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Microperimetry-guided inverted internal limiting membrane flap site selection to preserve retinal sensitivity in macular hole with glaucoma

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A R T I C L E I N F O

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A B S T R A C T

Purpose: In cases of macular hole (MH) that is difficult to close, including large, chronic, or highly myopic cases, the inverted internal limiting membrane (ILM) flap technique is often preferred and yields favorable surgical outcomes as compared to those yielded by conventional ILM peeling. However, no consensus exists on the optimal location and area for peeling and inverting the ILM, since multiple alternative methods have been reported alongside the original method. Several adverse effects associated with ILM peeling have been documented, including mechanical impairment of the retinal nerve fiber layer and decreased retinal sensitivity. Particularly, when glaucoma is concomitant, the retinal nerve fiber layer is fragile, raising concerns about a decrease in retinal sensitivity. Consequently, in patients with large MH alongside glaucoma, the goal is to select a procedure that maximizes the closure rate of the MH while minimizing any negative impact on glaucomatous visual field impairment. However, a technique for this purpose has not yet been validated.

Observations: A woman in her 60s presented with visual impairment (20/50), metamorphopsia, and central scotoma of unknown onset in the right eye. A full-thickness MH accompanied by epiretinal proliferation (EP) was identified, with a minimum diameter of 506 μm. Although a retinal nerve fiber layer defect was not evident on ophthalmoscopy, thinning of the ganglion cell complex (GCC), extending from the superotemporal aspect of the optic disc, was observed on optical coherence tomography. Both microperimetry and static visual field testing revealed reduced retinal sensitivity in the thinned GCC areas. A pars plana vitrectomy combined with cataract surgery was performed to address her condition. The EP was embedded into the foveal cavity. On the basis of the microperimetry results, the ILM within the absolute scotoma region was peeled on the superotemporal side of the fovea to create a flap, which was then placed over the MH. A gas tamponade was applied, and the patient was maintained in a prone position postoperatively. The MH was successfully closed after the surgery, resulting in visual improvement (20/25). No decline in retinal sensitivity after the surgery was observed.

Conclusions and importance: Determining the location and area of the inverted ILM flap on the basis of microperimetry results is a promising patient-tailored strategy for treating MH concomitant with glaucoma while preventing further ILM peeling-associated reduction in the retinal sensitivity.

1. Introduction

Macular hole (MH) is a condition in which the central foveal retina suffers a full-thickness loss, primarily due to vitreous traction; the standard treatment for MH is vitrectomy.[1,2] In conventional procedures, internal limiting membrane (ILM) peeling and gas tamponade are performed. Conversely, for MH that is difficult to close (such as in large, chronic, or highly myopic cases), the inverted ILM flap technique has often been chosen and yields favorable surgical outcomes as compared to those yielded by conventional ILM peeling.[3–7] In the original method for the inverted ILM flap technique, the ILM around the MH is centripetally peeled and inverted from all sides to cover the MH. Other methods have also been reported, such as the temporal inverted ILM flap technique[8] and the large semicircular ILM flap technique at the upper 180° of the MH,[9] and a consensus has not been reached regarding the most optimal location for and extent of ILM peeling and inversion.

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Since the ILM is the basement membrane of Müller cells, which are normal components of retinal tissue, complications resulting from ILM peeling have been frequently documented. These include mechanical impairment of the retinal nerve fiber layer,[10,11] reduced retinal sensitivity,[12,13] and changes in the electroretinogram.[14,15] Especially in cases of concurrent glaucoma, wherein the retinal nerve fiber layer is fragile, a postoperative decrease in the retinal sensitivity remains a concern.[16–18] Consequently, in patients with a large MH alongside glaucoma, the goal is to select a procedure that maximizes the closure rate of the MH while minimizing any negative impact on glaucomatous visual field impairment. However, a technique for this purpose has not yet been validated.

In this report, we present a case of a large MH concomitant with glaucoma, wherein we created an ILM flap within the scotoma area based on microperimetry results and successfully closed the MH while preserving retinal sensitivity.

