

Temporal Inverted Internal Limiting Membrane Flap Technique versus Conventional Internal Limiting Membrane Peeling Technique for Large Macular Holes: A Retrospective Comparative Study

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Research Article

Keywords: macular hole, temporal inverted ILM flap, conventional ILM peeling, ellipsoid zone, external limiting membrane, optical coherence tomography

Posted Date: July 7th, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-9931089/v1>

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Additional Declarations: No competing interests reported.

Version of Record: A version of this preprint was published at BMC Ophthalmology on August 12th, 2026. See the published version at <https://doi.org/10.1186/s12886-026-05228-3>.

Abstract

Background

Full-thickness macular holes (FTMHs) larger than 400 μm remain a surgical challenge with suboptimal closure rates when treated with conventional internal limiting membrane (ILM) peeling. The temporal inverted ILM flap technique has emerged as a promising alternative, yet direct comparisons—particularly regarding hole-size-specific outcomes and outer retinal microstructural recovery—remain scarce. This study aimed to compare the functional, anatomical, and morphological outcomes of these two surgical approaches.

Methods

This retrospective study included 32 patients with large idiopathic FTMHs ($> 400 \mu\text{m}$) who underwent surgery between 2020 and 2024. Patients were divided into two groups: conventional ILM peeling (Group 1, $n = 16$) and temporal inverted ILM flap technique (Group 2, $n = 16$). All procedures were performed by a single experienced surgeon. Best-corrected visual acuity (BCVA), MH closure rate, closure configuration, macular hole index (MHI), and outer retinal layer parameters including ellipsoid zone (EZ) and external limiting membrane (ELM) integrity were assessed using spectral-domain optical coherence tomography (SD-OCT) at baseline and 12 months postoperatively.

Results

Baseline characteristics were comparable between groups (all $p > 0.05$). Both groups showed significant postoperative BCVA improvement ($p < 0.05$). At 12 months, BCVA was significantly better in Group 2 (0.38 ± 0.32 vs. 0.71 ± 0.46 logMAR, $p = 0.039$). Overall primary closure rates were 100% vs. 75.0% ($p = 0.101$). Subgroup analysis by hole size revealed that in eyes with minimum MH diameter $\geq 550 \mu\text{m}$, the closure rate was significantly higher in Group 2 (100%, 8/8) compared with Group 1 (33.3%, 2/6; $p = 0.015$); both groups achieved 100% closure in holes of 400–549 μm . Postoperative EZ defect size was significantly smaller in Group 2 (539.12 ± 618.09 vs. $1028.62 \pm 606.93 \mu\text{m}$, $p = 0.039$), with approximately twice the degree of outer retinal layer recovery.

Conclusions

The temporal inverted ILM flap technique was associated with superior BCVA, better outer retinal layer recovery, and significantly higher closure rates in eyes with minimum MH diameter $\geq 550 \mu\text{m}$. These findings suggest it should be the preferred surgical approach for very large macular holes.

Trial registration

Not applicable (retrospective study).

Background

Full-thickness macular hole (FTMH) is characterized by a tissue defect extending from the internal limiting membrane (ILM) to the photoreceptor layer at the fovea [1, 2]. This condition frequently results in significant central vision loss, central scotoma, metamorphopsia, and other visual disturbances [3].

The International Vitreomacular Traction Study Group has established a size-based classification system for macular holes (MHs) using the minimum hole diameter: small ($\leq 250 \mu\text{m}$), medium ($251\text{--}400 \mu\text{m}$), and large ($> 400 \mu\text{m}$) [4].

Pars plana vitrectomy for MH repair was first described by Kelly and Wendel in 1991 [5]. The conventional ILM peeling technique has been reported to achieve closure rates of 80%–100% [6, 7]. Nevertheless, outcomes are closely linked to hole size, with minimum linear diameters exceeding 400–500 μm exhibiting lower closure rates [8, 9]. The temporal inverted ILM flap technique (IFT), originally described by Michalewska et al. [10, 11], has demonstrated higher closure rates in larger MHs compared with conventional ILM peeling.

Spectral-domain optical coherence tomography (SD-OCT) has enhanced postoperative assessment by providing detailed visualization of photoreceptor integrity, with restoration of the EZ and ELM closely associated with improved visual outcomes [12–14]. Only a limited number of studies have directly compared conventional ILM peeling and the temporal inverted ILM flap technique with respect to outer retinal microstructural recovery. The present study aimed to compare these two surgical approaches in the primary treatment of large idiopathic MHs.

