Optimising Outcomes in Macular Hole Surgery

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The prevalence of idiopathic macular holes in the general population has been estimated to vary from 0.2 to 3.3 per 1,000 people and they are most common in the sixth to seventh decade of life with female preponderance[1,2]. Macular holes (MH) were first described more than 100 years ago and were considered to be traumatic in origin. But now the most common etiology is known to be idiopathic.

Vitrectomy for Macular holes is now one of the most frequently performed procedure in any vitreoretinal practice. Kelly and Wendel first described role of vitrectomy and posterior hyaloid removal to relieve macular traction and reported an anatomic MH closure rate of 58%[3]. Prior to this MH were considered to be untreatable.

This review will discuss the established treatment modalities and touch upon newer advancements and how these may allow us to improve outcomes.

MACULAR HOLE PATHOGENESIS

Idiopathic macular holes result from tangential and antero-posterior traction on the fovea by prefoveal cortical vitreous which results in a foveal dehiscence that progresses from foveolar detachment to a full-thickness MH[4].

Recent studies of the early stages of FTMH using OCT suggest that FTMHs develop in a situation where there is failure of normal age related separation of the vitreous cortex from the posterior pole as a result of an abnormally tenacious attachment to the fovea. The residual attachment at the foveal centre, in the trampoline configuration, may act as a focal point where mechanical forces are transmitted from the vitreous to the foveolar surface leading to foveal traction[5].

Understanding this process has helped in the evolution of surgical techniques for macular hole closure.

NATURAL COURSE AND PROGRESSION

Natural history data available indicates that few cases of macular holes, especially smaller ones (50–100 μm) termed as macular microholes may close spontaneously. The reported incidence of spontaneous closure in the literature is 2.7% to 8.6%. Johnson[6] reported a high rate of spontaneous resolution of these holes within weeks, but often with a residual defect in the photoreceptor layer.

However, macular holes usually progress, and studies have shown a 21.7%–77% increase in hole size over 6 years of follow-up up to 750 μm or larger.

Preoperative considerations and prognostication for macular hole closure: Traditionally the size of the macular hole has been found to be inversely proportional to the surgical success rate. Also the hole closure type has been found to depend on the preoperative macular hole diameter. In other words, larger macular holes tend to result in type 2 closure postoperatively and smaller macular holes to type 1 closure. Hole closure pattern has been divided into two types. A type 1 is the preferred configuration with complete closure and no defect of the neurosensory retina. In type 2 closure a foveal defect of the neurosensory retina persists postoperatively although the whole rim of the macular hole is attached to the underlying RPE with flattening of the cuff (Figure 1).

Several reports revealed that a shorter duration of symptoms correlated with better postoperative visual improvement. However, it is important to remember that many macular hole patients may not be sure of the accurate duration of symptoms in the affected eye, especially if the contralateral eye is healthy.

ANATOMICAL OCT BASED PROGNOSTIC INDICATORS

Recent studies[7] with OCT have assessed that MH size and area of the inner segment/outer segment junction defect are important determinants for visual as well as anatomical outcome.

MH index (MHI) The MHI is defined as the ratio of the hole height to the basal hole diameter and is reported to be positively correlated to the postoperative visual acuity Several studies have shown that MHI value ≥ 0.5 is predicted to have better visual acuity (Figure 2).

The hole form factor (HFF) which is sum of the 2 arm lengths divided by basal hole diameter was described by Puliafito and colleagues[8]. The HFF is another predictor tool which was also seen to be correlated with the best corrected postoperative visual acuity and visual improvement.

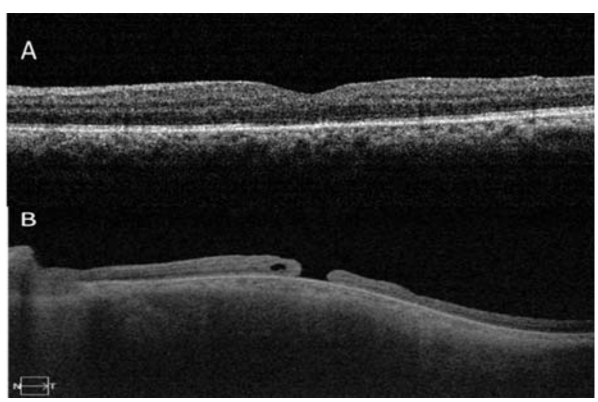


Figure 1: *OCT image showing two types of MH closure patterns:* ***Panel A*** *shows Type 1 closure which is the preferred configuration with complete closure and no defect of the neurosensory retina.* ***Panel B*** *showing Type 2 closure of MH with foveal defect of the neurosensory retina persisting postoperatively although the entire rim of the MH is attached to underlying RPE.*