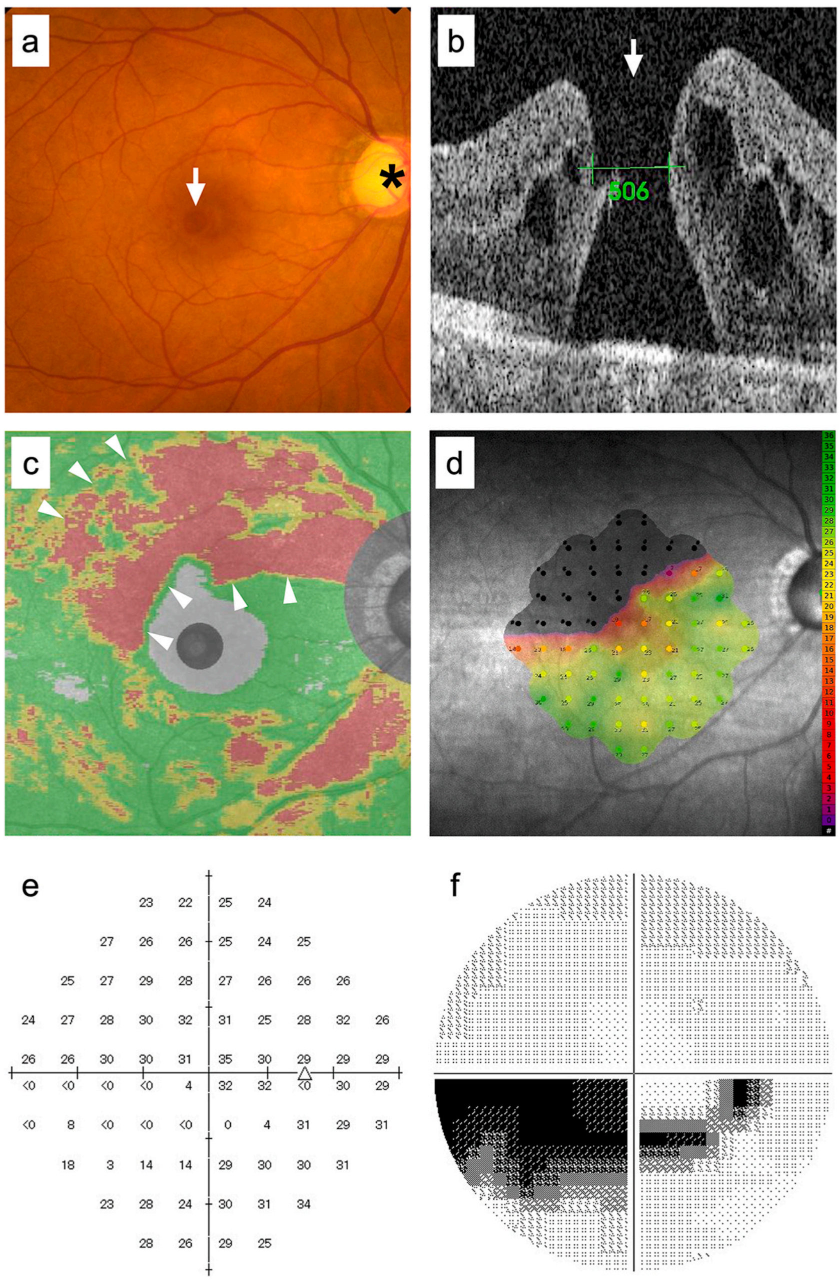

Fig. 1. Color fundus photograph, optical coherence tomography (OCT) B-scan image of the macula, OCT image illustrating the ganglion cell complex (GCC) thickness, microperimetry findings, and automated perimetry findings at the initial visit.

Color fundus photograph showing a macular hole (MH) of approximately one-third the disc diameter (arrow in [a]) and large optic disc cupping (asterisk in [a]). B-scan OCT shows a full-thickness MH (arrow in [b]) with a minimum diameter of 506 μm. Thinning of the GCC extends from the superotemporal aspect of the optic disc (arrowheads in [c]). Microperimetry using a 68-stimuli grid covering the central 10° shows decreased retinal sensitivity, consistent with the area of GCC thinning (d). Retinal sensitivity (dB) at each measurement point (e) and in grayscale (f) in the Humphrey visual field measured using the 30-2 Swedish interactive threshold algorithm; both images show a decrease in retinal sensitivity, consistent with the site of GCC thinning. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

