Prospective study of vitrectomy for epiretinal membranes in patients with good best-corrected visual acuity

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Abstract

Purpose: To evaluate the efficacy of epiretinal membrane removal in patients with good best-corrected visual acuity (BCVA) for improving visual function and quality of life (QOL). Methods: This prospective case study compared 37 subjects with preoperative BCVA≦logMAR0.046 (Good group) to 35 patients with logMAR BCVA 0.52−0.10 (Moderate group) at 3 and 6 months. Linear mixed-effect models were used for statistical analysis. The primary outcome was the horizontal metamorphopsia score (MH) at 6 months postoperatively (post-6 M), while secondary outcomes were postoperative BCVA, vertical metamorphopsia score (MV), aniseikonia, stereopsis and central foveal thickness. In the Good group, QOL was assessed using the National Eye Institute Visual Functioning Questionnaire-25 (NEI VFQ-25) at 6 and 12 months. Results: MH was significantly improved at post-3 M and post-6 M in the both groups but there were no significant differences between the two groups. MV showed no improvement at the final observation in either group. LogMAR BCVA was significantly improved at post-6 M in the Good group, which had significantly better vision than the Moderate group. Preoperative vertical and horizontal aniseikonia scores remained unchanged in the Good group at post-6 M but worsened in the Moderate group. The NEI VFQ-25 score improved in the Good group, reflecting improved general health, general vision, and mental health. Conclusions: Early epiretinal surgery was effective for MH, BCVA, aniseikonia, and QOL.

Background

Epiretinal membrane is a translucent tissue that develops on the retinal surface and is reportedly present in 7%−11.8% individuals age 40 years and older [1, 2]. Epidemiological studies conducted on the Japanese population have found that 4.0%−5.4% of individuals have epiretinal membranes, indicating that aging is a risk factor [3, 4]. A recent study utilizing optical coherence tomography showed an epiretinal membrane to be present in 8.6% of post-cataract surgery patients with a mean age of 74.9 years [5]. Thus, patients with epiretinal membrane will increase as the population ages.

Although the epiretinal membrane itself does not cause blindness, symptoms of metamorphopsia and aniseikonia will develop. Furthermore, best-corrected visual acuity (BCVA) will decrease with the progression of these clinical conditions. It has been reported that preoperative BCVA is associated with postoperative BCVA prognosis [6, 7], though patients with lower preoperative BCVA can obtain higher improvement rates [8]. Therefore, epiretinal membrane is not generally treated surgically in patients with good BCVA. Recently, important visual functions other than BCVA, including metamorphopsia, aniseikonia, and binocular vision, have received increasing attention. Okamoto *et al* reported that metamorphopsia has a greater effect on vision-related quality of life (QOL) than BCVA [9].

Micro-incision vitrectomy surgery has recently been introduced and was shown to increase the safety of retinal surgery [10]. Therefore, cases with good BCVA, i.e. at least better than or equal to logMAR 0.046 (decimal BCVA, 0.9), are also candidates for surgery. Even in recent studies[6, 9, 11, 12, 13, 14, 15], the averages of preoperative logMAR BCVA have ranged from 0.7 to 0.17, while reports of good BCVA (≦logMAR 0.046) are very rare [16].

The present study aimed to elucidate the efficacy of epiretinal membrane removal in patients with good BCVA for improving visual function and QOL.

Methods

The present study was conducted in accordance with the tenets of the Declaration of Helsinki following approval from the Institutional Review Board of Nihon University Hospital (Tokyo, Japan). Written informed content was obtained from all patients before enrollment.

This prospective case series included a total of 37 patients with epiretinal membrane with good BCVA (≦logMAR 0.046; decimal BCVA, 0.9; Good group) enrolled between December 2015 and September 2016. Data from these patients were compared with retrospective data obtained from 35 cases (moderate group) whose BCVA was measured at logMAR 0.52−0.10 (decimal BCVA, 0.3−0.8) between April 2015 and April 2016 at 3 and 6 months (M) postoperatively (post-3 M and post-6 M, respectively).

The following data were acquired: quantitative assessment of metamorphopsia using M-CHARTS® (Inami Co., Tokyo, Japan) [17], quantitative assessment of aniseikonia using the New Aniseikonia test (Handaya Co., Tokyo, Japan.) [18], stereopsis assessment using the Titmus Stereo test (TST; Stereo Optical Co., Inc.), and assessment of visual function using decimal BCVA measurements. Central foveal thickness (CFT) was measured using optical coherence tomography (OCT; Spectralis®, Heidelberg Engineering Inc., Heidelberg, Germany). Decimal BCVA data were converted to logMAR scores for statistical processing. Logarithmic transformation was performed on the TST results. The primary and secondary outcome measures are listed below. Because the Moderate group data were retrospective, only post-3 M and post-6 M were available, while in the Good group these data were measured prospectively at post-1 M, post-3 M, post-6 M, and post-12 M. Furthermore, patient satisfaction levels were assessed in the Good group only using the National Eye Institute Visual Functioning Questionnaire-25 (VFQ-25) [19].

Primary outcome measure:

Horizontal metamorphopsia score (MH) at post-6 M.

Secondary outcome measures:

i) Decimal BCVA (logMAR score) preoperatively and at post-1 M, post-3 M, and post-12 M

ii) MH preoperatively and at post-1 M, post-3 M, and post-12 M

iii) Vertical metamorphopsia score (MV) preoperatively and at post-1 M, post-3 M, post-6 M, and post-12 M

iv) Horizontal aniseikonia score (AH) preoperatively and at post-1 M, post-3 M, post-6 M, and post-12 M

v) Vertical aniseikonia score (AV) preoperatively and at post-1 M, post-3 M, post-6M, and post-12 M

vi) Stereopsis measured by TST preoperatively and at post-1 M, post-3 M, post-6M, and post-12 M

vii) CFT measured by OCT preoperatively and at post-1 M, post-3 M, post-6M, and post-12 M

viii) NEI VFQ-25 score preoperatively and at post-6M, and post-12 M

Statistical analysis included a mixed model to compare chronological changes in all assessed data for both the Good and the Moderate group. A multivariate model with intentional selection was used to analyze variables. Notably, a mixed model (trend model with observation time points used as continuous quantities) was applied, with postoperative MH as the response variable, factors, observation time points, and interactions detected at the observation time points; independent variables as the fixed effects; and patients as the random effect to assess the effects exerted by preoperative variables (e.g., age, sex, pseudo-macular hole, BCVA, CFT, horizontal metamorphopsia, vertical metamorphopsia, horizontal aniseikonia, and vertical aniseikonia) on postoperative MH changes.

The model that included the baseline MH obtained through variable selection was a mixed

one, with the month of observation serving as the category. Using this mixed model, the mean value for MH at each month of observation was compared with the baseline value.

SAS

program v.9.4 (SAS Institute, Cary, NC) was employed. Statistical significance was set at P <

0.05. Exclusion criteria were as follows: i) a previous history of vitrectomy, ii)

ocular inflammation, iii) retinal vascular diseases, and iv) cataracts influencing BCVA.