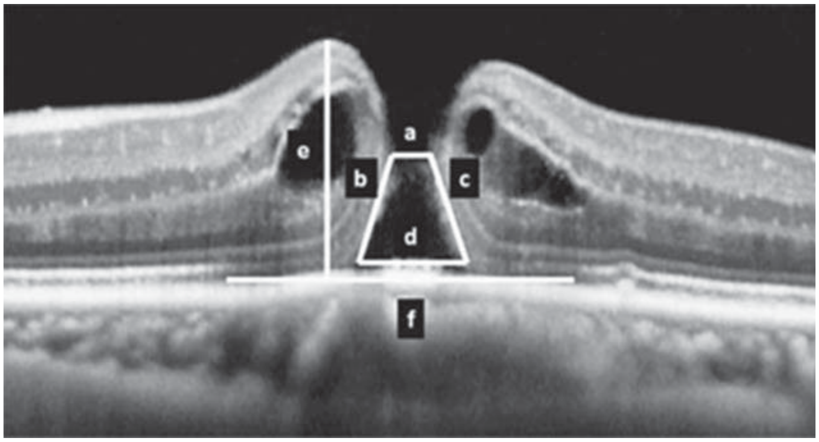


Figure 2: *MH parameters produced by OCT7.* ***a:*** *minimum hole diameter;* ***b:*** *left arm length;* ***c:*** *right arm length;* ***d:*** *basal hole diameter;* ***e:*** *hole height;* ***f:*** *IS/OS defect length. HFF = (b + c)/d; MHI = e/d (MHI= Macular hole index; HFF= Hole form factor)*

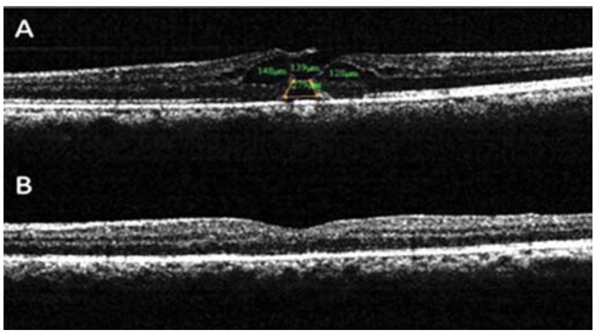


Figure 3: *SD-OCT image showing* ***(Panel A)*** *MH parameters in small macular hole. Basal hole diameter is 279μm. Left arm length is 148 and right arm length is 128μm. HFF calculated is 0.9.* ***(Panel B)*** *image showing good Type 1 closure of MH with Snellen visual acuity 6/6, N6.*

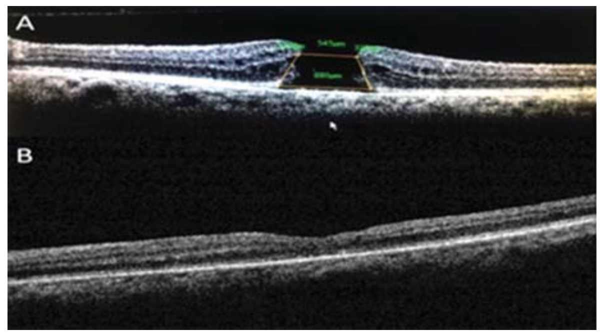


Figure 4: *SD-OCT image showing MH parameters in large macular hole. Basal hole diameter is 880μm. Left arm length is 310 and right arm length is 329μm. HFF calculated is 0.73. Panel B image showing good Type 1 closure of MH with Snellen visual acuity 6/12, N12.*

The diameter of the macular hole measured by OCT at the level of the retinal pigment epithelium and the minimum diameter provides a prognostic factor for postoperative visual outcome and anatomical success of macular hole surgery. The base diameter, measured by OCT, seems to have a better prognostic value as compared to slit lamp examination and it reflects the real size of the retinal lesion. Results calculated by Freeman and coworkers[9], found that macular hole with a small diameter was associated with better functional outcome.

Illustrate two of our patients where the MH index was calculated. HFF was 0.9 in smaller hole (Figure 3) and 0.73 in the larger hole (Figure 4). Good anatomical success achieved with Type 1 closure of MH in both cases. Also, Postoperative visual acuity in smaller MH was Snellen BCVA 6/6 and near vision N6. In large MH BCVA postoperative was 6/12 and near vision N12. Therefore, positive correlation was seen anatomically and visually as well.