2. Case report

2.1. Presentation, history, and ocular examination

A woman in her 60s was referred to our hospital with visual impairment, metamorphopsia, and central scotoma of unknown onset in the right eye. The patient had a medical history of breast cancer but no ophthalmological history. The best-corrected visual acuity (BCVA) was 20/50 in the right eye and 20/17 in the left eye. The intraocular pressure was 13 mmHg in both eyes. Slit-lamp examination of the anterior segments revealed mild cataract in both eyes. Fundus examination revealed an enlarged vertical cup-to-disc ratio of 0.9 in both eyes and an MH measuring approximately one-third of the disc diameter in the right eye (Fig. 1a). Using OA-2000 (Tomey, Nagoya, Japan), the axial lengths of the right and left eyes were determined to be 26.05 and 26.18 mm, respectively.

2.2. Optical coherence tomography, microperimetry, and automated perimetry findings

Optical coherence tomography (OCT) examinations comprised the use of swept-source OCT (DRI OCT Triton; Topcon Corporation, Tokyo, Japan) and spectral-domain OCT (RS-3000; Nidek Corporation, Tokyo, Japan). A full-thickness MH with epiretinal proliferation (EP) was observed, and its horizontal minimum diameter was determined to be 506 μm (Fig. 1b). Additionally, thinning of the ganglion cell complex (GCC) extending from the superotemporal aspect of the optic disc was observed in both eyes (Fig. 1c). Microperimetry using a 68-stimuli grid covering the central 10° (MAIA; CenterVue, Padova, Italy) revealed average retinal sensitivities of 16.3 and 20.4 dB in the right and left eyes, respectively (Fig. 1d). Static visual field testing, performed using the 30-2 Swedish interactive threshold algorithm in the Humphrey Field Analyzer II (Carl Zeiss Meditec Inc., Dublin, CA, USA), revealed mean deviation values of −8.45 and −7.89 dB in the right and left eyes, respectively (Fig. 1e and f). In both assessments, reduced retinal sensitivity was evident in areas corresponding to the thinning of the GCC (Fig. 1d–f).

2.3. Surgical procedure

Phacoemulsification, intraocular lens implantation, and 25-gauge pars plana vitrectomy were performed. Following the surgical principles of lamellar MH repair, the EP was peeled centripetally toward the fovea using forceps (GRIESHABER REVOLUTION DSP MAXGRIP Forceps; Alcon Grieshaber AG., Schaffhausen, Switzerland) and gently embedded within the central foveal cavity (Fig. 2a).[19–21] Subsequently, after staining the retinal surface with Brilliant Blue G (0.25 mg/mL; Sigma-Aldrich, MO, USA), the absolute scotoma region (i.e., the area with retinal sensitivity <0 dB) was identified based on microperimetry results and the retinal vascular patterns. The ILM within the region was peeled off to create a flap (Fig. 2b), which was then inverted and placed over the MH (Fig. 2c and d). Ophthalmic viscosurgical devices were applied to the inverted ILM flap to stabilize it, followed by fluid-air exchange and a 20% SF6 gas tamponade. The patient was placed in the prone position for 3 days after surgery.

2.4. Postoperative course

After the surgery, the MH was successfully closed (Fig. 3a–l). At the 9-month postoperative follow-up, the BCVA had improved to 20/25, and

