

Surgical Options in Management of Macular Hole

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Macular hole is a full-thickness defect in the neurosensory retina at the fovea that presents with diminution of vision. In majority of the causes, it is idiopathic, though many other etiological theories have also been proposed. Small macular holes are usually associated with better prognosis than the larger ones.

Abstract *Various surgical procedures have been described to manage this condition and there have been continuous improvements in the management techniques. This review article summarises all the surgical techniques and modifications.*

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Introduction

First reported in 1869 by Knapp in a patient who had suffered a severe contusional injury of the globe¹, Macular hole is a full-thickness defect in the neurosensory retina at the fovea. Most cases of macular hole are idiopathic, and predominantly affect women in 6th to 8th decade of their life.

Various mechanisms have been described to explain the pathogenesis of Macular Hole. These include contusion necrosis, antero-posterior and tangential vitreous traction, cystoid macular degeneration and retinal atrophy.

Pathophysiology

The first pathogenetic theory was described by Gass et al in 1988. He attributed the focal shrinkage of the vitreous cortex in the foveal area to be the pathogenetic mechanism behind the occurrence of macular hole.² With time various other pathogenetic theories have been described. These include:

1. **Vascular Theory:** Coats and Kuhnt³ described the degeneration of neurosensory layer of retina at the fovea due to vascular insufficiency in the macular area.
2. **Traumatic Theory:** Coup and Contre- Coup waves due to trauma causes macular necrosis and ultimately lead to development of traumatic macular hole.⁴
3. **Vascular and Cystoid Degeneration Theory:** Any retinal insult secondary to retinal vascular disease, diabetic macular oedema, macular telangiectasis, anti-vascular Endothelial growth factor (anti-VEGF) use in neovascular Age-related macular degeneration (AMD), severe hypertension, solar retinopathy, electrocution or trauma, leads to cystoid degeneration at the fovea. This further worsens to the formation of a macular hole.
4. **Vitreous-Macular Traction:** Interplay between anteroposterior vitreoretinal traction, tangential traction from muller cell proliferation, and oblique traction associated with persistent vitreo-foveal attachment lead to macular degeneration and subsequent macular hole formation. Lateral displacement of photoreceptors, another factor contributing to macular hole formation also explains "pin-cushion distortion" seen in macular hole.

Four Clinical stages of Macular Hole have been described by Gass.⁵ These are:

1. **Stage 1a:** (Impending Hole): 100- 200-micron, foveolar detachment- Yellow Spot
2. **Stage 1b:** (Occult Hole): 200-300-micron, foveal detachment- Yellow Ring
3. **Stage 2:** Small full-thickness macular hole less than 400 micron
4. **Stage 3:** Full-thickness macular hole more than 400 microns with or without an operculum. No Posterior Vitreous Detachment (PVD)
5. **Stage 4:** Full-thickness macular hole with complete PVD. May be associated with anterior displacement of pseudo-operculum.

International vitreomacular traction study group⁶ classifies macular hole as small, medium and large. This classification is based on size of macular hole and surgical outcome of the macular hole surgery.

1. **Small Macular Hole:** Minimum linear dimension less than or equal to 250 micron- associated with a 100% closure rate following vitrectomy and are most responsive to pharmacologic vitreolysis.
2. **Medium Macular Hole:** The dimension is 250 to 400 microns. These are associated with 95% closure rate following vitrectomy alone.
3. **Large Macular Holes:** The ones with a minimum linear dimension of more than 400 microns. These have 90 to 95% closure rate following vitrectomy alone.

Clinical Presentation

Patients with macular hole typically present with decreased vision, central scotoma and metamorphopsia.

Slit-lamp bio-microscopy with 90 D lens is the most appropriate clinical investigational modality. Size of macular hole, status of PVD, presence or absence of surrounding ERM, degenerative changes of RPE, operculum and presence or absence of surrounding cuff of fluid have to be noted. Traumatic macular holes can be identified by their ragged and irregular margins and can be easily differentiated from idiopathic macular holes which have smooth and regular

margins. Full-thickness macular hole can be differentiated from pseudo-holes or lamellar holes by Watzke Allen test or laser aiming beam test.