Methods

Study design and participants

This retrospective comparative study included patients who underwent surgery for large idiopathic MH ($> 400 \mu\text{m}$) at our institution between 2020 and 2024. Patients were allocated to two groups based on the surgical technique performed: conventional ILM peeling (Group 1, $n = 16$) and temporal inverted ILM flap technique (Group 2, $n = 16$). The study was approved by the institutional clinical research ethics committee (Selçuk University Medical Faculty, 2024/502) and conducted in accordance with the principles of the 1964 Declaration of Helsinki. Written informed consent was obtained from all participants.

Inclusion criteria were: age ≥ 18 years, minimum MH diameter $> 400 \mu\text{m}$, and minimum postoperative follow-up of 12 months. Exclusion criteria included recurrent, traumatic, or myopic MH; coexisting retinal diseases other than MH; any ocular comorbidity potentially affecting visual outcomes; and prior retinal surgery.

Clinical assessment

All patients underwent comprehensive ophthalmological examination at baseline and at 12 months postoperatively, including BCVA measurement, slit-lamp biomicroscopy, posterior segment evaluation with a 90-diopter non-contact lens, and SD-OCT (Heidelberg Engineering, Heidelberg, Germany). BCVA was measured using a Snellen chart and converted to the logarithm of the minimum angle of resolution (logMAR) for statistical analysis. Minimum and base MH diameters, MHI (calculated as minimum/base diameter ratio), closure configuration, and preoperative and postoperative EZ and ELM defect sizes were assessed using SD-OCT.

Surgical techniques

All procedures were performed by a single experienced surgeon using a standard 25-gauge pars plana vitrectomy system (Constellation Vision System, Alcon Laboratories, Fort Worth, TX, USA). Following core and cortical vitreous removal, the ILM was stained with membrane blue dye and any epiretinal membrane was peeled if present.

In Group 1, conventional ILM peeling was performed in a circular fashion approximately two disc diameters around the MH.

In Group 2, the temporal inverted ILM flap technique was performed as follows. After ILM staining, peeling was initiated approximately two disc diameters temporal to the MH. The ILM was carefully dissected in a temporal-to-nasal direction, creating a flap that remained attached at the temporal edge of the MH. The flap was then inverted and folded over the MH to cover it completely, with the inner surface of the ILM facing the hole. Fluid–air exchange was subsequently performed to stabilize the flap without the use of perfluorocarbon liquid or ophthalmic viscoelastic devices.

All eyes received 14% octafluoropropane (C₃F₈) gas tamponade at the conclusion of surgery. Patients were instructed to maintain a face-down (prone) position for 5 days postoperatively.

Statistical analysis

Statistical analyses were performed using SPSS version 21.0 (SPSS Inc., Chicago, IL, USA). Continuous variables are expressed as mean $\pm$ standard deviation or median (interquartile range). Normality was assessed using the Kolmogorov–Smirnov test. Between-group comparisons of normally distributed data used the independent samples t-test; non-normally distributed data were compared using the Mann–Whitney U test. Categorical variables were compared using the chi-square test or Fisher's exact test. A p-value of < 0.05 was considered statistically significant.

Use of artificial intelligence

Artificial intelligence (AI) language tools were used during the preparation of this manuscript solely for language editing and grammar checking purposes. All scientific content, data analysis, interpretation, and conclusions are the sole responsibility of the authors.

Results

Baseline characteristics

A total of 32 patients were included, with 16 in each group. Baseline demographic and clinical characteristics were comparable between groups (all $p > 0.05$) and are summarized in Table 1. Mean age was 69.25 ± 5.50 years in Group 1 and 67.62 ± 6.37 years in Group 2 ($p = 0.447$). No significant between-group differences were observed in sex distribution, preoperative BCVA, lens status, MH diameters, ELM and EZ defect sizes, or MHI.

Table 1
Baseline demographic and clinical characteristics of the study groups.

