HEMI-TEMPORAL INTERNAL LIMITING MEMBRANE PEELING IS AS EFFECTIVE AND SAFE AS CONVENTIONAL FULL PEELING FOR MACULAR HOLE SURGERY

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Purpose: To investigate the efficacy of hemi-temporal internal limiting membrane (ILM) peeling for idiopathic macular hole.

Methods: The medical records of patients with macular holes who had undergone vitrectomy with ILM peeling were studied. Forty-two eyes with macular hole were divided into 2 groups based on surgical procedure (hemi-temporal ILM peeling [hemi group]: 15 eyes; 360° ILM peeling [360° group]: 27 eyes). The closure rates and distances between the optic disc and the intersection of two retinal vessels most closely located nasally or temporally to the macular hole were compared.

Results: The primary closure rates were not significantly different between the two groups (hemi group: 93.3%; 360° group: 92.5%, $P = 0.92$). The temporal retinal vessels in the hemi group were displaced 120.5 ± 102.0 μm toward the optic disc at 1 week postoperatively, which did not differ significantly from the 360° group (136.1 ± 106.1 μm) ($P = 0.107$). However, the nasal retinal vessels in the hemi group were displaced by 42.4 ± 42.9 μm at 1 week postoperatively, which was significantly less than the 90.1 ± 77.3 μm displacement seen in the 360° group ($P = 0.040$).

Conclusion: Hemi-temporal ILM peeling may be preferable to 360° ILM peeling because of less displacement of the retina and greater safety.

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Kelly and Wendel[1] were the first to report pars plana vitrectomy with the creation of a posterior vitreous detachment and gas tamponade for successful macular hole (MH) closure. Advances in procedures used during vitreous surgery, for example, internal limiting membrane (ILM) peeling, have improved idiopathic MH closure rates.[2–5] Recently, Michalewska et al[6] have

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reported the efficacy of the inverted ILM flap technique for large MHs. Several groups, including ours,[7–11] reported that this procedure is useful for the treatment of intractable MH such as large MH and MH in high myopia, and MH-associated retinal detachment. However, its effectiveness and indications have not yet been clarified in common idiopathic MHs. The inverted ILM flap technique is more technically intricate than ILM peeling. Some reports indicated that the inserted ILM flap might prevent reconstruction of foveal architecture postoperatively in MH-associated retinal detachment cases.[8,10] Ishida et al[12] have recently reported greater postoperative displacement of the temporal compared with the nasal retinal vessels toward the optic disc in patients with idiopathic MH who had undergone vitrectomy with ILM peeling. Yoshizawa et al[13] also found that eyes in which the ILM was peeled had a shorter papillofoveal distance than those in which the ILM was not peeled for the treatment of diabetic

macular edema. These data suggest that the area of the ILM-peeled retina moves toward the optic disc. If so, less displacement of the nasal retina is assumed to lead to better MH closure. We therefore hypothesized that ILM peeling only on the temporal side would be more advantageous for MH closure than conventional total peeling around the MH. The aim of this study was to determine the effectiveness of hemi-temporal ILM peeling and contribution of temporal retina movement toward the optic disc to hole closure in patients with idiopathic MH.

Patients and Methods

This retrospective study protocol was approved by the Institutional Review Board of St. Marianna University Hospital and adhered to the tenets of the Declaration of Helsinki. We reviewed the medical records of consecutive idiopathic MH patients who were treated with pars plana vitrectomy and air tamponade with 360° ILM peeling (360° group) between January 2015 and March 2016 or treated with hemi-temporal ILM peeling (hemi group) between April 2016 and March 2017 at St. Marianna University School of Medicine Hospital. Best-corrected visual acuity was measured using the Landolt C acuity test and converted to a logarithm of the minimal angle of resolution for statistical analysis. The follow-up period was at least 1 month after the final surgery. Exclusion criteria were MH in high myopia (axial length >28 mm), large MH (basal hole diameter >1,000 μm), history of trauma, choroidal neovascularization, presence of a peripheral retinal break or proliferative vitreoretinopathy before the initial surgery, and cases in whom expansive gas, either perfluoropropane (C_3F_8) or sulfur hexafluoride (SF_6), replaced air tamponade during primary surgery.