Surgical procedure

In all patients, surgery was performed by the same surgeon (H.N.) using a 27-gauge vitrectomy system (CONSTELLATION® Vision System, Alcon Japan Ltd.) under retrobulbar anesthesia. All patients 50 years of age with phakic eyes underwent phacoemulsification and intraocular lens (IOL) implantation. Following core vitrectomy, a micro-hooked needle was created using a 27-G needle, and the epiretinal membrane was removed. Subsequently, the inner limiting membrane was removed following staining with 0.0625% brilliant blue G. After peripheral vitrectomy, approximately 30% of the vitreous cavity was replaced with air to accelerate the self-sealing of the sclerotomies. The posterior lens capsule was opened using a vitreous cutter to prevent posterior capsule opacification. The sclerotomies were then confirmed to have no leaking, and in patients with closure failure, a single 8-0 absorbable suture (coated 8-0 vicryl, ETHICON) was placed. In patients with a pseudo-macular hole, 100% fluid−air exchange was performed, and patients were required to lie in the prone position for 12−24 h.

Results

Background characteristics

Patient background characteristics are presented below. In the Good group, there were 17 males and 20 females, and the mean age was 64.1 years. The Moderate group was comprised of 13 males and 22 females, with a mean age of 66.7 years. In the Good and Moderate groups, 11 and 9 eyes presented with pseudo-macular hole configuration, respectively. There were no significant differences in sex, age, or percentage of pseudo-macular holes between the two groups (Table 1). In the Good and Moderate groups, two and one eye, respectively, had already undergone IOL implantation. In the Good group, one eye had been treated with lens sparing vitrectomy.

No postoperative complications such as vitreous hemorrhage, retinal detachment, endophthalmitis, visual field loss, cystoid macular edema, and cataract progression were reported.

BCVA

In the Good group, the average preoperative BCVA was logMAR −0.09 and averages of postoperative BCVA were logMAR −0.12 at post-3 M, −0.13 at post-6 M, and −0.13 at post-12 M, indicating significant improvement at each time point (P = 0.02, P = 0.01, and P = 0.01, respectively). In the Moderate group, the average preoperative BCVA was logMAR 0.23 and averages of postoperative BCVA were logMAR −0.01 at post-3 M and −0.06 at post-6 M, indicating significant improvement at both time points (both P < 0.0001). In the Good group as compared with the Moderate group, significantly better BCVA was demonstrated preoperatively, and at post-3 M, and post-6 M (P < 0.0001, P < 0.0001, and P = 0.003, respectively), as shown in Table 2 and Fig. 1).

Horizontal metamorphopsia scores

Investigation of MH indicated that in the Good group, as compared with the preoperative score of 0.84°, the postoperative scores were 0.52° at post-1 M, 0.44° at post-3 M, 0.45° at post-6 M, and 0.37° at post-12 M, indicating significant improvement at each time point (P = 0.0003, P < 0.0001, P < 0.0001, and P

< 0.0001, respectively). In the Moderate group, as compared with the preoperative score of 0.87°, MH was 0.86° at post-3M and 0.71° at post-6M, indicating significant improvement (P = 0.015 and P < 0.0001, respectively; Table 2, Fig. 2). However, there were no significant differences between two groups at post-3M and post-6M.

Vertical metamorphopsia scores

Investigation of MV indicated that in the Good group, as compared with the preoperative of 0.86°, the post-1 M, post-3 M, post-6 M, and post-12 M scores were 0.57°, 0.66°, 0.62°, and 0.77°, respectively, indicating significant improvement at post-1 M, 3 M, and 6 M (P = 0.0006, P = 0.048, and P = 0.018, respectively). However, there was no significant improvement at post-12 M (P = 0.38). In the Moderate group, compared with the preoperative score of 0.79°, MV was 0.48° at post-3M and 0.59° at post-6 M, indicating significant improvement at post-3 M (P = 0.004). However, no significant improvement was seen at post-6 M (P = 0.06). Neither group showed any significant differences preoperatively or at post-3 M and post-6 M (P = 0.62, P = 0.22, and P = 0.85, respectively; Table 2, Fig. 3).

Horizontal aniseikonia scores

Investigation of AH indicated that in the Good group, at the preoperative, post-1 M, post-3 M, post-6 M, and post-12 M time points, macropsia was observed at rates of 3.03%, 2.78%, 2.61%, 2.81%, and 3.17%, respectively, indicating no changes as compared with the preoperative rate (P = 0.68, P = 0.49, P = 0.71, and P = 0.82, respectively). In the Moderate group, at the preoperative, post-3 M, and post-6 M time points, macropsia was observed at rates of 3.6%, 5.11%, and 5.2% respectively, indicating significant worsening at post-3 M and post-6 M (P = 0.013 and P = 0.009, respectively). Though there were no significant differences between the groups at the preoperative time point (P = 0.51), in the Good group, significantly less macropsia was observed at post-3 M and post-6 M (P = 0.005 and P = 0.007, respectively; Table 2, Fig. 4).

Vertical aniseikonia scores

Investigation of AV indicated that in the Good group, at the preoperative, post-1 M, post-3 M, post-6 M, and post-12 M time points, macropsia rates were 2.78%, 2.56%, 2.56%, 2.96%, and 3.14%, respectively, indicating neither significant improvement nor worsening as compared with the preoperative rate (P = 0.69, P = 0.69, P = 0.75, and P = 0.52). In the Moderate group, macropsia was observed at rates of 4.09%, 5.2%, and 5.56% respectively, indicating significant worsening at post-6 M (P = 0.053 and P = 0.011). Macropsia was significantly milder in the Good group at the post-3 M and post-6 M time points as compared to the preoperative value (P = 0.004 and P = 0.004, respectively; Table 2, Fig. 5).

Binocular vision

Investigation of binocular vision indicated that in the Good group, binocular vision values at the preoperative, post-1 M, post-3 M, post-6 M, and post-12 M time points were 1.92, 1.97, 1.95, 1.98, and 1.93, respectively, indicating no change as compared with the preoperative value (P = 0.44, P = 0.60, P = 0.32, and P = 0.88, respectively). In the Moderate group, the preoperative, post-3 M, and post-6M values were 2.21, 2.11, and 2.04, respectively, indicating significant improvement at post-6 M (P = 0.014). Although intergroup comparison showed that stereopsis was significantly better in the Moderate group at the preoperative time point (P = 0.02), no significant intergroup differences were found at either post-3 M or post-6 M (P = 0.18 and P = 0.63, respectively; Table 2, Fig. 6).

CFT measurements

In the Good group, the preoperative, post-1 M, post-3 M, post-6 M, and post-12 M CFT measurements were 388.4, 376.2, 349.5, 338.8, and 329.1 μm, respectively, indicating significant thinning at post-3M, 6M and 12M (P = 0.001, P < 0.0001, and P < 0.0001). In the Moderate group, the values were 485.7, 402.7, and 381.2 μm preoperatively, and at post-3 M and post-6 M, indicating significant thinning at all three time points (P < 0.0001 and P < 0.0001). Intergroup comparisons indicated that at the preoperative and post-3 M time points, CFT was significantly reduced in the Good group as compared to the controls (P < 0.0001 and 0.02), whereas no significant difference was found at the post-6 M time point (P = 0.065; Table 2, Fig. 7).

Factors affecting changes in horizontal metamorphopsia score (multivariate analysis)

Factors affecting changes in postoperative MH, including age, preoperative BCVA, preoperative MH, preoperative MV, preoperative AH, preoperative AV, and preoperative CFT, were investigated. Multivariate analysis identified only preoperative MH as a factor that affected changes in postoperative MH. (P < 0.0001, Table 3).

Horizontal metamorphopsia score variation

Variations in MH, as shown by the category model created, are presented in Figure 8. The post-6 M score was predicted to be 0.4997° based on the preoperative MH of 0.9°.