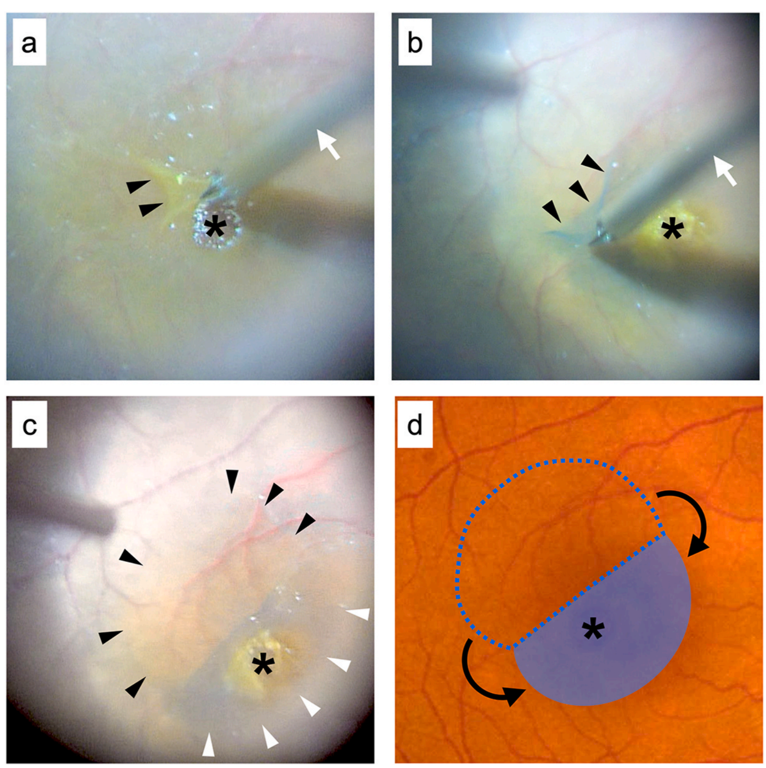

Fig. 2. Intraoperative photographs and schematic diagram of the extent of inverted internal limiting membrane (ILM) flap.
Epiretinal proliferation (EP; arrowheads in [a]) is grasped with forceps (arrow in [a]) and centripetally peeled toward the macular hole (MH; asterisk in [a]). The ILM (arrowheads in [b]) stained with Brilliant Blue G is grasped with forceps (arrow in [b]) and peeled toward the MH with the EP embedded (asterisk in [b]). Black arrowheads in (c) show the ILM-peeled area, and white arrowheads in (c) show the inverted ILM that completely covers the EP-embedded MH (asterisk in [c]). A preoperative color fundus photograph overlaid with schematic images showing the ILM-peeled (dotted area in [d]) and ILM-inverted (blue area in [d]) areas, indicating that the MH (asterisk in [d]) is completely covered by the inverted ILM. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

