Internal limiting membrane peeling for large macular hole: Tailoring the rhexis to the shape of the hole

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Purpose: To report a simple modification of internal limiting membrane (ILM) peeling tailored to the shape of the macular hole to improve the closure rates. **Methods:** This is a single-center interventional case series. conducted between 2016 and 2020. The minimum follow-up was 4 months. All surgeries were performed by one surgeon. Twenty consecutive patients (21 eyes) with large idiopathic macular holes (horizontal diameter: ≥600 μm) were enrolled; vertical hole diameters were also measured using spectral-domain optical coherence tomography (OCT). Following vitrectomy, ILM peeling was performed over a horizontally oval area (additional 1 disc-diameter temporally); perfluoropropane gas (C_3F_8, 15%) tamponade was used. Hole closure and change in best-corrected visual acuity (BCVA) were monitored after absorption of the gas. Preoperative and postoperative visual acuities were compared using paired t-test. IBM SPSS (ver. 26) was used for analysis. **Results:** The macular holes were horizontally oval rather than circular without exception: mean horizontal and vertical diameters were 714 μm (range: 600–1020 μm) and 602 μm (490–844 μm), respectively. Following vitrectomy, macular hole closure was obtained in 20/21 eyes by the last follow-up (mean: 28 months, median: 34 months; range 4–48 months). Mean Snellen BCVA improved from 20/200 to 20/63 ($P < 0.0001$). **Conclusion:** All the macular holes in the study were observed to be horizontally oval. A corresponding horizontal enlargement of the ILM rhexis yielded excellent anatomical and satisfactory visual outcomes.

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Gass first classified idiopathic macular holes in a landmark study and therein defined "large" macular holes as one with a diameter of 400 μm or more.[1] Such holes are difficult to close and may not have central continuity of the photoreceptor layer after even clinical closure.[2] Michalewska *et al*.[3] proposed using a flap of internal limiting membrane (ILM) to close large macular holes. Further modifications of ILM flaps and alternative techniques such as retinal expansion, arcuate retinotomy, and autologous retinal graft continue to evolve.[4] We propose a rationale to focus on increasing the tissue compliance of temporal retina and tailor ILM peeling to the shape of the macular hole in order to enhance the chances of hole closure.

Methods

This was a retrospective study of 21 eyes of 20 consecutive patients with large macular holes (MH) who underwent surgical treatment at a tertiary eye care center between 2016 and 2020. Informed consent was obtained from all the patients before surgery. The study complied with the Declaration of Helsinki and was approved by the institutional ethics committee.

All patients underwent a complete ophthalmologic examination, including measurement of the best-corrected visual acuity (BCVA), slit-lamp biomicroscopy, indirect ophthalmoscopy, and optical coherence tomography (OCT) at the baseline and at follow-up visits (1, 3, 6 months after surgery, and 6-monthly thereafter). Fundus-camera based autofluorescence imaging (FAF, Topcon Medical Systems, TRC50X, Oakland, NJ) was used to confirm retinal pigment epithelial changes, when suspected by fundus picture.

Snellen BCVA was converted to logarithm of minimum angle of resolution (LogMAR) for statistical analysis.

The inclusion criteria were idiopathic full-thickness macular holes with a minimum linear diameter of ≥600 μm, subject's age >18 years, and a minimum follow-up of 4 months. The minimum linear diameter was measured using the built-in calipers function of OCT (Avanti, Optovue, Fremont, CA, USA) at the narrowest hole width in the mid-retina as a line drawn roughly parallel to the retinal pigment epithelium.[5] The shape of the macular hole was noted, and the diameter at right angles to the horizontal diameter was measured. We primarily used 10 × 2 mm scans (5 × 5 grid) for assessing the size and shape of the macular hole. The exclusion criteria included traumatic etiology, high myopia (≥6 D), or other

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ocular conditions that could influence the surgical outcomes. Comparison of preoperative and postoperative visual acuity was done using paired *t*-test. IBM SPSS version 26 was used for analysis. $P < 0.05$ was considered statistically significant.

Surgical procedure

Following 25G pars-plana vitrectomy and posterior vitreous detachment (where necessary), internal limiting membrane (ILM) was stained with Brilliant Blue G dye (Ocublue Plus, Aurolab, India). Trypan Blue 0.06% dye (Auroblue, Aurolab India) was also used in six cases where epiretinal membrane (ERM) was observed on preoperative OCT. An edge of the stained membrane was lifted and peeled off in a circular fashion around the hole about 2DD, close to the arcades. The temporal rim of the ILM rhexis was then extended to approximately 3DD from the macular hole [Video Clip 1]. Phacoemulsification and intraocular lens implantation were performed unless the subjects were already pseudophakic. Fifteen percent perfluoropropane (C3F8) gas was used for tamponade. The patients were instructed to maintain a face-down position for as long as feasible during the day for a week. At one month and thereafter, hole closure was assessed by OCT as open or closed, with Type 1 or 2 configuration.[2]

