Retinal Displacement Toward Optic Disc After Internal Limiting Membrane Peeling for Idiopathic Macular Hole

MASAHIRO ISHIDA, YOSHIKAZU ICHIKAWA, RIEKO HIGASHIDA, YORIHISA TSUTSUMI, ATSUSHI ISHIKAWA, AND YUTAKA IMAMURA

- **PURPOSE:** To examine the retinal displacement following successful macular hole (MH) surgery with internal limiting membrane (ILM) peeling and gas tamponade, and to determine the correlation between the extent of displacement and the basal MH size.
- **DESIGN:** Retrospective, interventional, observational case series.
- **METHODS:** The medical records of consecutive patients with an idiopathic MH that had undergone vitrectomy with ILM peeling and gas tamponade were studied. The distances between the optic disc and the intersection of 2 retinal vessels located nasal or temporal to the fovea were measured manually preoperatively (A), and 2 weeks and 1, 3, 6, and 12 months postoperatively (B), on the fundus autofluorescence or near-infrared images. The basal and minimum diameters of the MHs were measured in the spectral-domain optical coherence tomographic images. The correlations between the ratio of the retinal displacement (A − B/A) and basal diameters of the MHs were determined.
- **RESULTS:** Twenty-one eyes of 21 patients (9 men, mean age: 64.6 ± 8.4 years) were studied. Ten eyes (47.6%) had stage 2 MH, 9 eyes (42.9%) had stage 3 MH, and 2 eyes (9.5%) had stage 4 MH. The temporal retinal vessels were displaced 260.8 ± 145.8 μm toward the optic disc at 2 weeks postoperatively, which was significantly greater than the 91.1 ± 89.7 μm of the nasal retinal vessels (paired t test, P < .001). The ratio of retinal displacement in the temporal field at 2 weeks was significantly correlated with the basal diameter of the MH (Spearman’s rank correlation coefficient = −0.476, P = .033).
- **CONCLUSIONS:** The greater displacement of the temporal retina than the nasal retina toward the optic disc postoperatively suggests that the temporal retina is more flexible and can be retracted toward the optic disc during the MH closure. (Am J Ophthalmol 2014;157:971–977. © 2014 by Elsevier Inc. All rights reserved.)

It is well established that pars plana vitrectomy, internal limiting membrane (ILM) peeling, and gas tamponade will lead to high rates of idiopathic macular hole (MH) closure.1–4 It has been suggested that the release of vitreoretinal traction by ILM peeling allows the flexible retina to retract toward the optic disc.5 The recent findings that pharmacologic vitreolysis can lead to a closure of an MH without surgery supports the idea that the primary cause of MH is vitreomacular traction.6 Analyses of spontaneously or surgically closed MHs suggested that the superficial layers of the sensory retina were the first to reattach during the process of MH closure.7–9 If the retina retracts to compensate for an MH at the fovea, then it is likely that the retina will be displaced after successful MH surgery. The degree of displacement should then depend on the size of the MH and should be larger if the MH is large.

Thus, the purpose of this study was to determine whether the retina is differentially displaced after vitrectomy with internal limiting membrane peeling in eyes with an MH. To accomplish this, we measured the distance between the optic disc and an intersection of blood vessels in the temporal and in the nasal retina preoperatively and postoperatively. We also determined whether the degree of displacement was significantly correlated with the size of the preoperative MH.

**METHODS**

This was a retrospective, interventional, observational case series study. We studied the medical records of 21 consecutive patients who had undergone successful vitrectomy for an idiopathic MH at the Teikyo University School of Medicine, University Hospital Mizonokuchi, from August 4, 2011 to March 14, 2013. The procedures used to treat the patients and the examination of their medical records was approved by the Institutional Review Board of the Teikyo University School of Medicine.