Standard 25-gauge or 27-gauge pars plana vitrectomy and phacoemulsification with intraocular lens implantation were performed in eyes that had cataracts, and vitrectomy alone was performed in pseudophakic eyes and eyes without cataracts. Triamcinolone acetonide was used intraoperatively to facilitate visualization of the vitreous and posterior hyaloids in all eyes. For better visibility, we stained the ILM with a solution of brilliant blue G, as described by Enaida et al.[14] The areas of ILM peeling were approximately a 2- to 3-disc radius in both groups. In the hemi group, the ILM was first grasped at the temporal raphe and peeled only to the temporal edge of the vascular arcade within 180° (Figure 1). After fluid–air exchange, nonexpansive gas was not used for tamponade in primary surgery. Each patient was asked to maintain a facedown position for 3 days postoperatively.
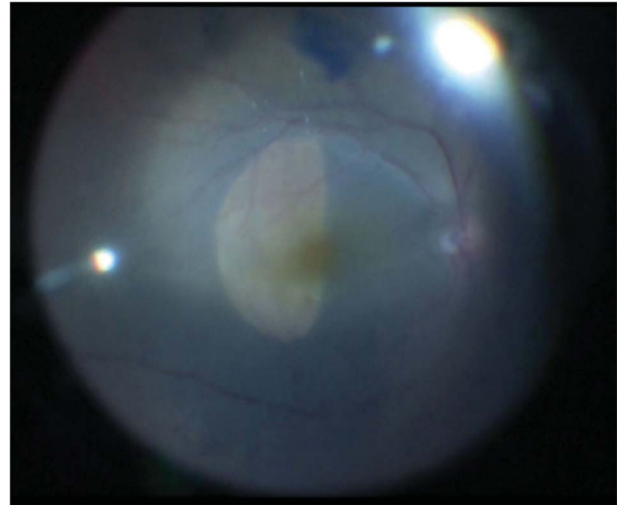

Fig. 1. Surgical video capture shot after peeling the brilliant blue G-stained temporal ILM in the hemi-temporal ILM peeling group.

All procedures were performed by three surgeons (A.S., J.K., H.T.). To evaluate the efficacy of hemi-temporal ILM peeling for idiopathic MH, the patients were divided into 2 groups based on the surgical procedure: hemi-temporal ILM peeling (hemi group) and 360° ILM peeling (360° group). Best-corrected visual acuity, MH closure rates, and displacement were compared between the two groups.

Spectral-domain optical coherence tomography (Cirus HD-OCT; Carl Zeiss Meditec, Dublin, CA) was used to evaluate the size and status of the MH preoperatively and postoperatively. The distance between the temporal margin of the optic disc and intersection of retinal vessels was measured using the caliper function of spectral-domain optical coherence tomography at baseline and 1 week and 1 month postoperatively, as described by Ishida et al.[12] Near-infrared imaging was used to measure the distance between the optic disc and the intersection of the retinal vessels. We selected two intersections of retinal blood vessels in each eye with near-infrared images using the caliper function of the spectral-domain optical coherence tomography apparatus, one in the temporal and the other in the nasal area. The basal diameter and minimum diameter of the MH were measured in the spectral-domain optical coherence tomographic images (Figure 2).

Statistical Analysis

All statistical analyses were performed using IBM SPSS Statistics version 21.0 (IBM Co, Armonk, NY). P values of less than 0.05 were considered to represent statistically significant differences. Data correlations between the two groups were analyzed using the
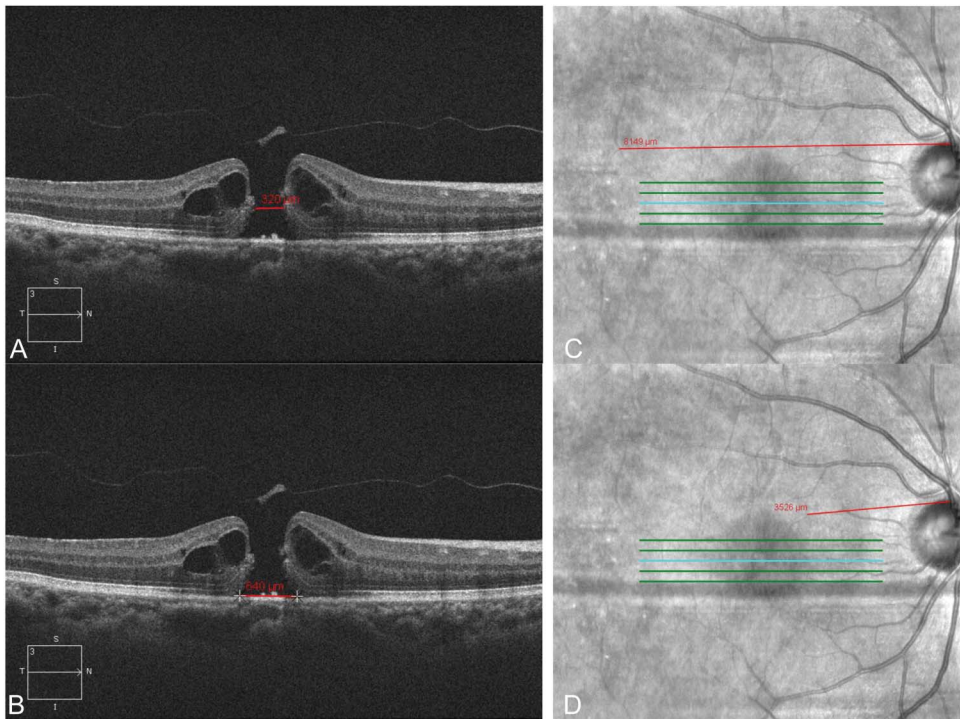
Fig. 2. A and **B.** Spectral-domain optical coherence tomographic images and near-infrared images. The minimum and basal MH diameters were 320 μm and 640 μm, respectively. The distances from the margin of the optic disc to the intersection of temporal vessels (**C**) and to the intersection of nasal vessels (**D**) were measured in near-infrared images.

