



THE MODERN MANAGEMENT OF CHALLENGING MACULAR HOLES

New surgical tools and techniques are changing how we approach large and myopic macular holes.

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Fueled by continued advances in retinal imaging, operative technologies, and surgical techniques, the treatment of full-thickness macular holes (FTMHs) has improved

dramatically. Pars plana vitrectomy, elevation of the posterior hyaloid, peeling of the internal limiting membrane (ILM), and fluid-air exchange followed by gas tamponade remains a standardized and highly successful approach,¹ with rates of anatomic hole closure approaching $\geq 90\%$ and improved BCVA of at least two lines seen in $\geq 70\%$ of eyes.^{2,3} Still, up to 10% of FTMHs fail to close, despite seamless execution of this classic technique.⁴ These poorer outcomes most commonly occur in eyes that are myopic and MHs with a minimum linear diameter (MLD) $\geq 500 \mu\text{m}$.^{5,6} The comparatively lower rates of anatomic hole closure in such eyes requires refined surgical techniques to provide an enhanced treatment benefit.

AT A GLANCE

- Several variants of the internal limiting membrane flap technique have emerged showing increased success in treating challenging macular holes.
- Each technique poses its own set of advantages and challenges that must be considered based on the configuration of the macular hole, the eye's anatomy, and the surgeon's preference and experience.
- Very large macular holes that fail to close with conventional surgical interventions may benefit from human amniotic membrane graft, macular hydrodissection, and autologous retinal transplantation techniques.

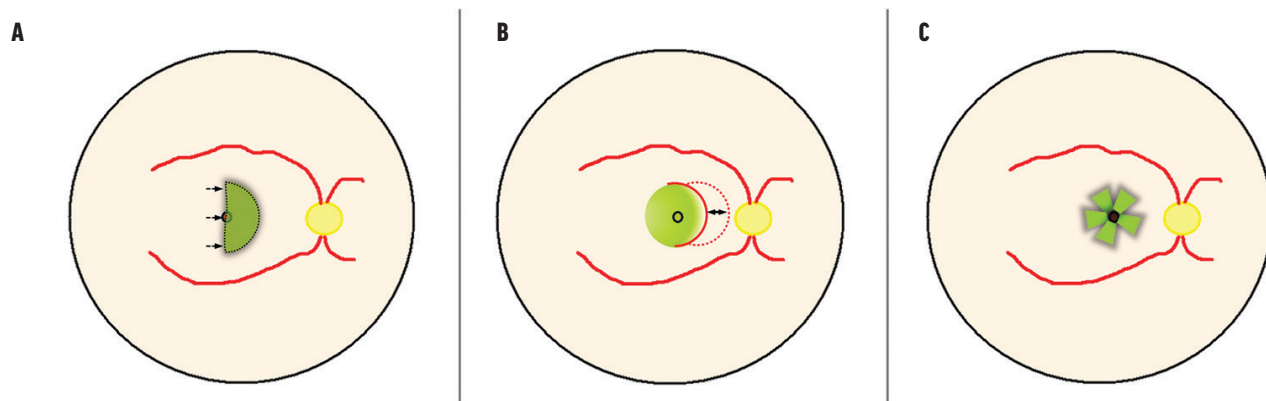


Figure 1. These images depict various ILM flap techniques, including the inverted ILM flap (A), with a semicircular flap that remains attached and inverted (arrows) along the temporal edge of the hole; the retracting door ILM flap (B), with the ILM now assuming a retracted position (solid red line) compared with its original position (dotted red line) still along its same natural orientation; and the flower-petal inverted ILM flap (C), with multiple ILM leaflets hinged circumferentially around the hole edge and subsequently inverted to cover the hole.

UPDATED APPROACHES

In 2010, Michalewska et al devised the inverted ILM flap.⁷ In their series, anatomic closure was achieved in 98% of eyes with FTMHs with an MLD $\geq 400 \mu\text{m}$ treated with the inverted ILM flap technique compared with 88% of eyes treated with conventional ILM peel alone.⁷

Subsequent reports confirmed the superior surgical outcomes achieved with the inverted ILM flap technique. In a large retrospective series of 620 eyes, Rizzo et al reported significantly greater anatomic success in MHs with an MLD $\geq 400 \mu\text{m}$ treated using an inverted ILM flap (95.6%) versus ILM peeling (78.6%).⁴ Moreover, the rate of anatomic hole closure in myopic eyes with an axial length (AL) $\geq 26 \text{ mm}$ managed with an inverted ILM flap (88.4%) was also significantly greater than myopic eyes that underwent ILM peeling (38.9%).