Cases with any ocular complications that could affect visual function, such as diabetic retinopathy, macular degeneration, myopic choriotinal atrophy, rhegmatogenous retinal detachment, cataract >grade III in the Emery-Little scale,10 and corneal diseases, were excluded. An idiopathic MH was diagnosed and classified as reported by Gass.11

Standard 3-port vitrectomy with 23 gauge instruments was performed on 20 eyes and with 25 gauge instruments...
on 1 eye by a single surgeon to repair the MH. After completion of core vitrectomy, a posterior vitreous detachment was created with active aspiration if one was not present. The ILM was peeled by grasping the ILM with vitreoretinal forceps without the use of dyes to make the ILM more visible, except in 1 eye, in which 0.125% indocyanine green was used. The ILM was grasped at the upper right to the fovea within the vascular arcade and peeled to the edge of the vascular arcade (approximately 2 or 3 disc diameters). After air–fluid exchange, 20% sulfur hexafluoride was used for tamponade. Patients were instructed to maintain a face-down position for 1 day and then allowed to assume any body position except a face-up position until the gas disappeared.

Spectral-domain optical coherence tomography (SD OCT, Spectralis; Heidelberg Engineering, Heidelberg, Germany) was used to evaluate the size and shape of the MH preoperatively and postoperatively. The distance between the temporal margin of the optic disc and an intersection of retinal vessels was measured using the caliper function of the SD OCT preoperatively (A) and 2 weeks and 1, 3, 6, and 12 months postoperatively (B). Fundus autofluorescence (FAF, Figure 1) and near-infrared (Figure 2) images were used to measure the distance between the optic disc and the intersection of the retinal vessels. We selected 2 intersections of retinal blood vessels in each eye. One was in the temporal ETDRS subfield and the other was in the nasal ETDRS subfield (Figure 3 left). The basal diameter and minimum diameter of the MH were measured in the SD OCT images (Figure 3 right).

Statistical analyses were performed using Excel (Microsoft, Washington, DC, USA) with add-in statistical software (SSRI, Tokyo, Japan). The descriptive data are presented as the means ± standard deviations. The best-corrected visual acuity (BCVA) was measured with a Landolt C chart in decimal units and then converted to logarithm of the minimal angle of resolution (logMAR) units. Paired t tests were used to determine whether differences over time were significant. The correlations between the MH size and distances of the retinal displacement were determined by Spearman rank correlations. A P value < .05 was considered significant.

RESULTS

THE MEDICAL RECORDS OF 21 EYES OF 21 PATIENTS (9 MEN, mean age, 64.6 ± 8.4 years) with MH were studied. Ten
eyes (47.6%) had stage 2 MH, 9 eyes (42.9%) had stage 3 MH, and 2 eyes (9.5%) had stage 4 MH. The average basal diameter of the MHs was 662.1 ± 238.1 μm with a range of 281–1116 μm. The minimum diameter of the MH was 271.8 ± 111.3 μm with a range of 63–459 μm. The mean postoperative follow-up period was 11.0 ± 5.6 months with a range of 3–19 months. The preoperative refractive error (spherical equivalent) was −1.5 ± 3.0 diopters (D). The clinical demographics of all of the participants are summarized in the Table.

FIGURE 2. Near-infrared images and spectral-domain optical coherence tomographic images of a 49-year-old woman with a macular hole. (Upper left) Near-infrared image showing a macular hole. The distance from the optic nerve to the intersection of temporal vessels and the distance from the optic disc to the intersection of nasal vessels were measured in this image. (Upper right) The temporal and nasal distances were measured 2 weeks postoperatively. The macular hole is closed. (Lower left) Preoperative optical coherence tomographic image. The basal macular hole diameter is 722 μm. (Lower right) Optical coherence tomographic image at 2 weeks after surgery.