Mann–Whitney nonparametric test. Closure rates were analyzed using the chi-square test.

Results

The baseline patient characteristics are shown in Table 1. Fifteen of 42 patients underwent hemi-temporal ILM peeling, and 27 patients underwent 360° ILM peeling. The age, duration of symptoms, preoperative best-corrected visual acuity, minimum and basal MH diameters, and axial length did not differ significantly difference between the two groups (all $P > 0.05$). Postoperative ophthalmic data are shown in Table 2. No significant differences were found in postoperative best-corrected visual acuity at 1 month after surgery ($P = 0.76$). The primary MH closure rates were 93.3% (14 of 15 eyes) in the hemi group and 92.5% (25 of 27 eyes) in the 360° group ($P = 0.92$) and thus did not differ significantly. All eyes with unclosed MH underwent secondary vitrectomy with fluid–air exchange followed by 20% SF_6 tamponade

Table 1. Baseline Patient Characteristics

Characteristic	Group		P
	Hemi-temporal ILM Peeling	360° ILM Peeling	
No. of patients	15	27	
Age (y)	61.5 ± 8.1	65.1 ± 5.1	0.140
Gender (M/F)	6/9	16/11	
Duration of symptoms (wks)	12.8 ± 12.6	7.8 ± 7.2	0.110
Preoperative BCVA (logMAR)	0.41 ± 0.18 (19/50 Snellen equivalent)	0.50 ± 0.27 (16/50 Snellen equivalent)	0.680
Minimum MH diameter (μm)	244 ± 94	240 ± 130	0.560
Basal MH diameter (μm)	508 ± 311	578 ± 250	0.680
Axial length (mm)	24.7 ± 1.74	23.7 ± 0.98	0.051
MH stage			
Ib	2	1	
II	5	14	
III	5	11	
IV	3	1	

BCVA, best-corrected visual acuity; F, female; logMAR, logarithm of minimum angle of resolution; M, male.

Table 2. Postoperative Ophthalmic Outcomes

	Group		
Outcome	Hemi-temporal ILM Peeling	360° ILM Peeling	P
Postoperative BCVA (logMAR)	0.14 ± 0.23 (39/50 Snellen equivalent)	0.11 ± 0.17 (36/50 Snellen equivalent)	0.760
Primary MH closure rate at 1 month (%)	93.3	92.5	0.920
Final MH closure rate (%)	100	100	
Migration to OD on nasal side (μm)			
1 week postoperatively	42.4 ± 42.9	90.1 ± 77.3	0.040
1 month postoperatively	55.7 ± 43.0	87.3 ± 83.4	0.107
Migration to OD on temporal side (μm)			
1 week postoperatively	120.5 ± 102.0	136.1 ± 106.1	0.639
1 month postoperatively	148.0 ± 104.2	134.0 ± 99.2	0.714

BCVA, best-corrected visual acuity; logMAR, logarithm of minimum angle of resolution; OD, optic disc.