Metz et al reported a superior rate of anatomic hole closure in a series of 68 eyes with large myopic FTMHs treated with an ILM flap (94%) compared with a complete ILM peel (61%) and, more importantly, showed that the inverted ILM flap technique is associated with a 22-times higher probability of anatomic success for all sizes of FTMH ($P = .001$).⁸

Furthermore, a meta-analysis of more than 1,400 eyes demonstrated that the inverted ILM flap technique achieves significantly greater rates of closure compared with ILM peeling alone for varying sizes of FTMH, eyes that are myopic, and in patients with retinal detachment.⁹

UNMET NEEDS

Despite the success of the inverted ILM flap technique, the management of large and atypical FTMHs remains challenging, particularly in patients with high myopia and holes with a MLD $\geq 500 \mu\text{m}$ (see *Measuring Macular Holes*). For example, the Manchester Large Macular Hole Study showed that MHs with a diameter $\geq 630 \mu\text{m}$ were significantly less likely to close.⁶ The study concluded that

this revised MLD threshold may more accurately classify a MH as *large* based on the probability of surgical closure with conventional ILM peeling, and the comparatively lower closure rates warrant adjuvant techniques such as ILM flaps.

Likewise, the BEAVRS Macular Hole Study Group demonstrated a stepwise decline in anatomic hole closure beyond a MLD $\geq 500 \mu\text{m}$, further highlighting the unmet need for new macular hole surgery techniques.⁵

New Flap Techniques

Several variants of the ILM flap technique have emerged showing increased success in more challenging MH scenarios (Figure 1). Shin et al described the use of PFO to prevent movement of the flap during fluid-air exchange.¹⁰ The investigators showed that a PFO-assisted inverted ILM flap achieved hole closure in 100% of patients with MHs with a mean MLD of $590.8 \mu\text{m}$. They also reported a significantly higher rate of anatomic success compared with conventional ILM peeling at 6 months.

Song et al described a technique in which viscoat is injected into and around the FTMH, ICG is injected, and the ILM is peeled to create a superior inverted ILM flap. Viscoat is then applied on top of the inverted ILM flap prior to performing fluid-air exchange.¹¹ In highly myopic eyes (mean AL of 29.83 mm) with MHs with a mean MLD of $597.6 \mu\text{m}$, Song et al reported anatomic closure in 100% of eyes and improved BCVA in 66.7% of cases.

To address the anatomic and surgical intricacies of myopic MHs, Finn and Mahmoud described the retracting door ILM flap technique.¹² This technique involves creating a large ILM flap starting nasal to the hole, carrying the flap over the fovea such that it remains attached temporally, and then carefully draping the ILM back over the MH. This technique requires minimal manipulation beyond the flap creation, relieves tractional forces, and achieves relaxation of the taut ILM as the flap retracts to assume a natural

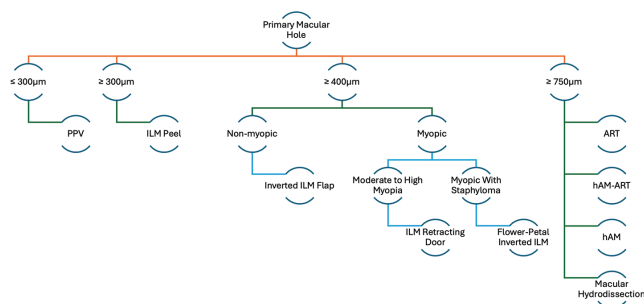


Figure 2. Our personal surgical algorithm for primary FTMHs.

position and orientation. Marlow et al demonstrated that the retracting door ILM flap technique can be modified to find success in eyes with FTMH and associated epiretinal membrane (ERM).¹³ With this technique, ICG is applied to start the ILM peel nasally, the peel is propagated to engage the negatively staining ERM, and a temporal hinge is maintained to allow the combined ERM/ILM tissue to drape over the hole as a single flap. The authors reported anatomic hole closure in 83% of FTMHs with a mean MLD of 681 µm and concurrent ERM and showed that this technique minimized loss of ILM.¹³

Another ILM flap variant that has demonstrated success is the flower-petal inverted ILM flap, which involves multiple ILM leaflets that are inverted in sequence to form a multilayered ILM scaffold covering the hole.¹⁴ In a series of 103 eyes with large FTMHs with a mean MLD of 712 µm, Joshi et al described this technique under PFO and

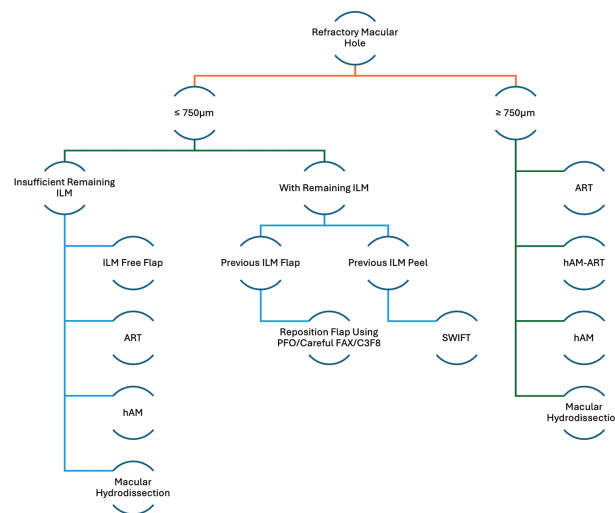


Figure 3. Our personal surgical algorithm for refractory FTMHs that have previously undergone surgery.

reported anatomic hole closure in 92.2% of cases.¹⁵ This flower-petal technique may be particularly useful in highly myopic eyes with posterior staphyloma, in which there is often fragmentation and discontinuity of the ILM.