Results

The average patient age was 63.6 years (range: 47–76; median: 65); there were 17 women. All the macular holes were found to be horizontally oval on OCT [Fig. 1a-d]. The horizontal diameters ranged 600–1020 μm (mean: 714 μm), the vertical diameters were 490–844 μm (mean: 602 μm); the former were larger by a mean of 112 μ (median: 92 μm; range: 41–279 μm) [Table 1]. The mean preoperative logMAR BCVA was 1.1 (Snellen equivalent: 6/60; range: 1.6–0.6, median: 1.3). The mean follow-up was 28 months (range: 4–48; median: 34). At the final follow-up, macular holes closed in 20/21 (95%) eyes. Type 1 macular hole closure was achieved in 18/21 cases (85.7%) as shown in Fig. 2a-d. Two macular holes had a type 2 closure at the last follow-up [Fig. 2e and f]: both recorded improved BCVA (by 2 and 3 Snellen lines). The largest macular hole (1020-μm horizontal diameter) remained open, becoming marginally smaller (920 μm). The closure rates for the macular holes were similar between the older (>65 years age group; 10 patients; hole closure rate: 100%) and younger patients (≤65 years age group; 11 patients, hole closure rate: 91%) ($P = 1.000$). The mean duration of visual loss was 9.8 months (median: 6 months; range: 2–48 months). There was no significant difference in closure rates for macular holes <6 months old and those with symptoms for ≥6 months (91.7% and 100%, respectively; $P = 1.000$). By the last follow-up, external limiting membrane (ELM) was restored in 13 cases (62%); both ELM and ellipsoid zone (EZ) were restored in five cases (24%). All the patients registered an improvement in BCVA, including those with type 2 closure and open but smaller macular holes. Mean postoperative BCVA was significantly improved to 0.49 Log MAR. (Snellen equivalent: 6/18; range: 1–0.2; median: 0.5; $P = 0.0001$; (Wilcoxon Signed Rank test) [Table 1].

There were no significant intra-/postoperative complications. We documented dissociated nerve fiber layer in 15/21 cases, but it did not affect the outcomes. Transient capillary bleeds were noted intraoperatively during ILM peeling, especially in eyes with epiretinal membrane (10), but a retinal hemorrhage requiring any intervention was not observed in any case. Punctate pigmentary disturbances were discernible at the site of ILM peeling initiation/extension in six cases [Fig. 2b]. Eccentric scotomata were not documented by microperimetry; however, none of our patients complained of parafoveal scotoma.