VFQ-25 (Good group only, Table 4)

<u>General health:</u> Post-6 M was 50.3 and post-12 M was 53.7, compared with 45.9 at the preoperative time point, indicating significant improvement at post-12 M (P = 0.004).

<u>General vision:</u> Post-6 M was 67.2 and post-12M was 69.3, compared with 59.5 at the preoperative time point, indicating significant improvements at both post-6 M and post-12 M (P = 0.005 and P = 0.0005).

<u>Ocular pain:</u> Post-6 M was 83.7 and post-12 M was 81.7, compared with 74.3 at the preoperative time point, indicating significant improvements at both post-6 M and post-12 M (P = 0.002 and P = 0.014).

<u>Near activities:</u> Post-6 M was 68.2 and post-12 M was 67.8, compared with 64.2 at the preoperative time point, indicating significant improvement at post-12 M (P < 0.0001).

<u>Distance activities:</u> Post-6 M was 77.5 and post-12 M was 79.2, compared with 75.7 at the preoperative time point, indicating no significant improvement at either postoperative time point (P = 0.45 and P = 0.138).

<u>Social functioning:</u> Post-6 M was 85.4 and post-12 M was 91.6, compared with 87.8 at the preoperative time point, indicating no significant improvement at either postoperative time point (P = 0.373 and P = 0.178).

<u>Mental health:</u> Post-6 M was 76.2 and post-12 M was 79.5, compared with 70.4 at the preoperative time point, indicating significant improvement at the post-6 M and the post-12 M time point (P = 0.047 and P = 0.002).

<u>Role difficulties:</u> Post-6 M was 79.6 and post-12 M was 82.9, compared with 80.4 at the preoperative time point, indicating no significant improvement at either postoperative time point (P = 0.81 and P = 0.45).

<u>Dependency:</u> Post-6 M was 91.5 and post-12 M was 93.0, compared with 89.0 at the preoperative time point, indicating no significant improvement at either postoperative time point (P = 0.23 and P = 0.058).

<u>Driving:</u> Post-6M was 74.2 and post-12 M was 73.4, compared with 74.3 at the preoperative time point, indicating no significant improvement at either postoperative time point (P = 0.996 and P = 0.906).

<u>Color vision:</u> Post-6 M was 94.4 and post-12 M was 95.7, compared with 93.2 at the preoperative time point, indicating no significant improvement at either postoperative time point (P = 0.649 and P = 0.332).

<u>Peripheral vision:</u> Post-6 M was 71.9 and post-12 M was 77.8, compared with 70.3 at the preoperative time point, indicating no significant improvement at either postoperative time point (P = 0.684 and P = 0.068).

No complications, such as postoperative endophthalmitis, retinal detachment, and vitreous hemorrhage, were observed.

Discussion

Our present results indicate that early surgery on patients in the Good group with decimal BCVA of at least logMAR 0.046 promoted significantly greater BCVA improvement than in the Moderate group. Epiretinal membrane is known to occasionally develop in younger patients [20]. Individuals in certain occupations and those leading certain lifestyles require a high level of visual function. Therefore, we have consider performing surgery on individuals with good BCVA to be an effective approach to maintaining high-quality visual function in such individuals.

Horizontal metamorphopsia is easily perceived by patients [17, 21]. Because it is more common to encounter horizontally oriented text than vertically oriented text while writing and reading, MH is of major importance. Surgery reportedly results in a greater improvement of MH than of MV [11, 13, 15]. Thus, MH at post-6 M was used as the primary outcome measure in the present study. No significant intergroup difference was found in MV at the final observation time point. MV is thought to be associated with horizontally oriented retinal contraction. Furthermore, MV is thought to be less likely to improve in response to surgery as well as being less likely to occur because of the presence of the optic nerve which may restrict horizontal displacement of the posterior retina and also because of the directionality of the axon of the retinal ganglion cells which course horizontally rather than vertically in the posterior pole [13, 21, 22].

MH showed improvement in both groups (Moderate group: 0.5°, Good group: 0.37°) at the final observation time point. Once metamorphopsia reaches 0.5° or worse, the patient reportedly becomes aware of the symptoms [21]. A previous study on quality of vision (QOV) reported that metamorphopsia has a more marked influence on QOV than on BCVA [23]. In the present study, in the Good group, MH improved to 0.37°, i.e. <0.5°, thereby indicating that it was useful for improving QOV.

Only the preoperative MH was selected as a factor that affected the postoperative MH. The calculation of MH using the category model indicated that the preoperative MH leading to postoperative scores of <0.5° was 0.9°. The preoperative MH of 0.9° represents a clinical data point that can be used as an index for determining surgery indications.

The aniseikonia investigation revealed significant worsening of both AV and AH in the Moderate group at post-6 M and that macropsia was >5%. However, in the Good group, macropsia remained at 3.17% (horizontal) and 3.14% (vertical), though there was no improvement. It has been reported that aniseikonia of ≧5% indicates a loss of binocular vision[24, 25]. Therefore, early surgery is also valuable for maintaining binocular vision. In the Moderate group, the reason for the worsening of postoperative macropsia was not identified. However, a report on aniseikonia by Okamoto *et al* stated that although there was no significant pre- vs. postoperative difference, macropsia increased postoperatively [26]. Takabatake *et al*, who investigated only vertical aniseikonia, reported improved macropsia at post-12 M, which was found to be associated with MH, i.e., vertical contractions of the retina [13]. The follow-up period for the Moderate group was 6 M, which indicates that the investigation conducted in this study alone was inconclusive as to the worsening of macropsia. In the

Good group, there was no worsening after the 12-M follow-up and aniseikonia was <5% at the last examination. Therefore, we consider performing surgery on patients with a preoperative value of <5% to potentially provide an index of surgical indications for patients with good BCVA.

Investigation of binocular function showed that although preoperative values were significantly better in the Good group than in the Moderate group, the post-6 M binocular vision of cases in the Moderate group improved, indicating that the significant difference between the groups had been lost over time. TST is reportedly associated with preoperative CFT.15 Preoperative CFT was significantly greater in the Moderate group than in the Good group and preoperative stereopsis was significantly poorer. However, the significant difference in CFT between the two groups had disappeared at post-6 M, such that there was no significant difference in stereopsis. Asaria *et al* reported that the longer the symptoms persist preoperatively, the worse the pre- and postoperative stereopsis can be [27]. In the present study, the time period from initial symptom onset in the Good group was unknown. If surgery is performed shortly after symptom onset, then better recovery of visual function can be achieved.

VFQ-25 assessment was performed only for the Good group. Okamoto *et al*, who evaluated patients with a mean preoperative logMAR score of 0.495, reported that the composite score improved from 66.2 preoperatively to 77.9 postoperatively and that all items, with the exception of general health and peripheral vision, showed significant postoperative improvement [9]. The preoperative BCVA was good in the present study. Therefore, the preoperative composite score was also high at 75.3. Despite this, the score at post-12M showed significant improvement to 82.0, indicating that the surgery in the Good group was effective. Postoperative scores for both general health and vision-related mental health improved, indicating that the patient satisfaction level also improved with the surgery. Both general vision and near activities improved, possibly due to the improvement in visual function itself. As vision itself improved, eye strain was alleviated, which in turn may have ameliorated ocular pain.