Investigations

Ocular Coherence Tomography: Swept-Source Ocular Coherence Tomography (SSOCT) gives a high-resolution image of vitreoretinal interface, neurosensory retina and retinal pigment epithelium (RPE). This helps to identify surrounding epiretinal membrane (ERM) cuff of fluid, vitreo-foveal adhesion, operculum or pseudo-operculum, and status of RPE. It also allows calculation of various macular hole indices that have a role in prognostication.

Various Macular hole indices are: (figure 1)

1. Macular Hole height (MHH): Vertical length between RPE and highest point of the hole
2. Base diameter: Measured at the level of RPE
3. Minimum linear diameter (MLD): Minimum measurable dimension
4. Macular hole inner opening: Distance between innermost layer in the defect
5. Tractional hole index (THI): MHH/MLD
6. Macular hole index (MHI): MHH/Base diameter
7. Hole forming factor (HFF): (left arm length of macular hole + right arm length of macular hole)/ base diameter

Greater MHI and THI are associated with better postoperative functional outcomes. MHI predicts external limiting membrane (ELM) restoration, while MLD and BD are predictive of anatomical closure.

Fundus Autofluorescence: This is another test for prognosis of a case of macular hole. Absence of foveal pigments in macular hole leads to hyper autofluorescence of healthy RPE. Poor autofluorescence from RPE due to pigmentary or other degenerative changes is associated with poor visual prognosis.

B Scan ultrasonography was used by Johnsons and co-workers⁷ to identify localised perifoveal detachment extending to surrounding arcades.

Microperimetry can be used to aid mapping of absolute and relative scotomas in macular hole patient both preoperatively and postoperatively.

Surgical Options for Management of Macular hole

Kelly and Wendel propagated the concept of pars plana vitrectomy, induction of PVD, removal of posterior vitreous cortex, fluid gas exchange and face down positioning for the repair of macular holes.⁸ Kelly and Wendel reported an anatomical closure rate of 58% and 73% and visual improvement in 42% and 55% cases in two consecutive reports.

This formed the basic concept of Macular hole surgery. Various modifications have been made to this and are associated with improved anatomical and visual outcomes.

ILM peeling for Macular Hole Surgery (MHS)

Eckardt in 1997, introduced the concept of internal limiting membrane (ILM) peeling in management of macular hole. Peeling of internal limiting membrane relieves the tangential traction caused by glial cells and hence enhances the anatomical and visual success rates of macular hole surgery.⁹ Cochrane review in 2013 showed better visual outcomes, better anatomical closure rates and lower re-surgery rates in patients who underwent ILM peeling when compared to those who underwent plain pars plana vitrectomy (PPV).¹⁰ ILM peeling is now a standard procedure in macular hole surgery.

Problems with ILM peeling

Recent studies have found that ILM peeling is associated with mechanical trauma to retinal nerve fibre layer (RNFL). Direct mechanical damage to retina while grasping the ILM and damage to Muller cell endplates that are attached to ILM during ILM peel leads to swelling of arcuate nerve fibre layer which can be seen as hyperreflective swelling on SSOCT.¹¹ Some patients develop small spindle shaped splitting of