Age, mean $\pm$ SD, years	Conventional ILM Peeling (Group 1)	Temporal Inverted ILM Flap (Group 2)	P value
	69.25 $\pm$ 5.50	67.62 $\pm$ 6.37	0.447
Sex (female/male), n (%)	9 (56.3%)/7 (43.7%)	11 (68.8%)/5 (31.2%)	0.465
Preoperative BCVA, mean $\pm$ SD (logMAR)	1.24 $\pm$ 0.53	1.16 $\pm$ 0.46	0.809
Lens status, Phakic/Pseudophakic, n (%)	10 (62.5%)/6 (37.5%)	13 (81.25%)/3 (18.75%)	0.433
Minimum FTMH diameter, mean $\pm$ SD (range), μ m	514.00 $\pm$ 104.91 (402–765)	560.00 $\pm$ 120.42 (415–830)	0.259
Base FTMH diameter, mean $\pm$ SD (range), μ m	1130.87 $\pm$ 308.46 (640–1725)	1114.25 $\pm$ 394.13 (511–2019)	0.895
Preoperative ELM defect size, mean $\pm$ SD (range), μ m	1418.37 $\pm$ 380.14 (898–2194)	1496.00 $\pm$ 522.85 (714–2350)	0.635
Preoperative EZ defect size, mean $\pm$ SD (range), μ m	1480.75 $\pm$ 563.50 (841–3187)	1502.31 $\pm$ 554.71 (778–2900)	0.985
Macular hole index (MHI), mean $\pm$ SD	0.475 $\pm$ 0.106	0.538 $\pm$ 0.129	0.144

BCVA: best-corrected visual acuity; ELM: external limiting membrane; EZ: ellipsoid zone; FTMH: full-thickness macular hole; MHI: macular hole index; SD: standard deviation.

Visual acuity outcomes

Mean BCVA improved from 1.24 to 0.71 logMAR in Group 1 and from 1.16 to 0.38 logMAR in Group 2 following surgery ($p < 0.05$ within each group). At 12 months, postoperative BCVA was significantly better in Group 2 compared with Group 1 (0.38 ± 0.32 vs. 0.71 ± 0.46 logMAR, $p = 0.039$). Postoperative outcomes are presented in Table 2.

Table 2
Postoperative visual acuity and macular hole closure outcomes at 12 months.

Postoperative BCVA, mean $\pm$ SD (logMAR)	Conventional ILM Peeling (Group 1)	Temporal Inverted ILM Flap (Group 2)	P value
	0.71 ± 0.46	0.38 ± 0.32	0.039*
Primary MH closure rate, n (%)	12/16 (75.0%)	16/16 (100%)	0.101
U-shaped closure, n (%)	11/16 (91.7%)	14/16 (87.5%)	0.999
V-shaped closure, n (%)	0/16 (–)	0/16 (–)	–
W-shaped closure, n (%)	1/16 (8.3%)	2/16 (12.5%)	–

BCVA: best-corrected visual acuity; MH: macular hole. *Statistically significant ($p < 0.05$).

Macular hole closure rates and closure configuration

The primary MH closure rate was 100% in Group 2 and 75.0% in Group 1 ($p = 0.101$). U-shaped closure was the most common configuration in both groups (91.7% in Group 1 and 87.5% in Group 2). No V-shaped closures were observed; W-shaped closure was detected in 8.3% of Group 1 and 12.5% of Group 2 eyes.

Subgroup analysis stratified by minimum hole diameter revealed that in eyes with minimum MH diameter $\geq 550 \mu\text{m}$, the closure rate was significantly higher in Group 2 (100%, 8/8) compared with Group 1 (33.3%, 2/6; $p = 0.015$, Fisher's exact test). Both groups achieved 100% closure in holes of 400–549 μm ($p = 1.000$). Subgroup data are presented in Table 3.

Table 3
Subgroup analysis of primary macular hole closure rate by minimum hole diameter.

Minimum MH Diameter	n (Group 1 / Group 2)	Closure Rate Group 1, n (%)	Closure Rate Group 2, n (%)	P value
400–549 μm	10 / 8	10/10 (100.0%)	8/8 (100.0%)	1.000
$\geq 550 \mu\text{m}$	6 / 8	2/6 (33.3%)	8/8 (100.0%)	0.015*
Total (> 400 μm)	16 / 16	12/16 (75.0%)	16/16 (100.0%)	0.101

MH: macular hole. P values calculated using Fisher's exact test. *Statistically significant ($p < 0.05$).

Outer retinal layer recovery

Mean preoperative ELM and EZ defect sizes were significantly reduced postoperatively in both groups. The mean reduction in ELM defect size was 645.8 μm in Group 1 and 1224.1 μm in Group 2; EZ defect reduction was 452.1 μm and 963.2 μm , respectively, representing approximately twice the degree of outer retinal layer recovery in Group 2. Postoperative EZ defect size was significantly smaller in Group 2 (539.12 $\pm$ 618.09 vs. 1028.62 $\pm$ 606.93 μm , $p = 0.039$). Although postoperative ELM defect size was also smaller in Group 2 (271.87 $\pm$ 495.84 vs. 772.56 $\pm$ 732.74 μm), this difference did not reach statistical significance ($p = 0.073$). Complete ELM restoration was observed in 62.5% of Group 2 and 37.5% of Group 1 eyes ($p = 0.157$). Complete EZ restoration was more frequent in Group 2 (18.8% vs. 6.3%; $p = 0.600$). Outer retinal layer parameters are summarized in Table 4. Representative SD-OCT images are shown in Figs. 1 and 2.