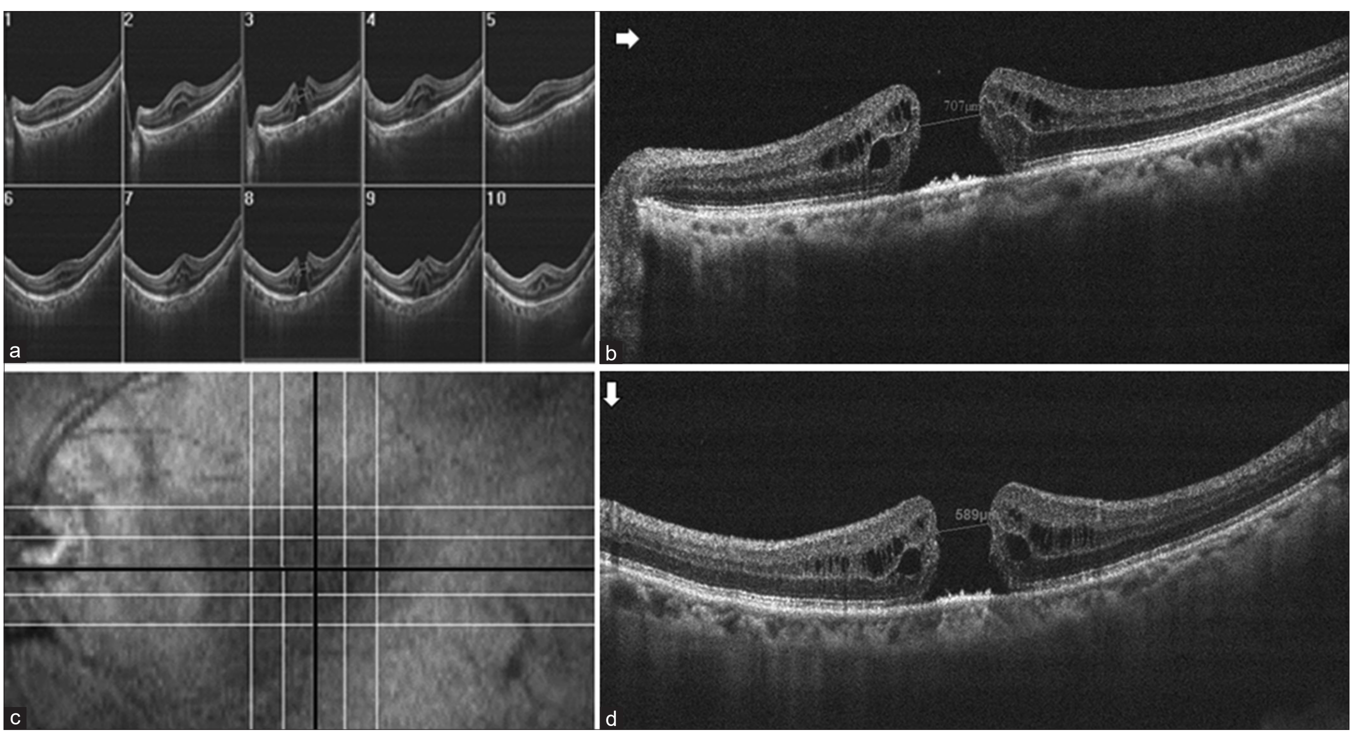

Figure 1: Despite the usual circular appearance, all the macular holes were horizontally oval when measured. (a and c) The 5 × 5 mm grid OCT scan output (Avanti Optovue) shows horizontal measurements above, and vertical measurements below the selected central scans (3 and 8) are highlighted in black. (b and d) The horizontal diameter is 707 μm while the vertical diameter is 589 μm

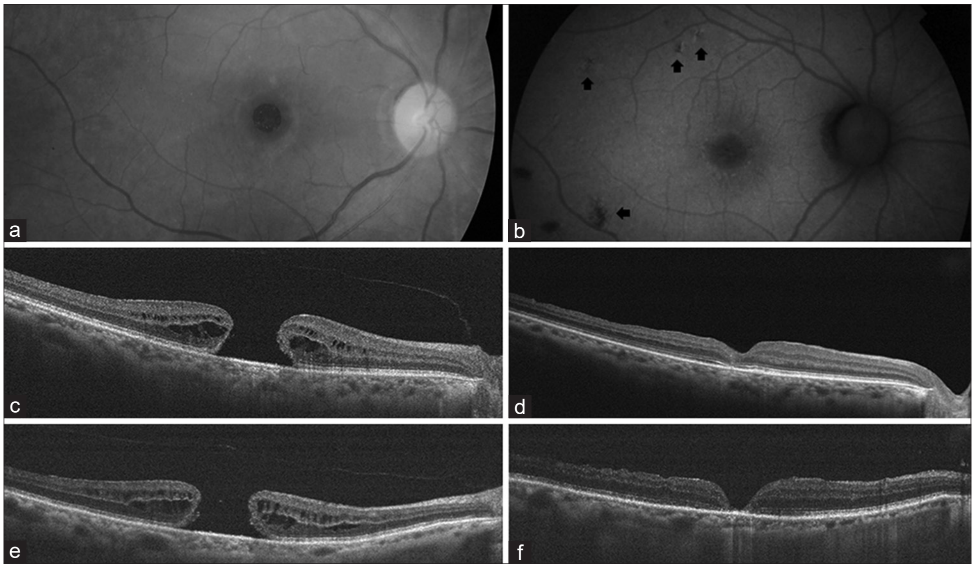

Figure 2: (a and c) The clinically circular macular hole in this 65-year-old lady measured 730 and 638 μm across horizontal and vertical diameters, respectively (horizontal scan shown). (b) Postoperative autofluorescence imaging reveals pigmentary disturbances (arrows) at the margins of the ILM-free area. (d) OCT reveals type 1 closure with central interruption of the external limiting membrane and ellipsoid zone. (e) This 76-year-old man presented with a larger macular hole (930 μm horizontally). (f) Postoperative OCT at 4 months shows the hole closed in a flat-open (type 2) configuration

Table 1: Patient demographics, macular hole dimensions, and postoperative visual outcomes

Age, sex	Preoperative BCVA	Horizontal hole diameter (m)	Vertical hole diameter (m)	Postoperative BCVA	Follow up (months)
76, M*	6/240	930	651	6/60	4
62, F	6/120	600	520	6/60	48
61, F	6/120	682	621	6/24	10
66, F	6/24	685	598	6/18	48
65, F	6/38	730	638	6/18	45
60, F	6/60	601	522	6/12	48
71, M	6/24	775	708	6/12	44
47, F	6/120	696	608	6/9	42
75, M	6/120	608	490	6/12	46
68, F	6/60	700	588	6/12	48
53, F	6/120	622	575	6/18	42
62, F†	6/60	1020	844	6/36	12
70, F	6/75	804	667	6/18	34
63, F	6/190	707	589	6/24	6
49, F	6/60	620	549	6/18	8
60, F	6/60	650	521	6/18	4
71, F‡	6/24	659	618	6/9	9
71, F‡	6/36	745	549	6/9	7
49, F	6/60	800	650	6/24	33
67, F	6/60	699	549	6/12	42
71, F	6/60	659	579	6/18	8