without additional ILM removal. The final MH closure rates were 100% in both groups. Subsequently, we analyzed 14 eyes in the hemi group and 25 eyes in the 360° group with successful primary MH closure. The migration length to the optic disc on the nasal side at 1 week postoperatively was 42.4 ± 42.9 μm in the hemi group and 90.1 ± 77.3 μm in the 360° group (Table 2). The migration length of the nasal retina at 1 week after surgery in the hemi group was significantly shorter than that in the 360° group ($P = 0.040$) while that of the optic disc to the nasal side at 1 month was 55.7 ± 43.0 μm in the hemi group and 87.3 ± 83.4 μm in the 360° group (Figure 3). At 1 month, there were no significant differences in the lengths between the 2 groups ($P = 0.107$). The migration lengths to the optic disc on the temporal side at 1 week and 1 month after surgery were 120.5 ± 102.0 μm and 148.0 ± 104.2 μm, respectively, in the hemi group, and 136.1 ± 106.1 μm and 134.0 ± 99.2 μm, respectively, in the 360° group. There were thus no significant differences between the two groups ($P = 0.639$ and $P = 0.714$, respectively).
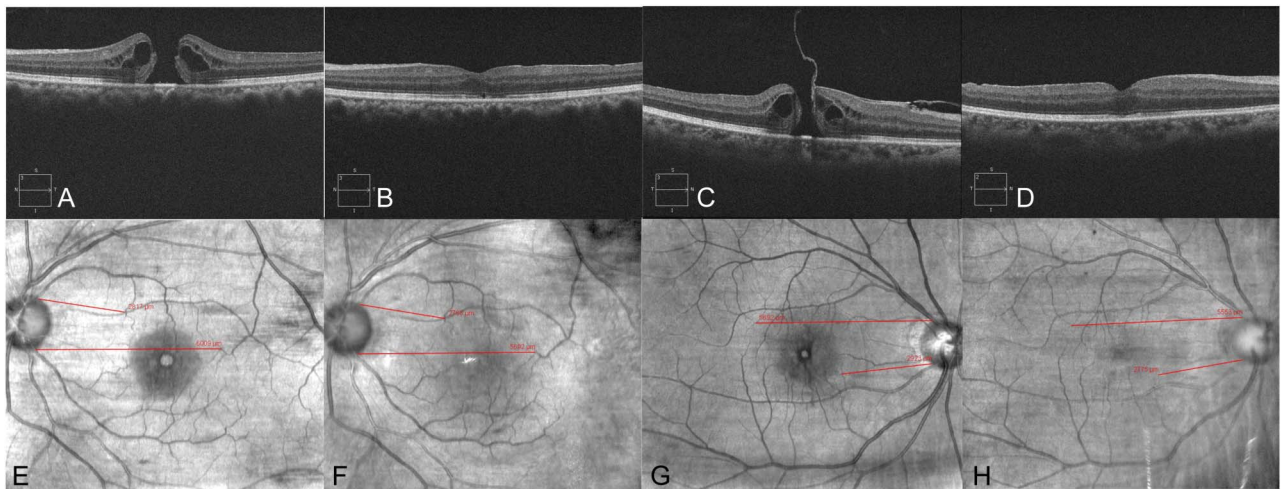

Fig. 3. A, B, E, and F. Spectral-domain optical coherence tomographic images and near-infrared images of a 72-year-old man who underwent hemi-temporal ILM peeling. A. The MH basal diameter was 800 μm before surgery. B. One week after surgery, the MH was closed. E. The distance from the margin of the optic disc to the intersection of temporal vessels and that to the intersection of the nasal vessels were 6,009 μm and 2,817 μm, respectively, at baseline. F. One week after surgery, the distance from the margin of the optic disc to the intersection of temporal vessels and that to the intersection of nasal vessels were 5,692 μm and 2,768 μm, respectively. The displacement of the temporal retina was 317 μm and that of the nasal retina was 49 μm at 1 week. C, D, G, and H. Spectral-domain optical coherence tomographic images and near-infrared images of a 63-year-old woman who underwent 360° ILM peeling. C. The MH basal diameter was 624 μm before surgery. D. One week after surgery, the MH was closed. G. The distance from the margin of the optic disc to the intersection of temporal vessels and that to the intersection of nasal vessels were 5,692 μm and 2,923 μm, respectively, at baseline. H. One week after surgery, the distance from the margin of the optic disc to the intersection of temporal vessels and that to the intersection of nasal vessels were 5,553 μm and 2,775 μm, respectively. The displacement of the temporal retina was 139 μm and that of the nasal retina was 148 μm 1 week postoperatively.