Table 4
Postoperative outer retinal layer parameters at 12 months.

Postoperative ELM defect size, mean $\pm$ SD, μm	Conventional ILM Peeling (Group 1)	Temporal Inverted ILM Flap (Group 2)	P value
	772.56 $\pm$ 732.74	271.87 $\pm$ 495.84	0.073
Postoperative EZ defect size, mean $\pm$ SD, μm	1028.62 $\pm$ 606.93	539.12 $\pm$ 618.09	0.039*
Complete ELM restoration, n (%)	6/16 (37.5%)	10/16 (62.5%)	0.157
Complete EZ restoration, n (%)	1/16 (6.3%)	3/16 (18.8%)	0.600

ELM: external limiting membrane; EZ: ellipsoid zone; SD: standard deviation. *Statistically significant ($p < 0.05$).

Discussion

In the present study, we evaluated the anatomical, morphological, and functional outcomes of conventional ILM peeling and the temporal inverted ILM flap technique in the management of large macular holes ($> 400 \mu\text{m}$). Both techniques resulted in significant postoperative visual improvement; however, the temporal inverted ILM flap technique was associated with superior functional outcomes, evidenced by significantly better BCVA at 12 months, a significantly higher closure rate in holes $\geq 550 \mu\text{m}$, and approximately twice the degree of outer retinal layer recovery.

The most striking finding of the present study was the subgroup analysis stratified by hole size. In eyes with minimum MH diameter $\geq 550 \mu\text{m}$, the closure rate was 100% in Group 2 compared with only 33.3% in Group 1 ($p = 0.015$), while both techniques achieved 100% closure in holes of 400–549 μm . This identifies a clinically meaningful size threshold above which the flap technique offers a decisive advantage. These findings are corroborated by large-scale studies; Jin et al. [15], in a registry-based analysis of 2,990 eyes, reported that closure rates declined markedly in holes $> 550 \mu\text{m}$ with conventional ILM peeling, while ILM flap techniques maintained high rates across all hole sizes (OR = 2.97, $p = 0.04$).

The superior closure rates with the temporal inverted ILM flap technique may be attributed to biological and mechanical mechanisms. The inverted ILM flap acts as a physical scaffold bridging the hole edges and supporting tissue ingrowth. Furthermore, the ILM harbors growth factors and extracellular matrix proteins—including fibronectin, laminin, and collagen IV—which stimulate Müller cell proliferation and photoreceptor regeneration [23]. By repositioning the flap over the hole, these trophic factors are concentrated at the injury site, facilitating more complete anatomical and functional recovery [23, 24].

High-level evidence from meta-analyses supports the anatomical advantage of ILM flap techniques. Tzoumas et al. [16] reported a markedly higher likelihood of primary closure (OR = 4.80, $p < 0.001$), particularly in holes $\geq 500 \mu\text{m}$. Akhtar et al. [17] demonstrated significantly improved closure rates across all hole sizes (OR = 2.47, $p < 0.001$). With respect to functional outcomes, Tzoumas et al. [16] also reported significantly better visual acuity in the ILM flap group at 3–6 months (MD = $-0.14 \log\text{MAR}$, $p < 0.001$), consistent with our findings.

The MHI was comparable between groups (0.475 ± 0.106 vs. 0.538 ± 0.129 , $p = 0.144$), confirming baseline equivalence of hole morphology and strengthening the validity of the between-group comparisons. In the literature, a lower MHI has been associated with higher surgical failure risk, and an MHI ≥ 0.5 has been proposed as a favorable prognostic threshold [8, 9, 25].

A key finding was the more favorable outer retinal microstructural recovery in Group 2. Postoperative EZ defect size was significantly smaller ($p = 0.039$), with approximately twice the degree of ELM and EZ recovery compared with Group 1. These findings are consistent with Baumann et al. [19] and Koçak et al. [21], who reported significantly higher rates of ELM and EZ restoration with ILM flap techniques. The high prevalence of U-shaped closure in both groups (91.7% vs. 87.5%) may have contributed to favorable visual outcomes, as U-shaped closure is consistently associated with superior foveal architecture [12, 14, 21, 22].

W-shaped closure, observed in 8.3% of Group 1 and 12.5% of Group 2 eyes, is a less frequently reported configuration associated with residual photoreceptor disruption and intermediate visual outcomes [12, 22]. Its prognostic significance remains less defined in the current literature.