Surgical Technique

Pars plana Vitrectomy: Vitrectomy for treatment of Macular holes has come a long way since Kelly and Wendel first described PPV for this indication in 1991.

Commonly performed technique includes vitrectomy, detachment of the posterior vitreous cortex, peeling of internal limiting membrane around the hole, fluid–gas exchange followed by gas tamponade (Figure 5).

The role of gas in macular hole closure has been debated. The most likely role is that the gas bubble acts first by dehydrating the hole edge and then by preventing fluid current from hampering the healing process.

Over the years, several variations and additions to the initial technique have been introduced with the aim of improving outcomes and safety. These include:

1) Advances in gauge of surgery
2) Chromovitrectomy using dyes to help visualize the ILM
3) Tamponade type and posturing requirements
4) Combined lens surgery
5) Surgical adjuncts

Advances in gauge

In the past decade's massive improvement in technology have taken place. From 20 G, we have advanced to microincision vitreous surgery (MIVS) with 23,25 and now 27 G vitrectomy.

Advantages of MIVS

a) Smaller cutter port size with more precise end cutting ability.
b) Less sclerotomy site trauma or break
c) Lower flow rates with less retinal traction.
d) Sutureless vitrectomy

ROLE OF ILM PEELING

It has been hypothesised that the ILM acts as a scaffold, facilitating the proliferation of a variety of cells, including myofibroblasts, fibrocytes and retinal pigment epithelium (RPE) cells which may generate tangential traction around the fovea, contributing to macular hole formation and its enlargement. The rationale for ILM peeling is therefore to relieve tractional forces occurring around the fovea and to ensure that any epiretinal tissue that could cause foveal traction, including epiretinal membranes (ERMs), is removed.

Chromovitrectomy: using dyes to help visualize the ILM

Visualizing the ILM is challenging and staining by use of various dyes is necessary (Figure 6). Dyes used commonly include Indocyanine green, trypan blue and brilliant blue.

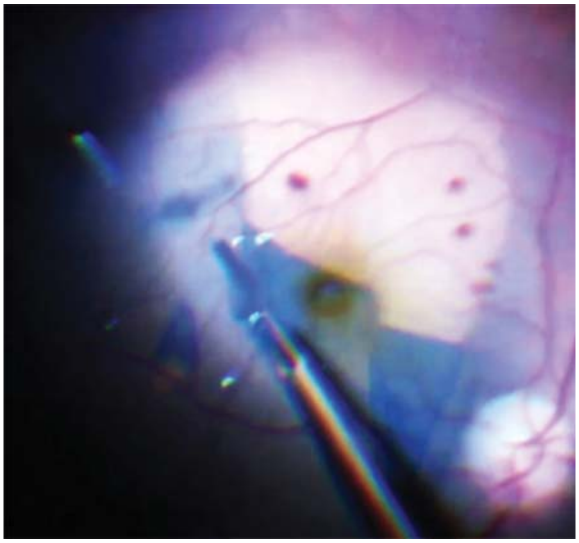


Figure 5: *Intraoperative image showing pars plana vitrectomy with ILM peel.*

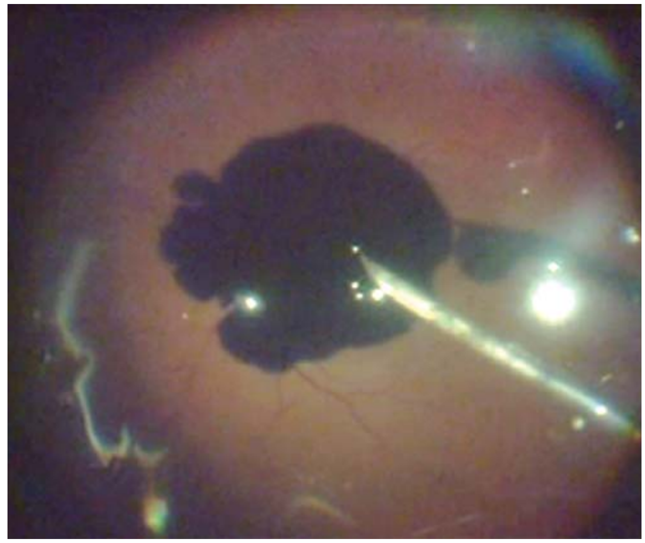
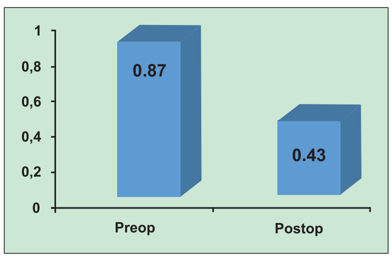