The mean distances from the optic disc to the intersection of nasal vessels were 3,010 ± 706 μm preoperatively, 2,966 ± 710 μm at 1 week, and 2,863 ± 646 μm at 1 month postoperatively in the hemi-group and 3,038 ± 587 μm preoperatively, 2,947 ± 554 μm at 1 week, and 2,951 ± 577 μm at 1 month postoperatively in the 360° group, indicating no significant differences between them at any time point investigated (P = 0.988, P = 0.725, and P = 0.817, respectively). The mean distances from the optic disc to the intersection of temporal vessels were 6,492 ± 1,153 μm before surgery, 6,371 ± 1,122 μm at 1 week, and 6,252 ± 1,101 μm at 1 month after surgery in the hemi group, and 6,052 ± 736 μm before surgery, 5,885 ± 780 μm at 1 week, and 5,918 ± 727 μm at 1 month after surgery in the 360° group. Therefore, no significant differences were found between the two groups at any time point (P = 0.139, P = 0.107, and P = 0.261, respectively).

Discussion

The release of anteroposterior and tangential traction forces on an abnormally persistent vitreofoveal adhesion has been suggested as the mechanism by which MH closure is achieved after vitrectomy with ILM peeling.[15,16] Internal limiting membrane peeling has gained widespread acceptance because it has been shown to improve closure rates, and therefore, most surgeons peel all around the circumference of the holes. In the current study, we demonstrated that hemi-temporal ILM peeling resulted in nearly the same MH closure rate as 360° ILM peeling, with less movement of the nasal retina than that of the temporal retina. This might suggest the substantial role of temporal retina movement in MH closure after vitrectomy with ILM peeling. In addition, hemi-temporal ILM peeling is preferable for safety because it does not involve the central papillomacular bundle during surgery, and it has been shown that central papillomacular bundle damage may affect central visual function and sensitivity.[17]

In this study, the primary MH closure rate was 92.9% (39 of 42 eyes), and the mean minimum MH diameter was 241.7 ± 118.1 μm in the 2 groups. Tadayoni et al[18] reported that ILM peeling might not be necessary for MH <400 mm in diameter. However, they used a long-acting expansive gas (17% C_2F_6) and instructed patients to maintain a facedown position for 10 days postoperatively, which was longer than the 3 days in our study. Using a long-acting expansive gas and longer maintenance of the facedown position might alter the contribution of ILM peeling. Our study

focused on the effect of ILM peeling, and thus, we excluded eyes in patients for whom expansive gas, either C_3F_8 or SF_6, was replaced during primary surgery. Expansive gas is usually used to facilitate MH closure because the interfacial tension of the gas across the hole is thought to prevent trans-hole fluid flow from the vitreous cavity and to reduce transretinal uveal–scleral outflow with reduced macular edema. Another suggested mechanism is that the gas interface acts as a surface to allow glial cell migration to bridge the gap between the retinal edges.[16] In the 1990s, some surgeons used long-acting C_3F_8 and C_2F_6 gas and instructed patients to maintain a prolonged facedown position for more than 1 week to 2 weeks.[19,20] However, that long duration of the facedown position posed a problem in patient discomfort. Which tamponade gas is better for MH closure remains under debate. Comparative studies have shown similar anatomical success rates with either SF_6 versus C_3F_8 and room air tamponade versus SF_6.[21,22]

Displacement of the retina was previously reported in eyes with an MH,[12] an epiretinal membrane,[23,24] and after rhegmatogenous retinal detachment surgery.[25] In this study, we also demonstrated displacement of the macular area around the hole toward the optic disc and found that the migration length to the optic disc was greater in the temporal than in the nasal retina in the 360° group, as previously reported by Ishida et al.[12] The migration lengths to the optic disc on the nasal side at 1 week and 1 month after surgery were 90.1 ± 77.3 μm and 87.3 ± 83.24 μm, respectively, in the 360° group, which is comparable with the data found in the study by Ishida et al (91.1 ± 89.7 μm at 2 weeks after surgery). In contrast, the migration lengths to the optic disc on the temporal side at 1 week and 1 month after surgery were 136.1 ± 106.1 μm and 134.0 ± 99.2 μm, respectively, in the 360° group, which are shorter than the lengths reported by Ishida et al (260.8 ± 145.8 μm at 2 weeks after surgery). In addition, the mean basal diameter of the MHs in the report by Ishida et al was 662.1 ± 238.1 μm, which was greater than the diameter of 578.1 ± 250.1 μm in our study. They found that the ratio of the displacement of the temporal retina was significantly correlated with basal hole diameter, which may be why the migration lengths in our study were shorter than those in the report by Ishida et al.