Several limitations of this study merit consideration. The retrospective design introduces the potential for selection bias. A post-hoc power analysis revealed a Cohen's d of 0.810 for BCVA, yielding an achieved power of 62.9% with 16 patients per group at an alpha level of 0.05; approximately 24 patients per group would be required to achieve 80% power. This limited power may account for the lack of statistical significance in some secondary outcome measures. Importantly, all procedures were performed by a single experienced surgeon, eliminating inter-surgeon variability as a confounding factor and strengthening the internal validity of the study. Future prospective randomized studies with larger cohorts and extended follow-up are warranted to confirm these results.

Based on our findings, the temporal inverted ILM flap technique should be considered the preferred approach for large macular holes, particularly those with minimum MH diameter $\geq 550 \mu\text{m}$, where

conventional ILM peeling demonstrated markedly inferior closure rates. For holes of 400–549 μm , both techniques appear anatomically equivalent; however, the superior outer retinal recovery and visual outcomes associated with the flap technique may still confer a functional advantage in this size range.

Conclusions

The temporal inverted ILM flap technique was associated with superior postoperative BCVA, significantly better outer retinal layer recovery, and a significantly higher closure rate in eyes with minimum MH diameter $\geq 550 \mu\text{m}$, compared with conventional ILM peeling. These findings suggest that the temporal inverted ILM flap technique offers a clinically meaningful advantage in the management of large macular holes, particularly for very large holes where conventional ILM peeling may be insufficient. Further prospective studies with larger sample sizes and extended follow-up are warranted to confirm these results.

Abbreviations

BCVA

best-corrected visual acuity

ELM

external limiting membrane

EZ

ellipsoid zone

FTMH

full-thickness macular hole

ILM

internal limiting membrane

IFT

inverted flap technique

logMAR

logarithm of the minimum angle of resolution

MH

macular hole

MHI

macular hole index

OCT

optical coherence tomography

SD-OCT

spectral-domain optical coherence tomography

Declarations

Ethics approval and consent to participate

The study was approved by the Selçuk University Medical Faculty Clinical Research Ethics Committee (approval number: 2024/502) and was conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from all participants.

Consent for publication

Written informed consent for publication was obtained from all patients whose clinical data and SD-OCT images are included in this manuscript. Copies of the consent forms are available for review by the Editor-in-Chief of this journal.

Competing interests

The authors declare that they have no competing interests.

Funding

No funding was received for this study.

Author Contribution

S.A.D.: conceptualization, study design, data collection, manuscript writing, and final approval. G.G.C.: data collection, critical revision of the manuscript, and final approval. Ş.G.: supervision, critical revision of the manuscript, and final approval. All authors read and approved the final manuscript.

Acknowledgements

Not applicable.