The present study prospectively analyzed patients in the Good group. In contrast, because previous data were utilized in the Moderate group, which was used for comparison, postoperative 1-M and 12-M data could not be obtained. Symptoms may also improve at 1 or 2 years postoperatively [28]. Therefore, further investigation of this issue over longer periods of time and with higher numbers of patients is required. The present study included 20 cases with pseudo-macular holes. Although there was no significant intergroup difference in terms of the pseudo-macular hold rate, further investigation without pseudo-macular hole cases should be conducted to investigate metamorphopsia and aniseikonia accurately.

No postoperative complications developed in the present study. However, the BCVA of one 79-year-old male patient with pseudo-macular holes decreased from 1.0 preoperatively to 0.7 in decimal BCVA at 12 M postoperatively. The patient had no subjective perception that his BCVA had declined. It is sometimes difficult to improve BCVA in patients with pseudo- and lamellar macular holes with vitreous traction [29]. Therefore, caution is required when determining surgical indications in such cases with good BCVA. Also, sufficient caution is essential when managing epiretinal membrane patients with uveitis[30], concurrent glaucoma [31], and cyst formation[32].

Recently, micro-incision vitrectomy surgery has come into widespread use and its safety has improved dramatically. Therefore, the surgical indications for macular surgeries have been expanding. Number of patients with epiretinal membrane are expected to increase as the mean age of the population rises. The results obtained in this study indicate that early epiretinal membrane surgery can improve QOL in patients with good BCVA.

Abbreviations

BCVA: Best-corrected visual acuity; MH: Horizontal metamorphopsia score, MV: Vertical metamorphopsia score, AH: Horizontal aniseikonia score, AV: Vertical aniseikonia score, OCT: Optical coherence tomography

Declarations

Ethics approval and consent to participate

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional research committee and with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards. The protocol was approved by the institution view board of Nihon University Hospital (Tokyo, Japan) with reference number 277-1. Written informed content was obtained from all patients before enrollment.

Consent for publication

Not applicable.

Availability of data and materials

The datasets used and analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

Involved in the design of the study (HN, RM, HS); conduct of the study (HN, YK, YW, KT, KF, TH, HS); collection, management, analysis of the data (HN, YK, YW); preparation of the manuscript (HN, HS); and critical revision of the manuscript (HN, HS). All authors read and approved the final manuscript

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Tables

Table 1. Patient background characteristics

	Good group (n = 37)	Moderate group (n = 35)	P-value
Sex (M:F)	17:20	13:22	0.48
Age (years ± SD)	64.1 ± 7.4	66.7 ± 7.8	0.15
Pseudo-macular hole (no. of eyes)	11	9	0.8

Table 2 Parameter values for the Good and Moderate groups

	Good group									Moderate group				
	Pre-op	Post-1 M		Post-3 M		Post-6 M		Post-12 M		Pre-op	Post-3 M		Post-6 M	
		Mean ± SD	P-value	Mean ± SD	P-value	Mean ± SD	P-value	Mean ± SD	P-value	Mean ± SD	Mean ± SD	P-value	Mean ± SD	P-value
logMAR BCVA	−0.09 ± 0.08	−0.12 ± 0.09	0.08	−0.13 ± 0.10	0.02	−0.13 ± 0.10	0.01	−0.13 ± 0.07	0.01	0.23 ± 0.11	−0.01 ± 0.14	<0.0001	−0.06 ± 0.13	<0.0001
MH	0.84 ± 0.60	0.52 ± 0.63	0.0003	0.44 ± 0.58	<0.0001	0.45 ± 0.59	<0.0001	0.36 ± 0.50	<0.0001	0.87 ± 0.66	0.65 ± 0.70	0.01	0.50 ± 0.60	<0.0001
MV	0.86 ± 0.57	0.57 ± 0.53	0.006	0.66 ± 0.66	0.05	0.62 ± 0.60	0.02	0.79 ± 0.69	0.38	0.79 ± 0.60	0.48 ± 0.47	0.004	0.59 ± 0.63	0.06
AH	3.03 ± 3.02	2.78 ± 2.89	0.68	2.61 ± 2.72	0.49	2.81 ± 2.89	0.71	3.17 ± 3.83	0.82	3.60 ± 4.55	5.11 ± 4.58	0.01	5.50 ± 3.89	0.009
AV	2.78 ± 2.62	2.56 ± 2.65	0.69	2.56 ± 3.06	0.69	2.96 ± 3.13	0.75	3.14 ± 3.34	0.52	4.09 ± 4.88	5.20 ± 4.71	0.05	5.56 ± 4.39	0.01
TST	1.92 ± 0.39	1.96 ± 0.55	0.45	1.95 ± 0.46	0.6	1.98 ± 0.57	0.32	1.93 ± 0.52	0.88	2.19 ± 0.55	2.12 ± 0.51	0.17	2.02 ± 0.44	0.01
CFT	388.4 ± 111.5	376.2 ± 78.9	0.3	349.5 ± 73.8	0.001	338.8 ± 73.7	<0.0001	329.1 ± 63.3	<0.0001	485.7 ± 158.8	402.7 ± 82.1	<0.0001	381.2 ± 85.5	<0.0001

BCVA, best-corrected visual acuity; MH, horizontal metamorphopsia score; MV, vertical metamorphopsia score; AH, horizontal aniseikonia score; AV, vertical aniseikonia score; TST, Titmus Stereo test; CFT, central foveal thickness

Table 3 Factors affecting postoperative horizontal metamorphopsia score (linear mixed-effects model, multivariate analysis)

Trend model		Regression				
			Parameter 95%CI			
		Est.	Lower limit	Upper limit	SD	P-value
Segment		−0.0085	−0.1730	0.1560	0.0825	0.9182
Time point (Trend)		0.0334	−0.0150	0.0818	0.0246	0.1757
Pre-op MH*		0.9424	0.7878	1.0970	0.0784	<0.0001
Pre-op MH* and Time point (Trend) interaction		−0.1673	−0.2136	−0.1209	0.0235	<0.0001

*MH, horizontal metamorphopsia score

Table 4 The National Eye Institute 25-item Visual Function Questionnaire (VFQ-25) composite score and 12 subscales in the Good group

VFQ-25 questionnaire scale	Preoperative	Post-6 M		Post-12 M	
	Average ± S.D	Average ± S.D	P-value	Average ± S.D	P-value
General health	45.9 ± 16.2	50.0 ± 14.9	0.09	53.6 ± 16.2	0.004*
General vision	59.5 ± 18.6	66.9 ± 17.5	0.005*	69.1 ± 16.3	0.0005*
Ocular pain	74.3 ± 19.3	83.2 ± 18.7	0.002*	81.1 ± 16.7	0.014*
Near activities	64.2 ± 17.2	67.4 ± 16.7	0.167	76.9 ± 15.1	<0.0001*
Distance activities	75.4 ± 14.2	77.5 ± 11.4	0.45	79.4 ± 11.6	0.138
Social functioning	87.8 ± 16.3	85.4 ± 15.9	0.373	91.8 ± 10.5	0.178
Mental health	70.4 ± 22.3	76.4 ± 19.3	0.047*	79.8 ± 15.7	0.0023*
Role difficulties	80.4 ± 20.3	79.3 ± 18.9	0.815	82.5 ± 16.1	0.45
Dependency	89.0 ± 14.6	91.2 ± 14.6	0.237	93.1 ± 12.0	0.058
Driving	74.3 ± 18.5	74.2 ± 25.6	0.996	73.4 ± 24.5	0.906
Color vision	93.2 ± 15.2	94.3 ± 10.7	0.649	95.7 ± 9.6	0.332
Peripheral vision	70.3 ± 21.1	72.1 ± 19.0	0.684	77.9 ± 18.0	0.067
Composite score	75.3 ± 14.6	77.7 ± 11.8	0.19	82.0 ± 10.8	0.002*