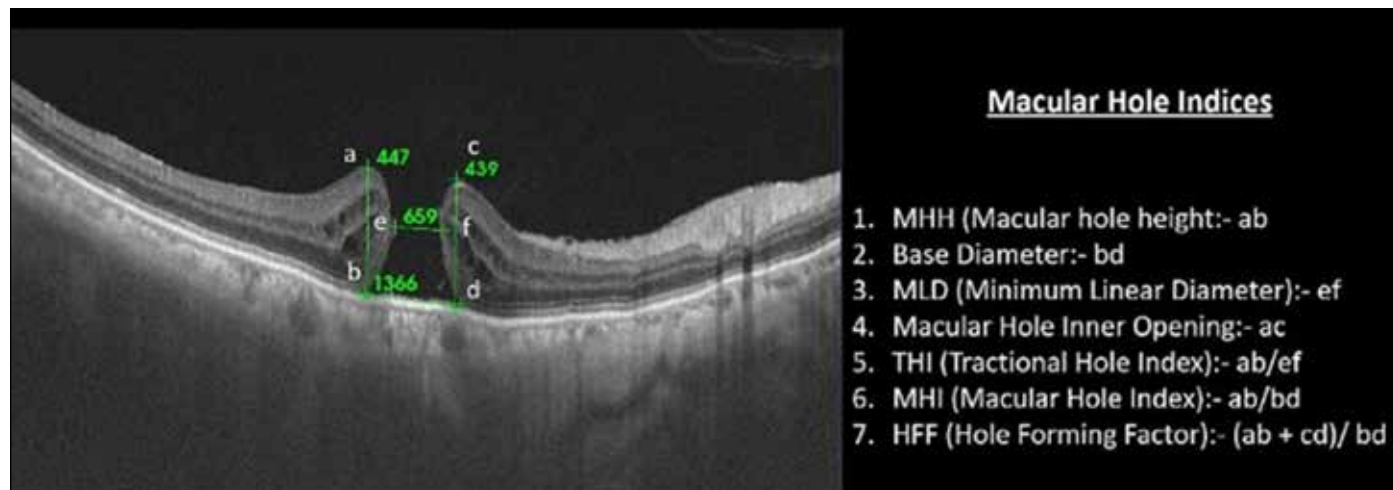


Figure 1: Swept Source OCT showing a full thickness macular hole with various macular hole indices

nerve fibre layer in ILM adjacent to peeled edge. This is known as dissociated Outer nerve fibre layer (DONFL).¹² This occurs due to irregular distribution of Muller cells after ILM peeling. Both conditions however do-not affect the final BCVA or macular sensitivity.

Area of ILM peeling also has significant influence on surgical outcomes of MHS. Bae et al¹³ demonstrated better improvement in metamorphopsia with relatively larger area of ILM peeling. Kumar et al¹⁴ reported a statistically significant relation of size of ILM peel and anatomical closure of macular hole.

Modifications of ILM peeling

The main modifications of ILM peeling include

- Fovea sparing ILM peeling: First introduced by Ho et al¹⁵ in early stage 2 MHs. This was associated with better foveal contour, lesser inner retinal damage and hence better visual outcomes.
- Inverted ILM flap: The concept was first introduced by Michalewska et al¹⁶ for management of larger MHs. The edge of peeled ILM was not removed but rolled and placed on the macular hole in an inverted manner (i.e. retinal surface of ILM facing the vitreous body). This provides a scaffold for proliferation of glial cells and hence leads to superior anatomical closure. Glial cells produce intermediate filaments that provoke tissue remodelling within the hole. Use of this technique in high myopic, traumatic and other refractory macular holes was found to be associated with better surgical outcomes.
- Temporal ILM peeling: Another modification is ILM peeling only in the temporal macula, thereby sparing the papillo-macular bundle area from possible detrimental effects of ILM peeling and also preventing nasal displacement of the retina.¹⁷

Surgeons may sometimes feel difficulty in ILM peeling such as retroversion of ILM flap during fluid air exchange. Viscoat assisted ILM peeling helps in smoother peel. The concept of Viscoat assisted ILM peel was first introduced by Song et al.¹⁸

In cases of failed MHS planned for re-surgery or in cases where inverted ILM flap could not be done, various other techniques have been described.

- ILM free-flaps may be used in cases of previously failed MHS with ILM peeling already done in the macular area. The free-flap is usually taken from the edge of already peeled area or from a more peripheral area and is transferred to hole area prior to fluid-air exchange, assisted by PFCL or viscoelastic agent.^{19,20}
- Grewal and Mahmoud²¹ introduced the use of autologous neurosensory retinal free flap for closure of myopic macular hole.
- Chen and Yang²² used autologous anterior or posterior lens capsule flap as a scaffold to plug the MH
- A new ILM abrasion technique has been proposed by Mahajan et al²³. He used diamond dusted membrane scraper over one - disc diameter area around fovea. The

advantages proposed are- complete removal of basement membrane of ILM and hole closure rates comparable to traditional ILM peeling.

Arcuate Retinotomies

In large macular holes ILM peeling alone may not be sufficient to remove all tangential traction on the retina. Arcuate retinotomies provide additional retinal compliance and allow repositioning of temporal retinal bridge and hence assist closure of large macular holes.²⁴ This technique consists of creation of longitudinal retinotomies along the course of nerve fibres and hence prevent transection of most fibres

Chromovitrectomy

Dyes to stain

Visualization of ILM during MHS is an important challenge faced by most of the surgeons. Hence dyes are an important component of MHS.