In nasal retina displacement, we showed that the migration length of the nasal retina at 1 week after surgery in the hemi group (42.4 ± 42.9 μm) was significantly shorter than that in the 360° group (90.1 ± 77.3 μm). These results suggest that removal of the nasal side of the ILM around the MH may accelerate retinal displacement toward the optic disc. Because it

is considered that removal of the ILM releases the tangential traction on the fovea from the temporal side, we suggest that ILM peeling increases the elasticity of the retina, leading to macular displacement. Although the ILM is composed of very thin tissue, its mechanical strength is about 1,000-fold greater than that of other cell layers, and the ILM comprises 50% of retinal rigidity.[26,27] Moreover, the ILM has 5-fold greater rigidity on the retinal compared with the vitreous side.[28] The peeled ILM thus reduces retinal compliance with anchoring at the optic disk. The unpeeled nasal ILM of an MH is therefore more likely to restrict the displacement of the retina toward the optic disc, which may contribute to hole closure. Ohta et al[29] noted thinning of the parafoveal temporal retina and thickening of the nasal retina after vitrectomy with ILM peeling in eyes with a closed MH. Based on the cumulative results, we speculate that the retinal nerve fiber layer may shrink after removal of the overlying ILM because the ILM serves as the basement membrane of the Müller cells.

However, the reason why the parafoveal temporal retina becomes more displaced toward the optic disc than the nasal retina is unknown. Considering that the nerve fibers in the parafoveal temporal retina are longer than those in the nasal retina under natural conditions, and if removal of the ILM caused nerve fibers to shrink in length in the same proportions, the displacement of the temporal retina would be greater than that of the nasal retina. However, this speculation cannot explain the displacement of the nasal retina in the hemi group. The optic nerve fibers are bundled and tethered to the lamina cribrosa.[30] Therefore, when the parafoveal temporal nerve fibers are shrunk with ILM peeling, nasal nerve fibers might be drawn together in the optic disc.

In MH surgery, peeling of the ILM has a success rate ranging from 92% to 97%, whereas pars plana vitrectomy without peeling has success rates of 78% to 89%.[3,31,32] Over the past 15 years, ILM removal during MH surgery has been widely accepted as a technique to improve the MH closure rate.[12] However, hemi-temporal ILM peeling alone may be sufficient for hole closure and, because it creates less displacement of the nasal retina, may have a potential advantage for hole closure without the potential for central papillomacular bundle damage. Hemi-temporal ILM peeling therefore appears to be a useful, safe procedure for idiopathic MH treatment.

Study Limitations

Limitations of this study included the short period of observation, relatively small number of eyes, and the performance of the surgeries by three surgeons, which may have affected the statistical analyses of the results. In addition, the study design was retrospective. Cases of intractable MH such as large MH, MH in high myopia, and MH-associated retinal detachment were excluded because most cases of intractable MH were treated with vitrectomy using the inverted ILM flap technique between January 2015 and March 2017 in our hospital.

It is also difficult to determine whether expansive gas, either SF_6 or C_3F_8, affected the retinal migration in this study. However, we believe that the choice of gas has little effect on the migration when the MH is successfully closed because the main role of tamponade is to stiffen the hole by keeping its edges dry using the surface tension of the gas bubble.[33] Our preliminary data comparing the migration length of eyes with 360° ILM peeling using either room air or SF_6 showed no differences between them (data not shown). We did not quantify metamorphopsia in this cohort and therefore cannot discuss the effect of less retinal displacement on the relief of distortion. Previously, however, it was reported that postoperative retinal displacement is related to postoperative metamorphopsia.[34] Thus, hemi-temporal ILM peeling may result in less postoperative metamorphopsia and improved visual acuity. Further studies are needed to determine the efficacy and safety of hemi-temporal ILM peeling for MH. For this purpose, a randomized prospective study comparing hemi-temporal with 360° ILM peeling in eyes with MH, including large MH, is ongoing in our hospital (UMIN clinical trial registry: 000027810).

In conclusion, we demonstrated that hemi-temporal ILM peeling did not result in a lower closure rate than 360° peeling. Moreover, the migration length of the nasal retina in the hemi group was significantly shorter than that in the 360° group after MH surgery, suggesting a substantial role of the movement of the temporal retina in MH closure.

Key words: macular hole, inner limiting membrane peeling, macular displacement, hemi-temporal ILM peeling.

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