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Data Availability

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

References

1. Rogers AH, Duker JS. Section 9 - Macular Diseases. In: Rogers AH, Duker JS, editors. *Retina*. Edinburgh: Mosby; 2008. p. 163–187.
2. Duker JS, Waheed NK, Goldman DR, editors. *Handbook of Retinal OCT*. Philadelphia: W.B. Saunders; 2014. p. 56–57.
3. Gass JD. Idiopathic senile macular hole. Its early stages and pathogenesis. *Arch Ophthalmol*. 1988;106(5):629–39.
4. Duker JS, Kaiser PK, Binder S, de Smet MD, Gaudric A, Leys A, et al. The International Vitreomacular Traction Study Group classification of vitreomacular adhesion, traction, and macular hole. *Ophthalmology*. 2013;120(12):2611–9. doi:10.1016/j.ophtha.2013.07.042.
5. Kelly NE, Wendel RT. Vitreous surgery for idiopathic macular holes. Results of a pilot study. *Arch Ophthalmol*. 1991;109(5):654–9.
6. Eckardt C, Eckardt U, Groos S, Luciano L, Reale E. Removal of the internal limiting membrane in macular holes. *Ophthalmologe*. 1997;94(8):545–51.
7. Rahimy E, McCannel CA. Impact of internal limiting membrane peeling on macular hole reopening: a systematic review and meta-analysis. *Retina*. 2016;36(4):679–87. doi:10.1097/IAE.0000000000000917.
8. Salter AB, Folgar FA, Weissbrot J, Wald KJ. Macular hole surgery prognostic success rates based on macular hole size. *Ophthalmic Surg Lasers Imaging*. 2012;43(3):184–9.
9. Ullrich S, Haritoglou C, Gass C, Schaumberger M, Ulbig MW, Kampik A. Macular hole size as a prognostic factor in macular hole surgery. *Br J Ophthalmol*. 2002;86(4):390–3.
10. Michalewska Z, Michalewski J, Dulczewska-Cichecka K, Adelman RA, Nawrocki J. Temporal inverted internal limiting membrane flap technique versus classic inverted internal limiting membrane flap technique: a comparative study. *Retina*. 2015;35(9):1844–50. doi:10.1097/IAE.0000000000000555.
11. Michalewska Z, Michalewski J, Adelman RA, Nawrocki J. Inverted internal limiting membrane flap technique for large macular holes. *Ophthalmology*. 2010;117(10):2018–25. doi:10.1016/j.ophtha.2010.02.011.
12. Michalewska Z, Michalewski J, Nawrocki J. Correlation between foveal structure and visual outcome following macular hole surgery: a spectral optical coherence tomography study. *Graefes Arch Clin Exp Ophthalmol*. 2008;246(6):823–30.
13. Wakabayashi T, Fujiwara M, Sakaguchi H, Kusaka S, Oshima Y. Foveal microstructure and visual acuity in surgically closed macular holes: spectral-domain optical coherence tomographic analysis. *Ophthalmology*. 2010;117(9):1815–24. doi:10.1016/j.ophtha.2010.01.017.
14. Darwish A. Post-operative role of OCT and OCTA in the evaluation of idiopathic macular hole surgery: a review article. *Med Res Arch*. 2025;13.
15. Jin Z, Jaycock P, Williams C, Yorston D, Steel DH. Internal limiting membrane flap versus conventional peeling for idiopathic full thickness macular holes: a registry analysis of 2990 eyes.

Clin Exp Ophthalmol. 2026;54(1):86–98.

16. Tzoumas N, Potrata E, Maan ZN, Steel DH. Internal limiting membrane flaps in macular hole surgery: a systematic review and individual participant data meta-analysis. *Ophthalmol Retina*. 2025;9(8):717–30.
17. Akhtar SMM, Naqvi SA, Khalid M, Iqbal M, Ahmed MZ, Bashir H, et al. Critical analysis of macular hole repair techniques: a comprehensive systematic review and meta-analysis comparing internal limiting membrane flap and internal limiting membrane peeling for any size of macular hole. *BMC Ophthalmol*. 2025;25(1):174. doi:10.1186/s12886-025-03990-8.
18. Reynaldo N, Garyudanefi, Susetyo PB. Comparison of ILM peeling vs. inverted ILM flap for macular hole closure and visual outcomes: systematic review and meta-analysis. *Int J Retina Vitreous*. 2025;11(1):81.
19. Baumann C, Zhao J, Wickham L, Yorston D. Effect of inverted internal limiting membrane flap on closure rate, postoperative visual acuity, and restoration of outer retinal layers in primary idiopathic macular hole surgery. *Retina*. 2020;40(10):1955–63. doi:10.1097/IAE.0000000000002674.
20. Ghoraba H, Mansour HO, Elgouhary SM, Kamel MA, Zaky AG, Ghoraba HH. Pars plana vitrectomy with internal limiting membrane flap versus pars plana vitrectomy with conventional internal limiting membrane peeling for large macular hole. *Cochrane Database Syst Rev*. 2023;8(8):CD015031. doi:10.1002/14651858.CD015031.pub2.
21. Kocak N, Yeter V, Birinci H. Comparative study of conventional internal limiting membrane peeling versus temporal inverted internal limiting membrane flap for large macular hole treatment. *Indian J Ophthalmol*. 2023;71(1):188–94. doi:10.4103/ijo.IJO_1362_22.
22. Tsuboi K, Fukushima M, Akai R. How optical coherence tomography has changed the management of macular holes: a narrative review. *Taiwan J Ophthalmol*. 2025;15(3):344–53.
23. Omoto T, Ueno S, Kominami T, Ueno H, Nishida K, Terasaki H. The role of inverted internal limiting membrane flap in macular hole closure. *Invest Ophthalmol Vis Sci*. 2017;58(11):4763–70. doi:10.1167/iovs.17-22304.
24. Kinoshita T, Onoda Y, Maeno T. Long-term surgical outcomes of the inverted internal limiting membrane flap technique in highly myopic macular hole retinal detachment. *Graefes Arch Clin Exp Ophthalmol*. 2017;255(9):1731–6.
25. Kumar S, Rao GN, Sinha N, Khanduja S, Garg S. Predictive relevance of optical coherence tomography indices in conjunction with visual acuity and surgical outcomes of idiopathic macular hole. *Heliyon*. 2024;10(20):e39261. doi:10.1016/j.heliyon.2024.e39261.