Several variants of the ILM flap technique have proven successful over the last decade, and each technique poses its own set of advantages and challenges that must be considered based on the configuration of the FTMH, the eye's anatomy, and the surgeon's preference and experience (Figure 2).

MEASURING MACULAR HOLES

Obtaining an accurate measurement of a macular hole (MH) is inherently challenging. Because OCT is conventionally based on a set axial length (AL) of 24 mm, measurements in longer eyes are prone to inaccuracy. To account for this discrepancy, the size of the measured hole must be adjusted as a ratio of the patient's actual AL to the machine's assumed AL (Table).¹ For example, a 500 µm MH as measured on OCT in an eye with an AL of 30 mm has a true minimum linear diameter (MLD) of 625 µm, which should be calculated by multiplying

the measured MLD by the eye's correct AL and then dividing by 24.

This presumed underestimation in size may explain, in part, the historically limited anatomic success reported in myopic MHs managed with ILM peeling. Calculating the accurate size of myopic MHs can guide the type of surgical approach to successfully close those holes and achieve better visual acuity.

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TABLE. ADJUSTED MACULAR HOLE SIZE BASED ON AXIAL LENGTH

Axial Length	24 mm	27 mm	30 mm	33 mm	36 mm
Minimum Linear Diameter	400 µm	450 µm	500 µm	550 µm	600 µm
	500 µm	562 µm	625 µm	687 µm	750 µm
	600 µm	675 µm	750 µm	825 µm	900 µm
	700 µm	787 µm	875 µm	962 µm	1,050 µm
	800 µm	900 µm	1,000 µm	1,100 µm	1,200 µm



DESPITE THE SUCCESS OF THE INVERTED ILM FLAP TECHNIQUE, THE MANAGEMENT OF LARGE AND ATYPICAL FTMHS REMAINS CHALLENGING.

Managing Complex Cases

The use of more invasive techniques is reserved for patients with very large MHs, in which success using ILM flaps has been shown to decline significantly and proportional to MLD exceeding 750 μm . Such eyes may benefit from the use of human amniotic membrane graft (hAM), macular hydrodissection, and autologous retinal transplantation (ART) techniques that have had comparatively greater success in recent investigations.^{2,16} The CLOSE Study Group analyzed outcomes using these adjuvant techniques in FTMHS $\geq 800 \mu\text{m}$ and reported anatomic success rates of 100% with hAM, 90.5% with ART, and 83.3% with macular hydrodissection. Notably, only eyes treated with ART demonstrated a significant improvement in vision with a mean BCVA improvement of approximately four lines in eyes with MHs $\geq 1,000 \mu\text{m}$.² More recently, a combined hAM-ART technique in eyes with large myopic MHs and associated outer retinal atrophy has shown promise.¹⁷

The management of refractory FTMHS is equally complex. These types of MHs are frequently larger, commonly associated with higher orders of myopia or chronicity, and often have little remaining ILM. Our personal treatment algorithm for refractory MHs is initially guided by MLD (Figure 3). For holes $\leq 750 \mu\text{m}$ with insufficient residual ILM following previous repair surgery, surgical options include the use of an ILM free flap, ART, hAM, and macular hydrodissection.

Surgeons must consider that ILM free flaps are prone to displacement, involve “stuffing” ILM into the hole in an orientation that is not physiologic, and may be less effective in inducing subsequent glial cell proliferation; furthermore, the MH remains without neurosensory retina. Although the ART and hAM techniques provide a neurosensory tissue plug, they may be better suited for larger holes. In eyes with sufficient residual ILM following previous peel, the superior wide-base ILM flap transposition technique

has shown anatomic success and improved vision.¹⁸ This technique involves a wide-based ILM flap harvested distal to the area of previous peeling that is then manipulated to assume an inverted position draping the area of the MH. In cases previously treated using an ILM flap technique, the flap may be repositioned under PFO to cover the hole, followed by a careful and slow fluid-air exchange and long-acting gas tamponade to prevent displacement. For refractory MHs $\geq 750 \mu\text{m}$, our preferred surgical treatment choice is ART or combined hAM-ART, similar to very large primary FTMHS. ■

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