FIGURE 3. Identification of intersections of retinal vessels and optical coherence tomographic image used to measure diameter of macular hole. (Left) ETDRS subfield was used to identify nasal and temporal intersections of the retinal blood vessels. (Right) Spectral-domain optical coherence tomography was used to measure basal and minimum sizes of macular hole.
### TABLE. Clinical Characteristics of the 21 Cases of Macular Hole Undergoing Vitrectomy With Internal Limiting Membrane Peeling

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Mean: 64.6 ± 8.4

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<th>DT (µm)</th>
<th>DN (µm)</th>
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**Note:**
- **DN** = distance from the optic nerve to the nasal vessel.
- **DT** = distance from the optic nerve to the temporal vessel.
The average distance from the optic disc to the intersection of the temporal vessels (DT) was 4869.1 ± 412.1 μm preoperatively (21 eyes), and it was 4608.3 ± 432.9 μm at a mean postoperative period of 10.9 ± 2.1 days (range: 8–15 days; 21 eyes), 4618.0 ± 418.2 μm at 1 month (21 eyes), 4596.0 ± 428.9 μm at 3 months (20 eyes), 4556.1 ± 385.7 μm at 6 months (19 eyes), and 4609.0 ± 357.7 μm at 12 months (13 eyes) after the surgery (Figure 4 left).

The mean distance from the optic disc to the intersection of the nasal vessel was 2707.1 ± 388.0 μm preoperatively and 2616.0 ± 389.4 μm at 2 weeks, 2620.6 ± 400.9 μm at 1 month, 2564.6 ± 387.5 μm at 3 months (20 eyes), 2573.5 ± 424.0 μm at 6 months (19 eyes), and 2613.5 ± 490.1 μm at 12 months (13 eyes) after the surgery (Figure 4 right). The distance to the temporal intersection was significantly shorter postoperatively than the preoperative distance at all times (P < .0001 at 2 weeks; P < .0001 at 1 month, P < .0001 at 3 months, P < .0001 at 6 months, and P < .0001 at 12 months; paired t tests).

The postoperative distance to the intersection of the nasal vessels was also significantly shorter than the preoperative distance at all times (paired t tests, P = .0002 at 2 weeks, P = .0014 at 1 month, P = .0002 at 3 months, P = .0006 at 6 months, and P = .0011 at 12 months).

The change of the temporal distance postoperatively was −260.8 ± 145.8 μm with a range of −608 to 69 μm at 2 weeks. The change in the nasal distance at 2 weeks was −91.1 ± 89.7 with a range of −316 to 16 μm, which was significantly less than the change in the temporal distance (P < .001; paired t test). The mean percentage change of the temporal distance was −5.4% ± 3.1% (range −13.0% to +1.4%) and that for the nasal distance was −3.4% ± 3.4% (range −12.3% to +0.6%) at 2 weeks. The percentage change in the distance was significantly less in the nasal retina (P = .0033; paired t test).

The postoperative displacements of the temporal and nasal retinal vessels are drawn schematically in Figure 5.

The distance to a temporal intersection in the fellow eyes without any macular diseases (17 eyes) was 4658.9 ± 387.0 μm at baseline and 4670.1 ± 388.4 μm postoperatively (paired t test; P = .24). The distance to the nasal intersection in the fellow eyes (17 eyes) was 2880.6 ± 455.6 μm at baseline and 2887.2 ± 451.3 μm postoperatively. (P = .37). An MH was found in 2 eyes and an epiretinal membrane was found in 2 of the fellow eyes. These eyes were excluded from the statistical analyses.

The percentage change in the temporal distance at 2 weeks was significantly correlated with the basal diameter of the MH (Spearman’s rank correlation coefficient = −0.476, P = .033); however, it was not significantly correlated with the minimum diameter (Spearman’s rank correlation coefficient = −0.357, P = .111). The percentage change of the nasal distance at 2 weeks was correlated with neither the basal diameter nor the minimum diameter of the MH (Spearman’s rank correlation coefficient = −0.136, P = .542 and rs = 0.171, P = .445, respectively).