*significant difference from preoperative score (linear mixed-effect model)

Figures
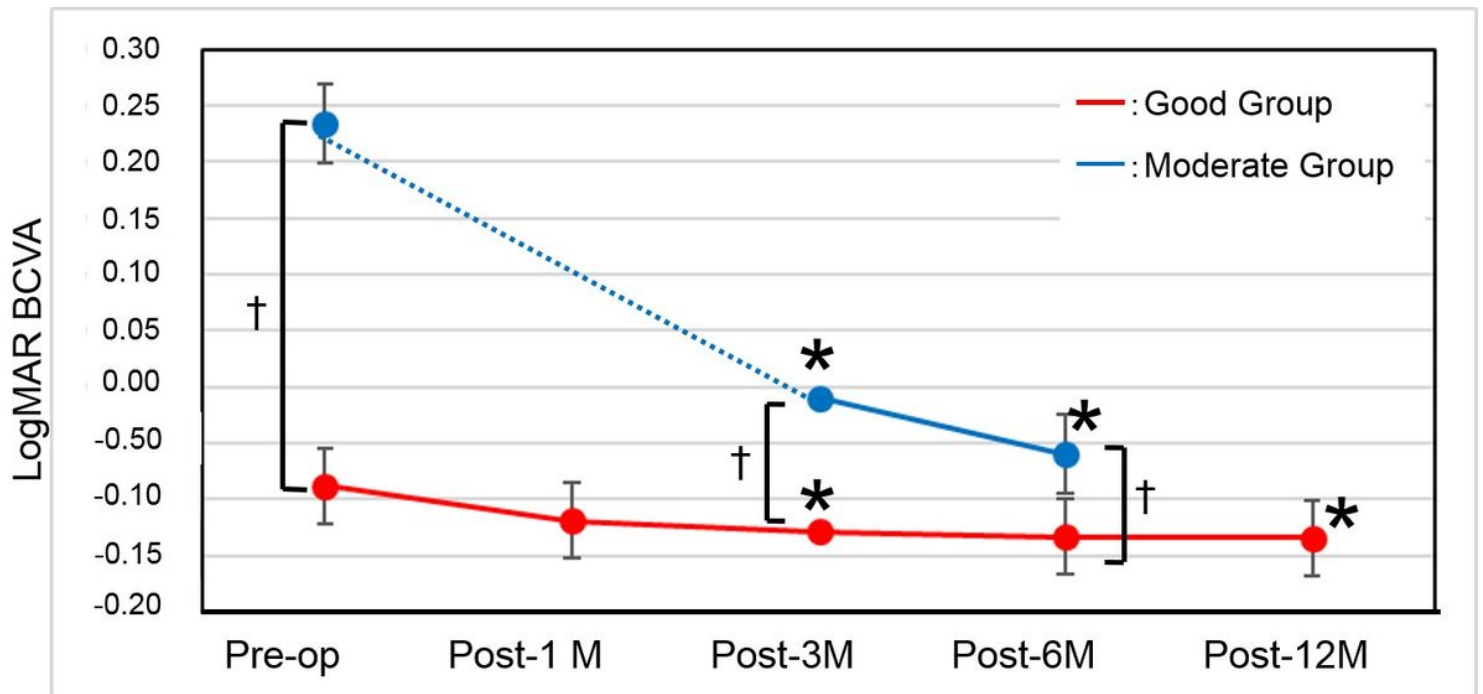
Figure 1

Change in best-corrected visual acuity (BCVA) (logMAR) Red line: Good group, Blue line: Moderate group. *P < 0.05 compared with preoperative; †P < 0.05 between groups. Because the data obtained at one month were missing from the Moderate group, the dotted line indicates the period between the preoperative and post-6 M time points.
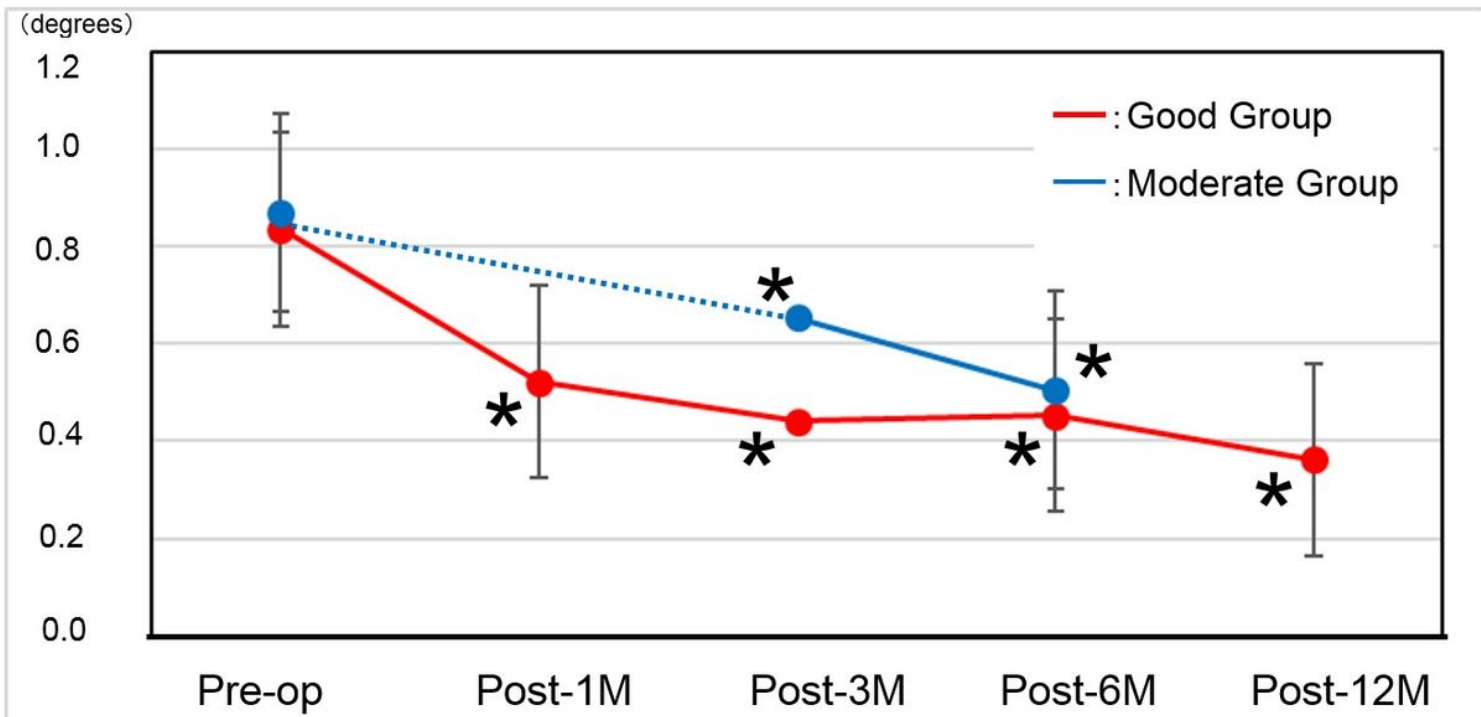
Figure 2