Figure 6: *Intraoperative image showing staining of ILM with use of dye.*



Graph 1: *Bar graph depicting pre and postop log MAR BCVA. Preoperative log MAR BCVA is 0.87 and postoperative log MAR BCVA is 0.43. This was statically significant. (p<.001)*

We did a retrospective study in 171 eyes of 168 patients with idiopathic macular hole to assess the anatomical success and functional safety and efficacy of dyes of different formulations of Brilliant Blue G dye for ILM staining in MH Surgery and also compare it to the earlier used dyes – Indocyanine Green and Trypan Blue.

We had a 97.7% closure rate (Figure 7) with no statistical difference in between groups. There was a significant improvement in log Mar BCVA postoperatively (p<.001) (Graph 1). 50% of our patients achieved postoperative vision of 20/40 or better (Table 1).

However recent trend has been to use brilliant blue in view of safety concerns with ICG dye[10].

Table 1: Postoperative line improvement in all patients and in different groups

Preop BCVA	All groups	ICG	Trypan Blue	Ocublue Plus	ILM Blue	Brilliant Peel
<20/60 (0.477)	2.3	0	2.7	1.8	1.9	3.0
20/60-20/200	3.4	3.7	3.8	2.9	3.9	2.3
>20/200	7.5	8.2	8.1	8.4	6.4	6.1

Newer innovations in Macular Hole Surgery

Inverted Flap technique: The inverted ILM flap technique was initially described by Michalewska et al[11]. They had reported anatomical closure in 100% of cases with macular hole size ≥400 µm. The technique involves placing small remnants of peeled ILM that are left attached to the hole margins on the macular hole upside down (Figure 8). The inverted ILM flap acts as a bridging tissue across the MH by covering it. The inverted flap has been found especially useful in highly myopic eyes and also in Macular hole associated with RD in myopes as these are cases generally associated with poorer rates of macular hole closure even after successful RD surgery.

Temporal flap technique: This is the modified original inverted ILM flap technique done for large MHs. In this a 2 disc diameters of ILM is removed from the temporal side of the fovea and inverted to cover the MH while leaving the nasal ILM in place. The advantage of this technique is that it decreases the risk of surgical trauma and dissociated optic nerve fibre layer appearance and provides same anatomical and functional results[12].

Autologous blood/plasma: This has been described mainly for two purposes. Dr Chakrabarti et al[13] described a macular plug consisting of autologous gluconated blood plug (AGBL) for closing macular holes without need for prone positioning or any tamponade. They found this to be a safe procedure especially in patients unable to maintain prone positioning. Lai et al[14] studied a modified technique of combining an inverted ILM flap and layering it with autologous blood for closing macular holes in high myopes with MH associated RD.

Autologous neurosensory retinal free flap. Drs Grewal and Mahmoud[15] described a new technique involving the use of an autologous neurosensory retinal free flap for closure of refractory myopic MHs with associated foveoschisis and/or RD. This technique involves harvesting an autologous neurosensory retinal free flap and positioning it over the refractory MH to provide a scaffold and plug for hole closure.

TAMPONADE AND POSTOPERATIVE POSITIONING

After MH surgery, the standard of care is still to maintain prone positioning for a period varying from one to two weeks. This places a burden on the patients and would lead to a certain

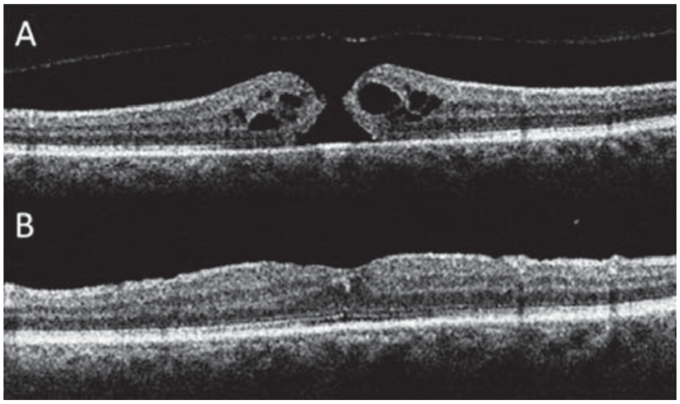


Figure 7: ***(Panel A)****: SD-OCT image showing full thickness MH and* ***(Panel B)*** *showing good Type 1 MH closure postoperative.*

