group. This rate slowly decreased, and visual improvement was attained by eight (50%) eyes at 12 months. Four eyes (36%) attained visual improvement at 3 months in the MH group, which showed the least improvement of all the groups. The rate of visual improvement was similar throughout follow-up and was 40% at the final visit at 12 months.

A macular hole was recognized in two eyes 3 and 4 months after surgery. One was in the FD and the other in the RS group, although neither patient had any visual symptoms of macular hole formation. A reoperation was performed on the RS eye 2 weeks later for peripheral rhegmatogenous retinal detachment. A total of six MH eyes underwent retreatment for persistent macular hole: additional long-term gas tamponade in two eyes, and vitrectomy including extended ILM peeling and gas tamponade in four eyes. After the retreatment, the macular hole was closed in one eye but not in the other five eyes. No serious intraoperative or postoperative complications such as intraocular hemorrhage occurred, nor was there any infectious endophthalmitis.

Predictive Factors

We attempted to detect predictive factors that significantly affected the surgical outcome. Because the presence of a macular hole is thought to have a strong effect on the visual outcome, we concentrated on this analysis only in the FD and RS groups. We analyzed age, preoperative BCVA, the duration of symptoms with respect to postoperative BCVA, and visual improvement (Table 3). Preoperative BCVA and patient age were significantly ($P < 0.05$ and $P < 0.01$, respectively) correlated with the postoperative BCVA (Figs. 1, 5). The duration of symptoms and the preoperative BCVA were significantly ($P < 0.05$ and $P < 0.01$, respectively) correlated with visual changes (Figs. 6, 7).

Table 3. Correlation between preoperative factors and visual outcome in all patients who underwent vitrectomy for myopic foveoschisis

		P value	
Preoperative factor	*n*	Postoperative BCVA (6 months)	Visual change (6 months)
Age	33	0.019[a]	0.160
Duration of symptoms	33	0.131	0.027[a]
Axial length	19	0.267	0.787
Refractive error	22	0.097	0.257
Preoperative BCVA	33	<0.001[a]	<0.001[a]

[a]Statistically significant.

Discussion

It is still uncertain if ILM peeling is essential during vitrectomy for myopic foveoschisis. The ILM is usually peeled according to most previous reports,[8–11] but recent studies report favorable results without ILM peeling.[12–14] Although we did not compare the ILM peeling cases with those

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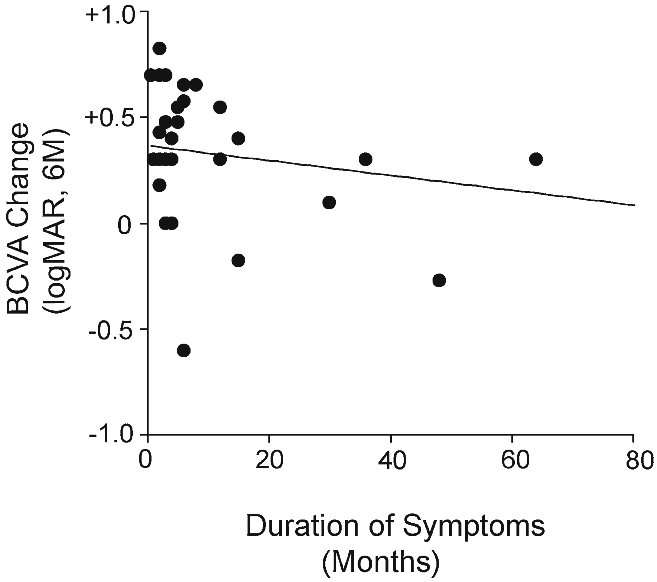

Figure 6. The visual acuity change 6 months after vitrectomy to treat the FD or RS type of myopic foveoschisis was significantly correlated with the duration of symptoms ($r^2 = 0.09$, $P < 0.05$). Visual change is represented as the gain in logMAR vision after surgery.

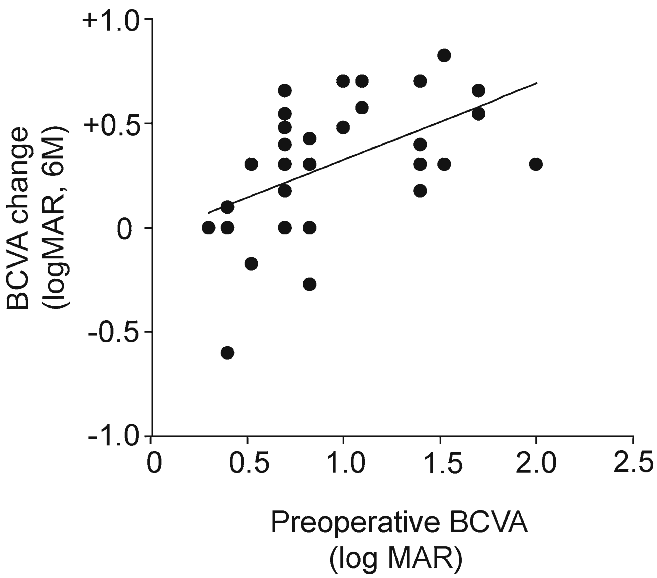

Figure 7. The visual change 6 months after vitrectomy was significantly correlated with the preoperative BCVA in the FD and RS types of myopic foveoschisis ($r^2 = 0.26$, $P < 0.01$).

without peeling, these recent studies suggest that ILM peeling is unnecessary. In this study, we peeled the ILM with the aid of ICG; over 80% of FD patients, 50% of RS patients, and 64% of all patients without a macular hole attained significant visual improvement 12 months after surgery. Although we cannot rule out a possible negative impact of ICG staining, the surgical results seem to have reached a satisfactory level. Kobayashi and Kishi[10] report that in their surgical cases of MF, one of nine eyes (11%) developed a macular hole postoperatively, but in our series no major complications such as retinal detachment or proliferative vitreoretinopathy occurred. We can therefore state that our surgical procedure is relatively safe.