Figures

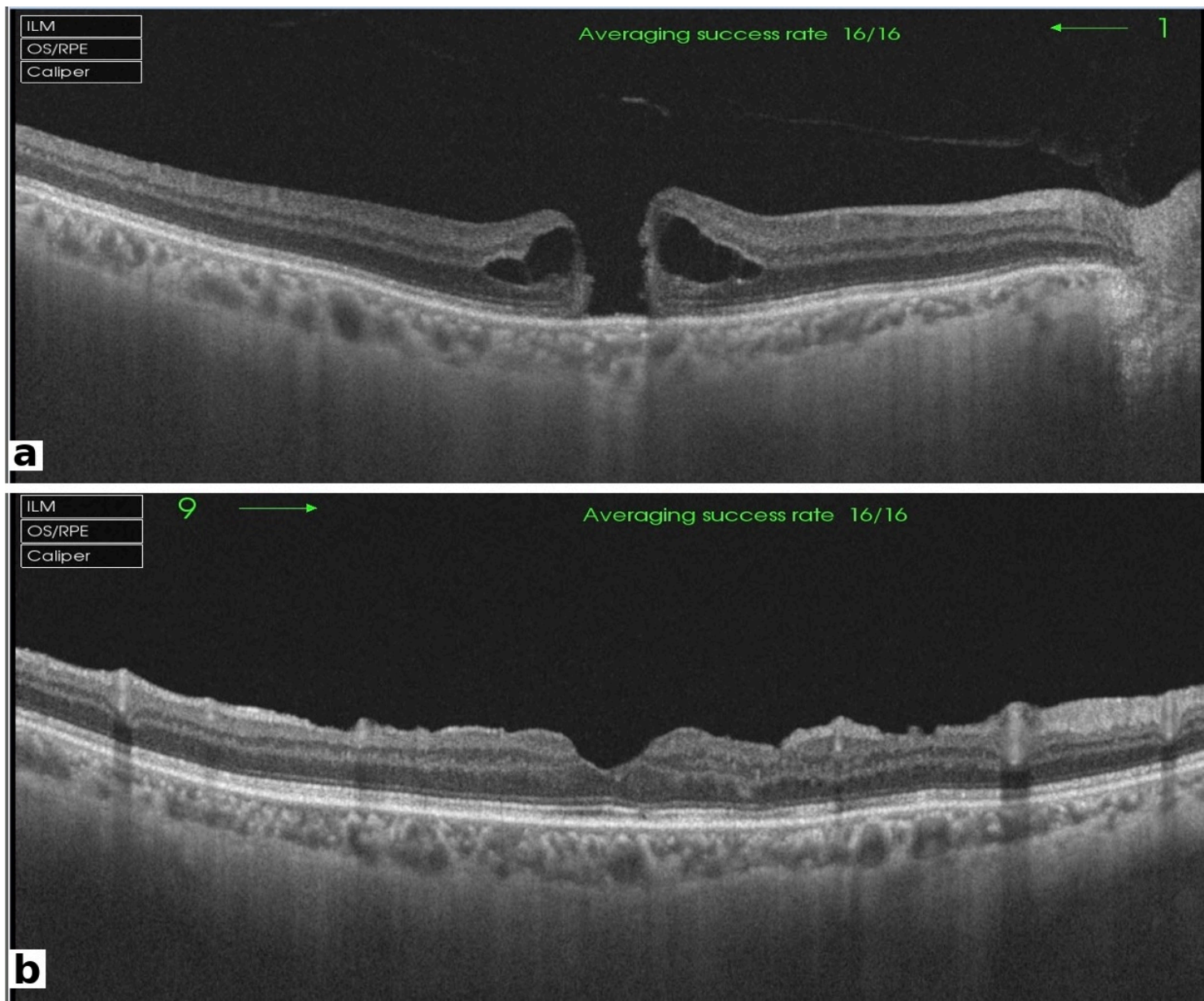


Figure 1

SD-OCT images of a representative patient treated with the temporal inverted ILM flap technique.

Representative spectral-domain optical coherence tomography (SD-OCT) images from a patient in the temporal inverted ILM flap group (Group 2). (A) Preoperative SD-OCT image demonstrating a large full-thickness macular hole (FTMH) with significant disruption of the ellipsoid zone (EZ) and external limiting membrane (ELM). (B) Postoperative SD-OCT image at 12 months showing complete U-shaped anatomical closure of the macular hole with full restoration of both ELM and EZ integrity, consistent with favorable outer retinal layer recovery.