Horizontal metamorphopsia scores Red line: Good group, Blue line: Moderate group. *P < 0.05 compared with preoperative score.
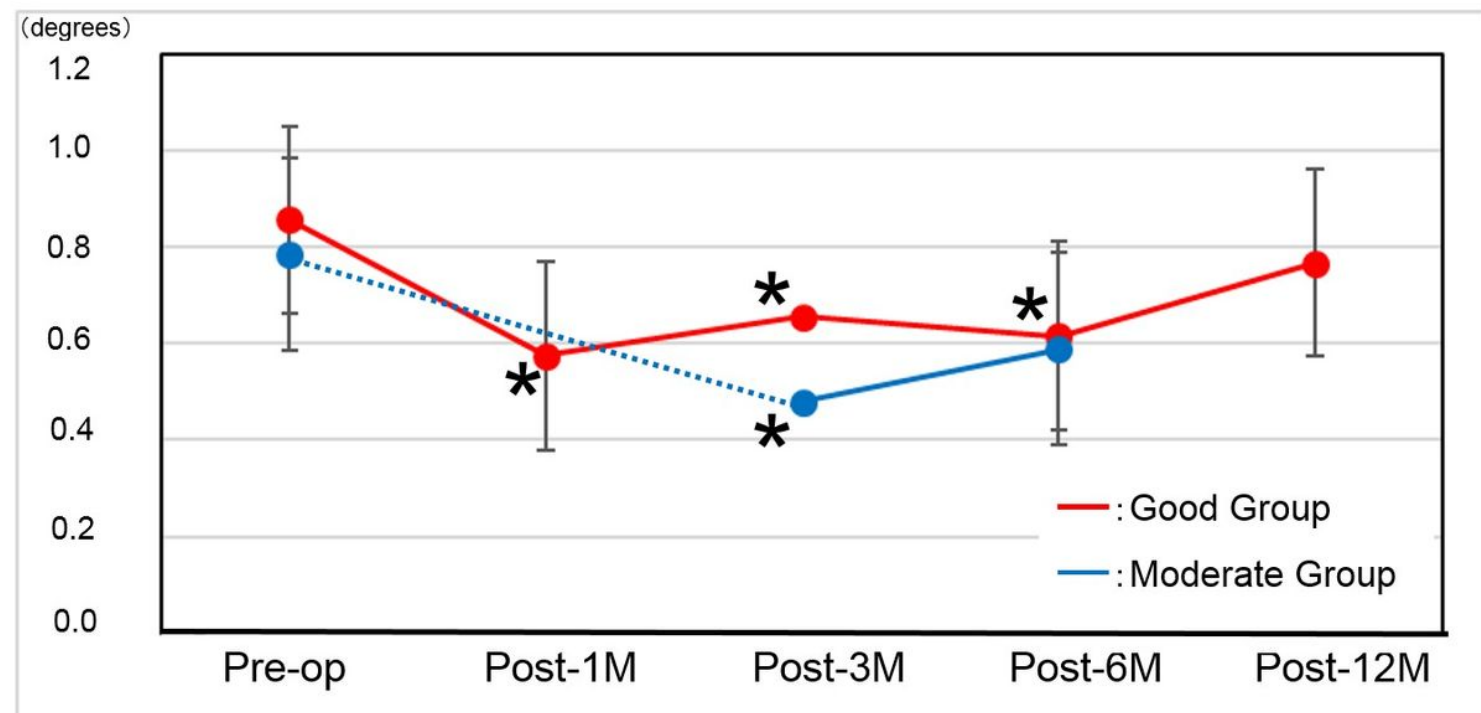
Figure 3

Vertical metamorphopsia scores Red line: Good group, Blue line: Moderate group. *P < 0.05 compared with preoperative score.
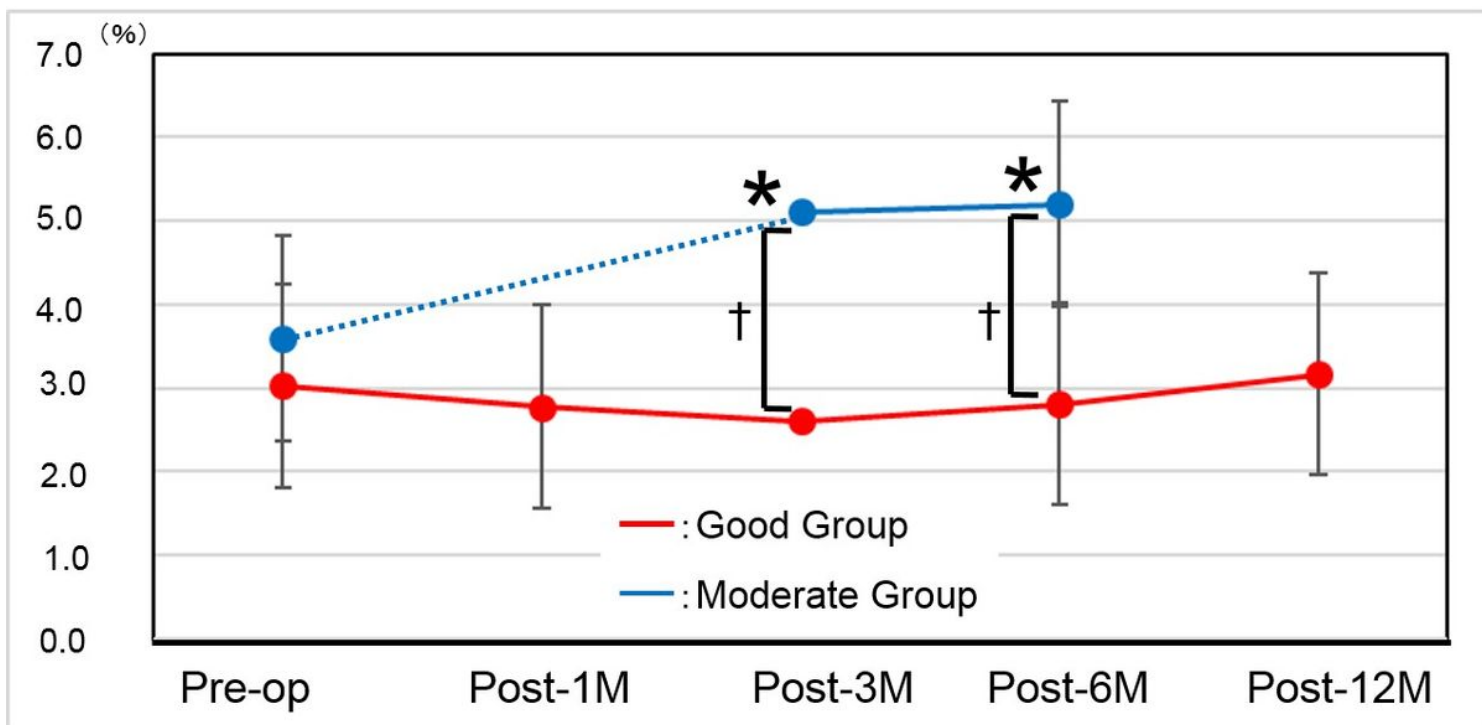
Figure 4