Retinal vascular microfolds specific to high myopia indicate a potent vascular traction on the retina, which is thought to be a major cause of MF.[6,18] Other investigators have emphasized the importance of the ILM as a cause of MF.[4] In addition, inner retinoschisis, which is thought to be ILM separation from the neural retina, is often observed in eyes with MF.[5] These observations led us to hypothesize that the retina is split by the rigidity of the inner retinal components such as the ILM, retinal vessels, and ERMs, a fact which makes ILM peeling essential for foveal reattachment in MF. ICG-assisted ILM peeling is reported to cause toxicity to the retina and RPE in vivo and in vitro.[19,20] TA-assisted ILM peeling has recently been reported;[21] however, this procedure is difficult to perform in a highly myopic atrophic fundus because of the low contrast between the retina and RPE.

MF has a relatively heterogeneous appearance and manifests with a variety of OCT findings,[15,16] making it difficult to discuss its nature, including its pathogenesis, surgical results, and natural course. We divided the eyes into three groups, the FD, RS, and MH groups, based on the attachment or detachment of the photoreceptors and the presence or absence of full-thickness macular holes. Retinal detachment is supposed to be included in FD type, and retinoschisis, lamellar hole to be in RS type. The inner and outer segments of the photoreceptors have a strong signal on OCT images, enabling them to be identified even in high myopia. In addition, recent technological advances have resulted in high-speed, high-resolution OCT instruments. We believe our classification is also useful for the new Fourier-domain OCT, as it is easy, simple, and predictive.

In the FD group, visual acuity improved significantly after surgery, and continued to improve until the end of the follow-up. The improvement was significantly greater than that in the other two groups, but a similar difference was not observed in the preoperative and postoperative BCVA. As is often seen after reattachment surgery for conventional rhegmatogenous retinal detachment, reattachment of the photoreceptors at the fovea may have resulted in slow but steady visual recovery in the FD group. Because surgery provides recovery of the foveal photoreceptors, surgery can be more beneficial for this type of patient.

The significant visual improvement in the RS group 3 and 6 months after surgery indicated that even eyes without foveal detachment had visually functional improvement, probably due to retinal functional recovery around the fovea. This also indicates that retinoschisis, even without photoreceptor detachment, can result in retinal functional damage, and can be cured by surgery. However, the visual improvement in the RS group was lower than that in the FD group, probably because there was no photoreceptor detachment at the fovea in the RS group. The visual improvement in the RS group gradually decreased over time, and was no longer statistically significant at 12 months. This trend was different from those in the FD and MH groups. The reason is unknown, but chorioretinal atrophy may be implicated. From these observations, the RS group attained visual improvement by recovering the foveal structure; however, the benefits were relatively limited compared with those in the FD group.

Myopic foveoschisis is known to lead to macular hole formation, and once a macular hole develops, the prognosis is quite poor.[17] The MH group had no significant visual improvement after surgery in this study, and the prognosis of this group was the worst among the three groups. Therefore, prevention is crucial. Macular hole and retinal detachment cases are known to have a similar closure rate of about 40% after vitrectomy,[22] similar to that in our MH group. However, once retinal detachment occurs, the patient may face recurrent detachment or proliferative vitreoretinopathy. Because this was not a prospective study, the efficacy of vitrectomy to prevent macular hole retinal detachment (MHRD) is still uncertain. However, we believe even a macular hole is a good surgical indication to avoid a worse prognosis. In fact, there were no major intraoperative or postoperative complications in this study. A randomized prospective study may be needed to prove the protective effect of surgery against retinal detachment. However, we believe surgery is beneficial.

From our observations, it seems that the natural course of MF is from RS to FD and then to MHRD, but it is still controversial how a macular hole is actually generated. Because there are some exceptional cases and progression is sometimes slow, the patient's status may appear to be stationary, which may raise a question about when surgery should be performed. Surgical benefits are greater in FD cases than in RS cases, indicating we should wait until photoreceptor detachment. However, the final achieved vision was similar for FD and RS. Since once photoreceptors detach, macular hole formation may occur within 1 month, we concluded that vitrectomy can be performed with informed consent whenever the patient complains of visual disturbances, even in cases of RS.

We showed that the duration of symptoms is a significant predictive factor for visual outcomes in vitrectomy. The data showed that a shorter duration of symptoms resulted in a better outcome, likely because a longer duration of foveal damage due to either foveal detachment or architectural disturbances produces worse outcomes. However, two patients with a symptom duration of approximately 40 and 60 months attained more than two lines of visual improvement, suggesting that surgery can be beneficial even for such patients. Thus, it is not certain what duration of symptoms is appropriate before surgery.

Another important factor that affected the visual outcome was the preoperative BCVA. Good vision before surgery may lead to good vision but to little improvement after surgery, making it difficult to establish surgical indications. Our current indication is a BCVA worse than 20/40, but it is not clear whether this cutoff is appropriate. Our surgical results showed that approximately 70% of patients attained significant BCVA improvement after surgery, and a case with spontaneous resolution of MF has been reported.[23] Thus, although it may not be optimal, our indication seems to be suitable.

The current study showed the safety level and the effectiveness of vitrectomy for MF. Further study may disclose its more detailed pathogenesis and natural course, which can provide better procedures and indications for surgery.

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