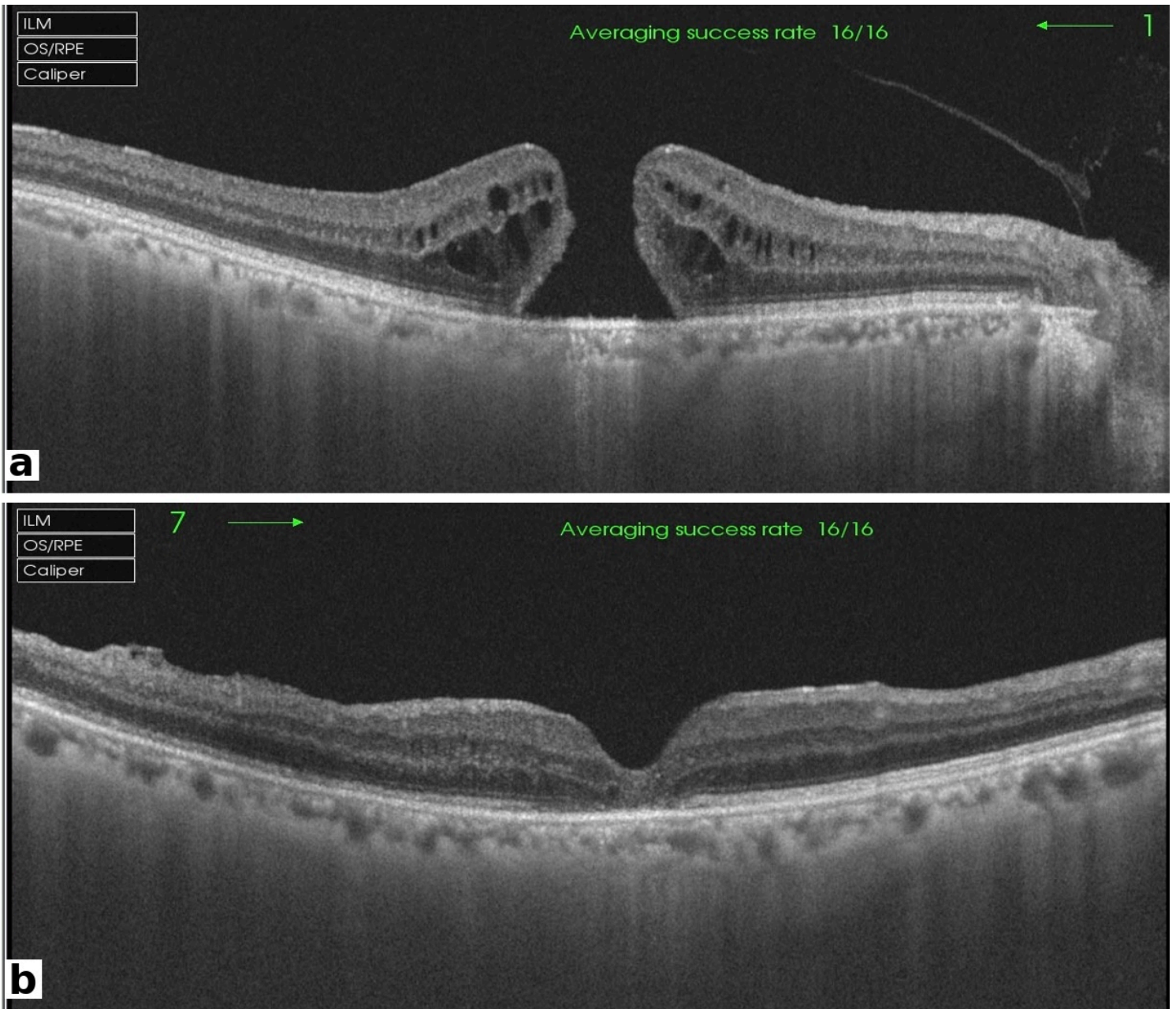


Figure 2

SD-OCT images of a representative patient treated with the conventional ILM peeling technique.

Representative spectral-domain optical coherence tomography (SD-OCT) images from a patient in the conventional ILM peeling group (Group 1). (A) Preoperative SD-OCT image showing a large full-thickness macular hole with disruption of the EZ and ELM. (B) Postoperative SD-OCT image at 12 months demonstrating anatomical hole closure; however, persistent defects of both ELM and EZ are evident, consistent with incomplete outer retinal layer recovery despite successful anatomical closure.