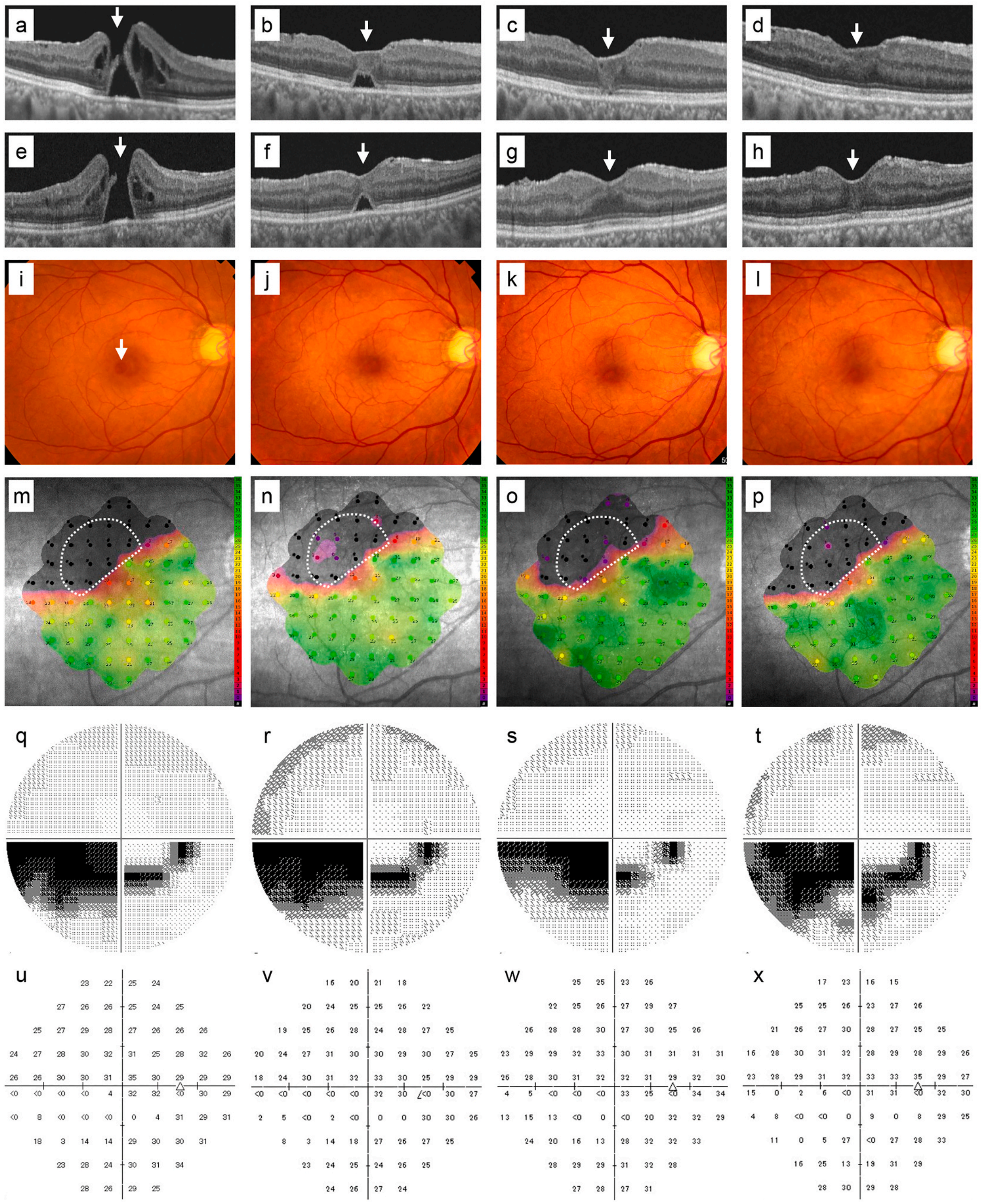

Fig. 3. Preoperative and postoperative optical coherence tomography (OCT) B-scan images, color fundus photographs, microperimetry results, and automated perimetry results.

Horizontal OCT images (a–d), vertical OCT images (e–h), color fundus photographs (i–l), findings of microperimetry performed using a 68-stimuli grid covering the central 10° (m–p), and grayscale (q–t) and retinal sensitivity (u–x) images of Humphrey visual field measured using the 30-2 Swedish interactive threshold algorithm preoperatively (a, e, i, m, q, and u) and at 1 month (b, f, j, n, r, and v), 3 months (c, g, k, o, s, and w), and 9 months (d, h, l, p, t, and x) after he surgery are shown. The dotted areas in microperimetry (m–p) indicate the internal limiting membrane (ILM)-peeled area. Preoperative OCT revealed a full-thickness macular hole (MH; arrows in [a] and [e]). The inner layer of the MH closed 1 month postoperatively (arrows in [b] and [f]), and the MH was completely closed at 3 and 6 months postoperatively (arrows in [c], [d], [g], and [h]). Color fundus photographs showing the MH preoperatively (arrow in [i]) and no MH at 1, 3, and 9 months postoperatively (j–l). Microperimetry shows no obvious change in the retinal sensitivity, inside or outside the ILM-peeled area, from before the surgery (m) to 1, 3, and 9 months after the surgery (n–p). Automated perimetry also shows no apparent changes from before the surgery (q and u) to 1, 3, and 9 months after the surgery (r–t and v–x). (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

microperimetry revealed an average retinal sensitivity of 18.0 dB (Fig. 3m–p). Static visual field testing revealed a mean deviation value of −9.13 dB (Fig. 3q–x). A comparison of retinal sensitivity for 47 points, excluding 21 points that were absolute scotomas at the initial presentation, was performed before and after the surgery. Since the decibel values were on a log scale, they were transformed to 1/Lambert (1/L) values ($1/L = 10^{dB/10}$) on a linear scale in accordance with previous reports for averaging and statistical analysis.[16,22–24] Thus, compared to the preoperative mean 1/L value (382.84 ± 275.26), the mean 1/L values at all postoperative time points, i.e., 1 month (481.19 ± 260.26, $P = 0.015$, paired-t test), 3 months (726.82 ± 795.21, $P = 0.0024$, paired-t test), and 9 months (633.70 ± 586.99, $P = 0.012$, paired-t test), were significantly higher (Fig. 4).