Horizontal aniseikonia scores Red line: Good group, Blue line: Moderate group. *P < 0.05 compared with preoperative score; †P < 0.05 between groups.
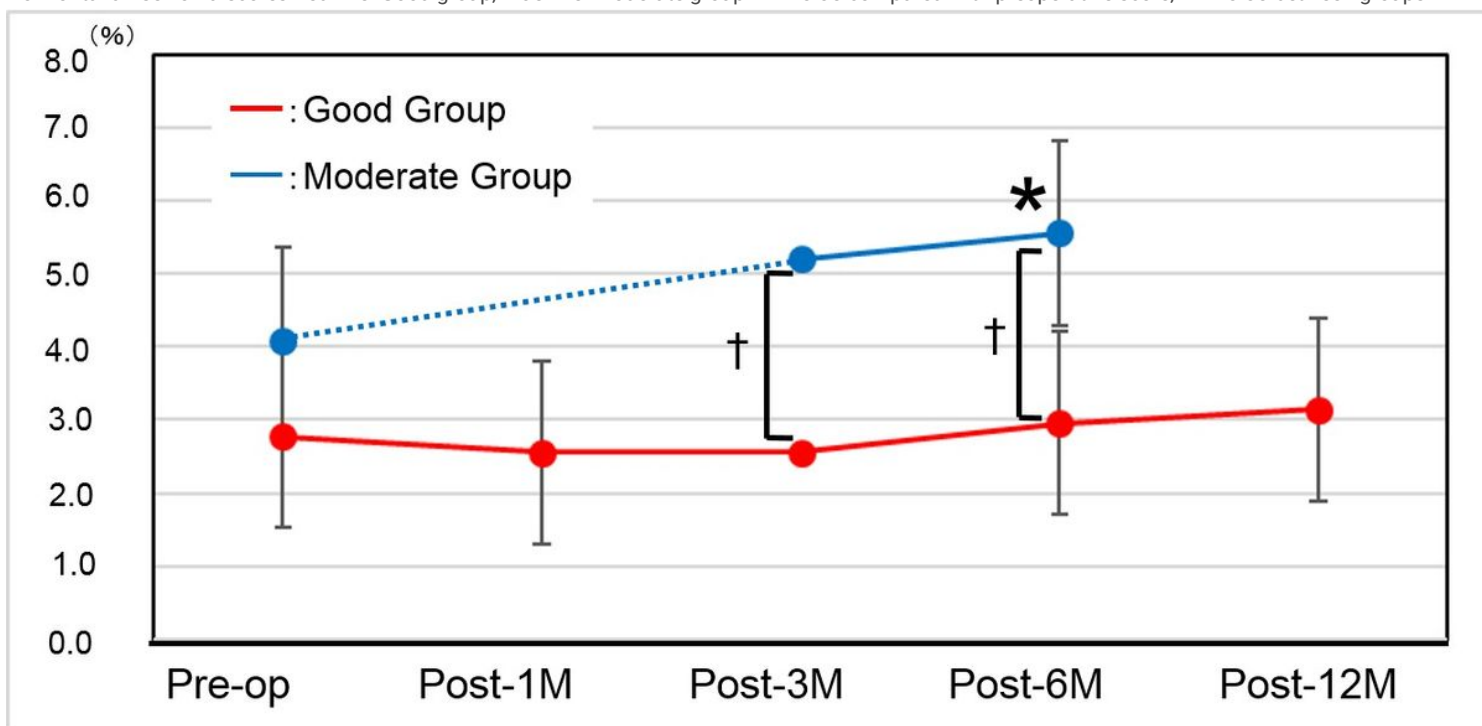
Figure 5

Vertical aniseikonia scores Red line: Good group, Blue line: Moderate group. *P < 0.05 compared with preoperative score; †P < 0.05 between groups.
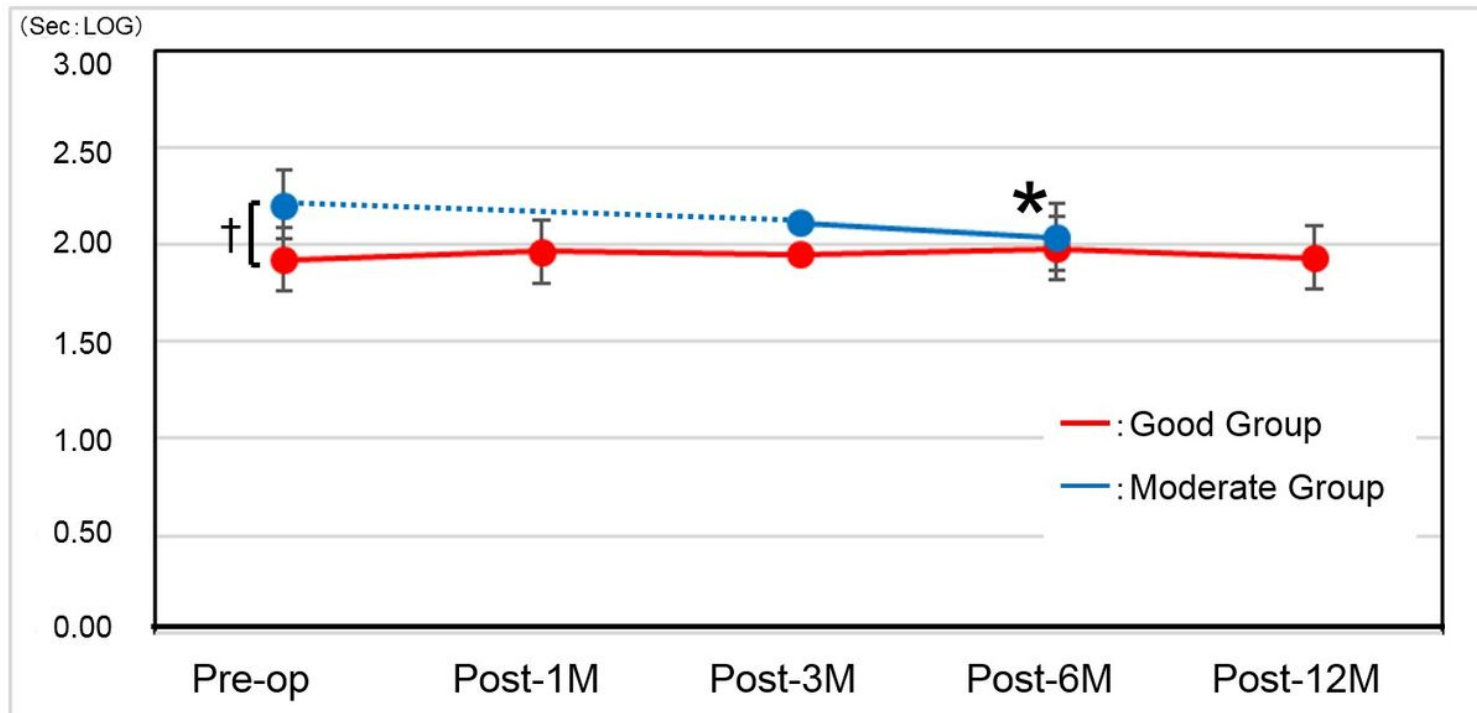
Figure 6