The mean best-corrected visual acuity postoperatively was 0.171 ± 0.150 logMAR units, which was a significant improvement over the mean preoperative BCVA of 0.733 ± 0.251 logMAR units (P < .0001). Twenty of the 21 eyes (95.2%) had an improvement of BCVA of ≥0.2 logMAR units postoperatively (Figure 6). One eye (4.8%) had the same BCVA postoperatively.

**DISCUSSION**

OUR RESULTS SHOWED THAT THE RETINA WAS DISPLACED toward the optic disc after pars plana vitrectomy with ILM peeling. The retinal vessels temporal to the fovea...
were displaced significantly more than the nasal vessels. The ratio of the displacement of the temporal vessels was significantly correlated with the maximum size of the preoperative MH.

An epiretinal membrane distorts and displaces the fovea, and the fovea returns to the normal location after removal of the membrane. An epiretinal membrane distorts and displaces the fovea, and the fovea returns to the normal location after removal of the membrane. Retinal displacements are frequently observed after vitrectomy to reattach a detached retina. Thus, Shiragami and associates found that 27 of 43 eyes that had undergone vitrectomy for a rhegmatogenous retinal detachment had an unintentional displacement of the retina in the fundus autofluorescence images. The displacement was more likely to occur if the detachment was large or the macula was detached.

A release of vitreoretinal traction would make the retina retract, and our findings showed that the retinal vessels temporal to the fovea were displaced toward the optic disc more than the nasal vessels. Recently, Yoshikawa and associates reported that the papillofoveal distance in the OCT images was shortened after vitrectomy with ILM peeling in eyes with diabetic macular edema. They reported that eyes in which the ILM was peeled had a shorter papillofoveal distance than those in which ILM was not peeled.

The reason why the retina moved toward the optic disc was not determined. However, it is known that nerve fibers consist mainly of microtubules, and their depolymerization makes the axons shrink. We suggest that one possible explanation for the movement might be that ILM peeling might cause microtubules to depolymerize by some unknown biological causes, or bare retinal nerve fibers might be more likely to be influenced by intravitreal chemical factors and make the nerve fibers around the ILM peeled area shrink. Because the optic nerve fibers are tethered to the lamina cribrosa, the nerve fibers in the retina would move toward the optic disc after shrinkage of the fibers. If ILM peeling promotes the nerve fibers to shrink where the ILM was peeled, this may be one of the reasons why the temporal retinal fibers shrank more than the nasal.

The ILM is the basal lamina of the Müller cells, and permanent damage to part of the Müller cells leads to a loss of structural support of the retina and the retinal nerve fiber layer. This would then make the optic nerve easier to move. Because the retinal structural damages following ILM peeling are more likely in the temporal retina, as revealed by Nukada and associates and Ohta and associates, this may be one of the reasons why the temporal retina shrank more.

The degree of the retinal displacement was significantly correlated with the maximum baseline diameter of the MH. The MH is at the center of macula, and therefore if the MH is large, it allows the temporal retina more space to move. Consequently, the retinal vessels temporal to the fovea would be displaced a greater distance from the optic disc in eyes with larger MHs.

There are limitations in this study. First, this was a retrospective study and there were no controls. In addition, the distances between optic disc and retinal vessels were measured manually. The results shown should be reconfirmed by cases undergoing MH surgery by different surgeons. There has been an earlier study that showed a postoperative displacement of fovea in eyes with an MH; however, that study did not measure the differences of displacement between temporal and nasal vessels or the correlation of displacement with MH size, as were found...
in our study. We are still unable to specify what biological forces made the retina lose its structural supports by ILM peeling, to cause the retina to move toward the optic disc.

In conclusion, we found that the temporal retinas of eyes that have undergone vitrectomy with ILM peeling are displaced toward the optic disc more than the nasal retinas. The retinas with larger MHs move more than those with smaller MHs. Further studies with a larger number of cases and experimental studies would be required to confirm our findings and would help to determine biological explanations for our findings.

REFERENCES