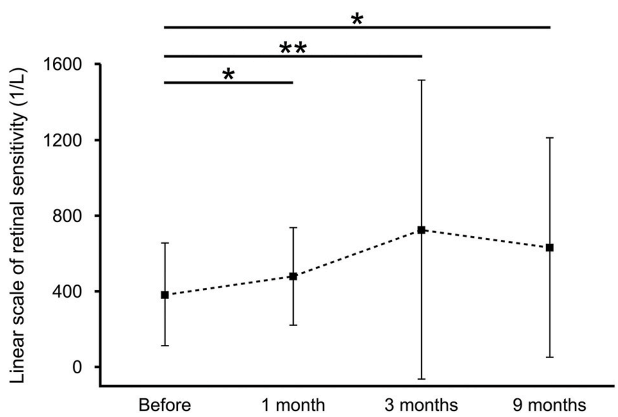

Fig. 4. Changes in the retinal sensitivity measured by microperimetry preoperatively and postoperatively. Twenty-one points that were absolute scotomas in microperimetry performed using a 68-stimuli grid covering the central 10° at the initial visit were excluded. The log values of retinal sensitivity at each of the remaining 47 measurement points were converted to linear 1/Lambert (1/L) values ($1/L = 10^{dB/10}$). The graph shows the changes in the mean 1/L values from before the surgery to 1, 3, and 9 months after the surgery. *, $P < 0.05$; **, $P < 0.01$.

3. Discussion

Through the present case, we have demonstrated the potential effectiveness of microperimetry-based inverted ILM flap technique for closing large MH concomitant with glaucoma while preserving retinal sensitivity. The presented case exhibited challenging characteristics of MH, with a minimum diameter exceeding 500 μm and an axial length of over 26 mm; these factors make MH closure difficult.[7] Although the inverted ILM technique has proven beneficial for MH that is difficult to close, the present case was complicated by glaucoma, which necessitated the mitigation of potential glaucomatous visual field worsening caused by ILM peeling.[16–18] To address this challenge, microperimetry was performed to identify the region surrounding the MH that was already an absolute scotoma; thereafter, only the ILM within the region was peeled and inverted. Consequently, successful closure of the MH and visual improvement were achieved while preserving retinal sensitivity. In fact, a mild but significant increase in the retinal sensitivity was noted postoperatively; this could be attributed to the effect of the simultaneous cataract surgery or to the increased central sensitivity secondary to MH closure. Therefore, the microperimetry-based technique presented in this report holds promise as an approach that can be tailored to individual patients, offering the potential to close large MH while minimizing any negative impact on glaucoma-related visual field impairments.

This single-case study has several limitations. First, the relatively short postoperative observation period limited the assessment of the long-term progression of glaucoma and the potential late complications of the inverted ILM technique (such as epiretinal membrane formation). Second, simultaneous cataract surgery and EP embedding in this case made assessment of the exclusive impact of the inverted ILM flap method on MH closure and retinal sensitivity changes complex. Third, the ILM within the absolute scotoma region, which extended superior to the MH, was peeled and inverted in this case. However, the efficacy of this procedure in various situations remains unclear, such as when the absolute scotoma region exists inferior to the MH, when the retinal sensitivity is reduced (although not to <0 dB), or when the extent of the scotoma is distant from the MH. Fourth, microperimetry may not always be necessary in eyes with advanced glaucoma with extensive areas of visual field impairment; in such cases, the appropriate ILM peeling site can be determined by visual field testing alone. Fifth, microperimetry has a narrower dynamic range of stimulation and is unable to detect very low retinal sensitivity; damage to the retina may exist even in areas showing a retinal sensitivity of 0 dB in any perimetric tests.

4. Conclusions

In conclusion, this study suggests that the personalized selection of the inverted ILM flap site on the basis of microperimetry results could be a useful approach for closing large MH concomitant with glaucoma while preventing further ILM peeling-associated reduction in the retinal sensitivity. Large-scale prospective studies are required to validate the practical utility of this promising patient-tailored treatment strategy.

Patient consent

The patient consented to publication of the case in writing.

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Authorship

All authors attest that they meet the current ICMJE criteria for authorship.

CRediT authorship contribution statement

Ryo Matoba: Conceptualization, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. **Yuki Kanzaki:** Formal analysis, Writing – review & editing. **Tetsuro Morita:** Formal analysis, Writing – review & editing. **Shuhei Kimura:** Data curation, Investigation, Writing – review & editing. **Mio M. Hosokawa:** Data curation, Investigation, Writing – review & editing. **Yusuke Shiode:** Data curation, Investigation, Writing – review & editing. **Yuki Morizane:** Supervision, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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