Stereopsis (TST) Red line: Good group, Blue line: Moderate group. *P < 0.05 compared with preoperative score; †P < 0.05 between groups.
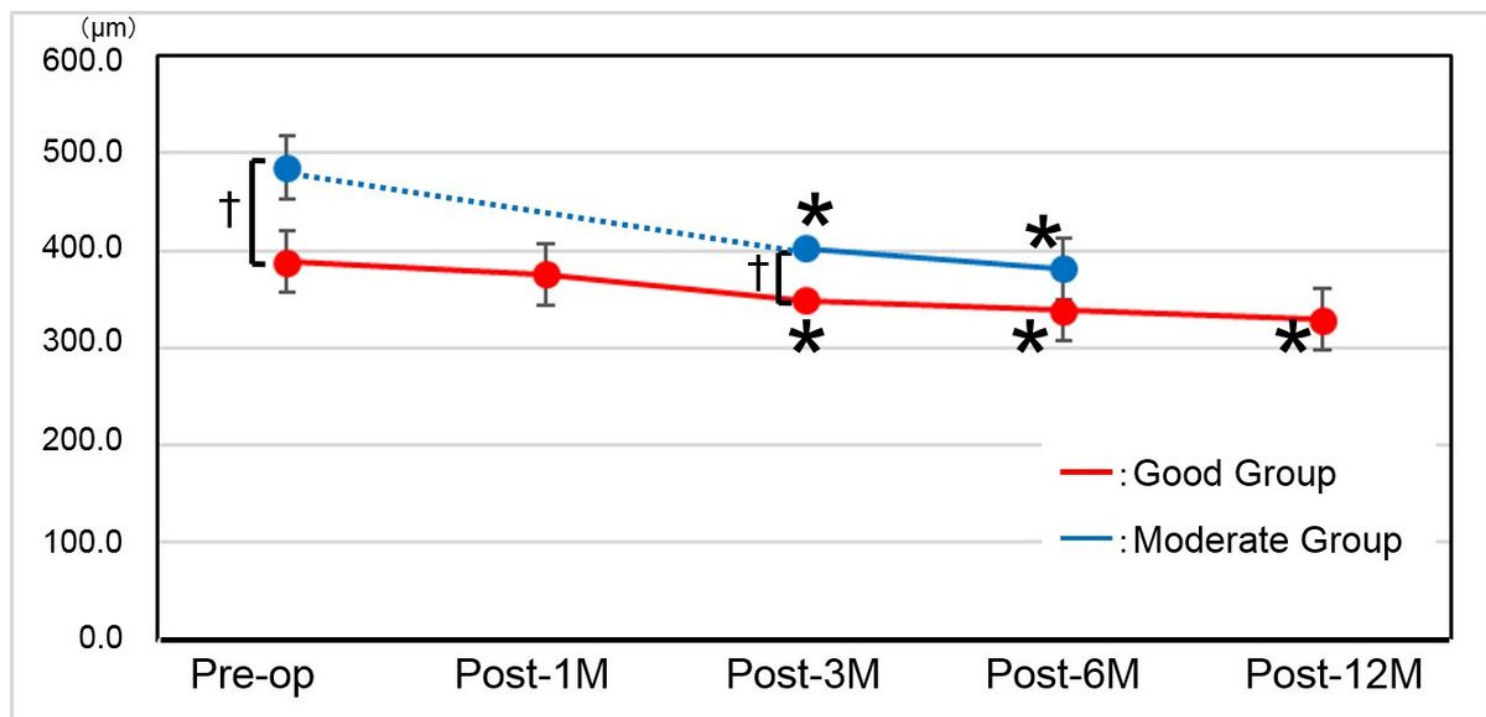
Figure 7

Central foveal thickness Red line: Good group, Blue line: Moderate group. *P < 0.05 compared with preoperative score; †P < 0.05 between groups.
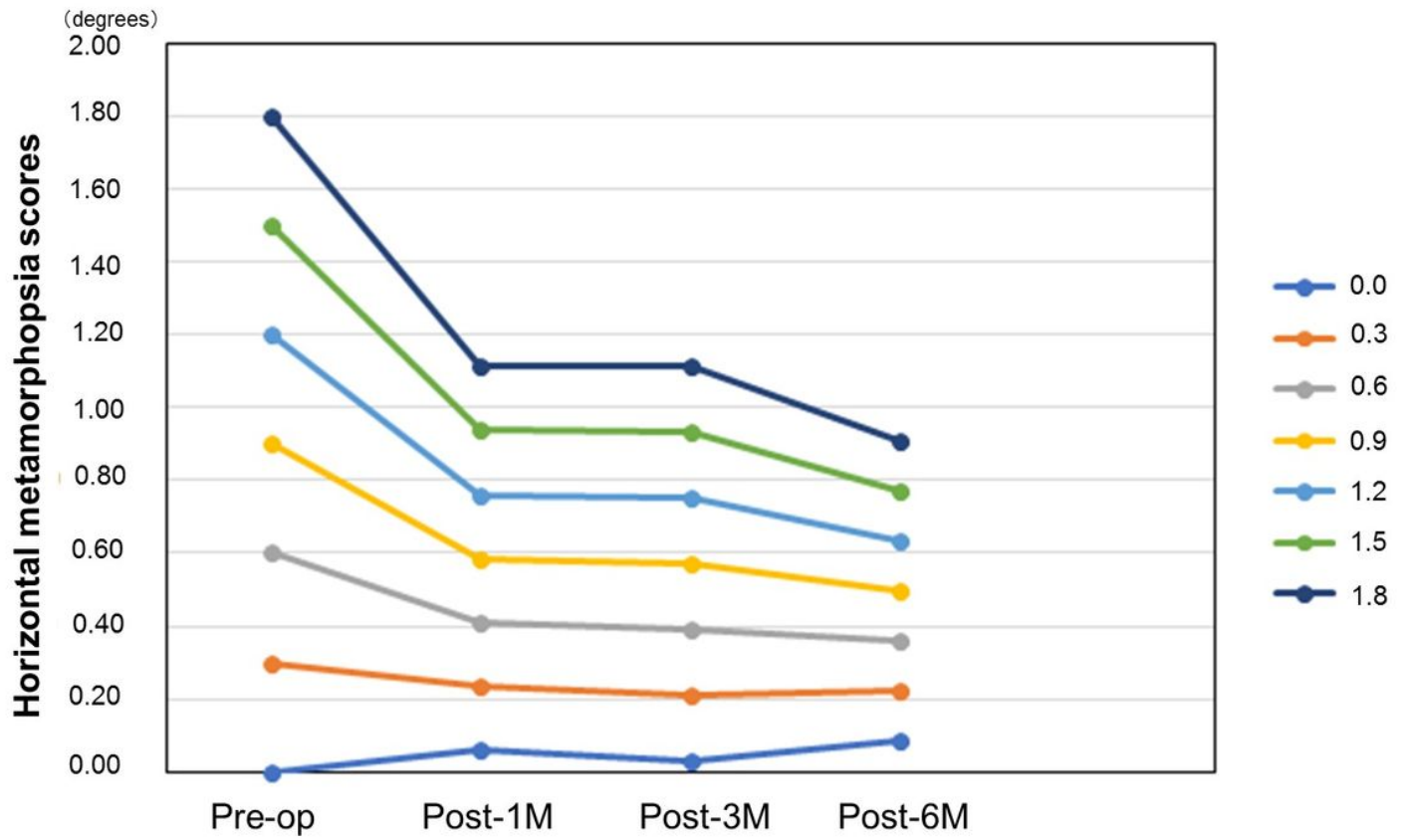
Figure 8

Changes in horizontal metamorphopsia score (using category model) The post-6 M metamorphopsia score expected based on preoperative horizontal metamorphopsia score of 0.9° is 0.4997° (blue line).