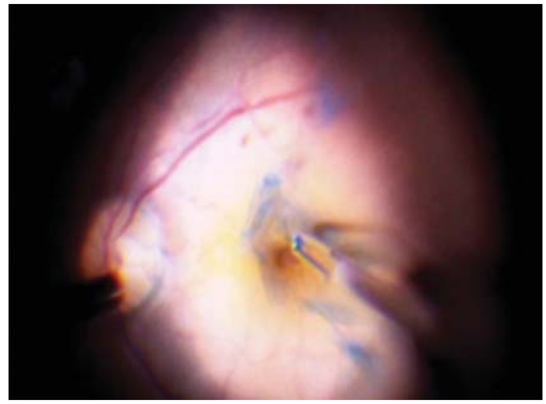


Figure 8: *Intraoperative image showing pars plana vitrectomy with inverted flap technique.*

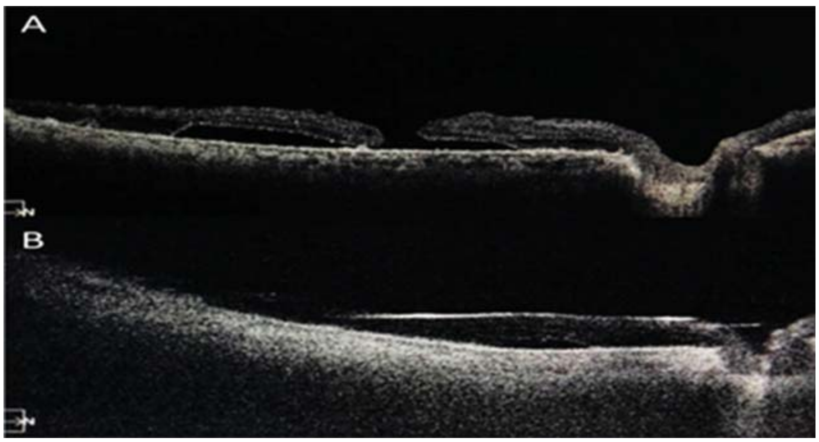


Figure 9: *Swept source OCT image* ***(Panel A)*** *with full thickness MH and* ***(Panel B)*** *taken at 1st postoperative day through gas bubble showing closed macular hole with persisting neurosensory detachment.*

subset of patients being excluded due to positioning issues.

Large number of studies have shown successful closure of various sixes of MH without prone positioning. Guillaubey et al[16] and Tadayoni et al[17] reported 87.5% and 91.4% MH closure, respectively, in their subgroups with no facedown positioning. Lange et al[18] reported a 60% closure rate in their subgroup with no face-down positioning, and only a 40% closure rate in MHs of more than 400 mm.

In contrast Iezzi et al reported 100% closure in their series of 68 macular holes of varying sizes and stages with no prone position. They attribute their success to broad area of ILM peeling of 8000 microns. They found that broad peeling (delamination) of a taut ILM may enhance overall retinal compliance by restoring the neurosensory retina's intrinsic elasticity, allowing it to relax after tangential forces are removed.

Avoiding prone positioning would have a major impact in MH surgery as most subjects are elderly and several are prone to orthopaedic issues. Ultimately the surgeon needs to decide what technique works well for him and then practice that technique.

OUR SURGICAL REGIME

We generally perform a wide area of ILM peeling (arcade to arcade) and use brilliant blue as the dye to stain the ILM. Tamponade used is generally SF6, however for larger holes C3F8 is used. Inverted flap technique is generally reserved for large macular holes or those in high myopes. We also perform inverted ILM flap in cases which develop macular hole post-surgery for other indications especially in myopic eyes.

With advent of Swept source OCT, we are being able to image the status of the MH on the first post-operative day through the gas bubble, unlike earlier when we used to wait for the gas to be absorbed. This could help in reduction of duration of prone postioning for the patient (Figure 9).

CONCLUSION

Technological advancements are pushing the boundaries of vitreoretinal surgery. This is especially true in the case of macular hole surgery where smaller gauge and refinements and modifications in technique like the inverted ILM flap are allowing closure of macular hole, which would have been considered untreatable a few years ago.

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