Commonly used dyes include- Indocyanine green (ICG), brilliant blue G (BBG) and trypan blue (TB).

ICG was used in yesteryears to stain ILM. Its use has been reported to be associated with toxicity to retinal ganglion cells (RGCs), glial cells and RPE.

Few cases of RPE atrophy have also been reported in patients where TB was used to stain the ILM.

BBG is the safest and time-tested dye that is associated with superior staining properties, better visual outcomes and minimal to no toxicity to RPE and RGCs.

Acid violet 17 is a recently introduced dye for use in MHS. Since this dye is specific to ILM, it gives superior staining and better contrast when compared to BBG.^{25,26} Further studies need to be done to establish its safety.

Role of microscope integrated optical coherence tomography (Mi-OCT):

Mi-OCT is a useful intraoperative adjunct in MHS. Mi-OCT gives high resolution, real time imaging of ILM peeling. This has a specific role in cases where visualization of ILM is difficult. Mi-OCT also allows visualization in thinned out retina, and thereby helps guide ILM peeling to avoid intra-op break formation. It also helps in identification of residual ILM, epiretinal membrane (ERM), and adequacy of inverted ILM flaps.

Adjuncts Role of autologous serum

Various studies have been done to assess the role of growth factors, autologous serum, platelet rich plasma, thrombin and fibrin mixtures in an attempt to enhance the macular hole closure rate. None of the studies proved the efficacy of any of these adjuncts in improving the anatomical and functional outcome of MHS in cases with small MHs. One large case control study by Banker et al reported a slight adjuvant effect of autologous serum in enhancing the closure of large macular hole.²⁷ Kung et al in 2013, reported improved visual outcomes in autologous serum assisted MHS, with no difference in anatomical closure rates in patients undergoing ICG assisted MHS. He attributed this outcome to the ability of autologous serum to flush off the excess ICG from retinal surface and hence reduce its retinotoxicity.²⁸

Tamponade and post op positioning

Intraocular tamponade with gas plays an important role in MHS. Commonly used ones include per-flouro-propane (C3F8) and sulfur hexafluoride (SF6). Gas not only provides a scaffold for cellular proliferation, but also helps in extrusion of subretinal fluid from posterior pole.²⁹ A gas fill of at least 65% on postoperative day 4 has been associated with better surgical outcomes as it ensures adequate gas macula contact.³⁰ Traditionally, gas tamponade has been supplemented with face down positioning for at least 7 days. This is especially important in macular holes with diameter more than 400 microns.³¹

In patients who cannot manage face down position (e.g. children or adults with orthopaedic issues) silicon oil insertion can be done. Silicone oil is also an option when long term tamponade is required in cases with multiple MHS failures.

Face-down positioning is inconvenient and not adhered completely by the patients. To improve tolerance, recent studies suggest shortening of duration of face-down position or use of face-up position or even alleviated positioning with similar anatomical closure rates.^{32,33,34,35}

Macular Hole Closure Patterns

A macular hole is said to be closed when there is flattening and reattachment of the hole rim along the whole circumference of the macular hole. Two types of closure have been defined.³⁶

- **Type 1 closure:** There is no interruption in the continuity of foveal tissue above the RPE layer
 - **Type 2 Closure:** There is an interruption in continuity of inner retinal layers and RPE is denuded.
- Imai et al gave another OCT based classification of macular hole closure and divided it into three types.³⁷
- Type "U"- Normal foveal contour on OCT
 - Type "V"- Steep foveal contour
 - Type "W"- Foveal defect of neurosensory retina

To Sum Up

Macular holes can be very efficiently managed surgically leading to improved anatomical and visual outcomes. Standard procedure consists of PVD induction, staining of ILM with nontoxic BBG dye, ILM peeling with or without inverted ILM flap, fluid air exchange and intraocular gas injection with face down positioning for a few days. Regular follow up should be done with SS OCT to assess for anatomical closure and visual acuity assessment, Amsler grid monitoring to look for functional recovery.

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