BCVA: Best-corrected visual acuity. *Macular hole closed in a type 2 (flat-open) configuration, †Macular hole became smaller but remained open, ‡Right and left eyes respectively of the same patient

Discussion

Surgery for macular hole began after Gass' landmark observations about its pathogenesis: As centrifugal migration of largely intact photoreceptors following a dehiscence at central umbo. Release of vitreomacular traction led to centripetal migration and restoration of the continuity of the photoreceptors. Gass stated that full-thickness idiopathic macular holes were "central round defects."[1] This clinical presumption about the shape of the macular hole remains undisputed to date, though it can be easily measured and verified. We observed that the macular holes were uniformly largest in the horizontal meridian, and report a consequent modification of ILM peeling based on the horizontally oval shape of macular holes. We were able to locate only one study in the literature that specifically referred to the oval shape of macular holes as part of the overall asymmetry in 3-D analysis. However, they did not highlight the implications of this finding except in a more accurate preoperative assessment of hole size.[6] By advancing the horizontal extent of ILM peeling by an extra 1DD on the temporal side, we successfully closed 95% of the macular holes, with visual improvement in all the eyes. The outer retinal bands (ELM and EZ) were restored more than a half and a quarter of the eyes, respectively; however, delayed structural recovery is common in large macular holes.[7]

In large, grade 4 macular holes, ILM peeling is mandatory to improve closure rates by releasing the tangential surface traction.[5] Though apparently thin and delicate, ILM is a surprisingly stiff and brittle membrane, which substantially contributes to retinal stability as well as rigidity. Therefore, removal of ILM improves retinal tissue compliance and allows elastic centripetal migration of the inner retina.[8] Though Michalewska *et al.* first reported successful closure of large macular holes (>400 μm) with a novel technique of ILM flap insertion, the Manchester Large Macular Hole Study recently advised that the term "large" should be reserved for much larger holes (>630 μm) as conventional ILM peeling up to the arcades could close >90% of the smaller holes.[9] A more recent and larger study has similarly shown a success rate of 97% for 400–500-μm macular holes and suggested a cut-off of 500 μm to define a large macular hole.[10] There are very few surgical studies on such extra-large (500–600 μm) macular holes.

Closure should be carefully evaluated in these holes as central bridging tissue may be mistaken for a type 1 closure. An ILM flap which overlies, rather than being stuffed into the macular hole, may be an ideal scaffold,[11] but it is frequently difficult to retain in place; not to mention the risk of iatrogenic foveolar damage during the maneuver. Another intuitive suggestion is to enlarge the area of ILM peeling, which has been reported to close 47%–69% of the refractory macular holes, though the extent of enlargement was not specified.[4] A recent randomized clinical trial reported no significant improvement in closure rates as the area of ILM rhexis was increased from 2DD to 4DD.[12] When the outcomes were stratified by the Macular Hole Closure Index (ratio of hole edge elevation to base diameter), the closure rates were very poor in the 2DD group (18%) and better—if only by comparison—in the 4DD group (76%). Further, this trial included a range of macular hole sizes (starting from 127 μm) and a smaller average hole size (484.5 μm) as compared to the present study. For macular holes 650 μm or larger, closure rates have been reported to fall to 76% in the Manchester study.[9]

We also peeled ILM over a vertical diameter of about 4DD like the previous studies;[9,12] but simply by extending the horizontal arc of IML rhexis by another 1DD, we were able to close more than 90% of the macular holes averaging 700+ μm in diameter. Temporal retina is more pliable[13] and is therefore better suited for relaxation by additional ILM removal, an idea further supported by the reports of temporal arcuate retinotomy,[14] temporal only ILM peeling,[15] and temporal flap.[16] The literature has repeatedly demonstrated the greater relevance of horizontal tangential traction for hole closure; we provide a rationale for these observations by showing that the macular holes—at least when large—are horizontally oval, not circular. Despite its simplicity, our technique had anatomic and functional success rates similar to or better than more complex and invasive procedures (autologous graft) using perfluorocarbon liquid in similar-sized macular holes.[17] The only macular hole that failed to close was the largest in the series (>1000 μm): It reduced in size by 100 μm, with 1-Snellen line of visual improvement. Similar partial success has been reported by Charles *et al*.[14] with arcuate retinotomy.

Conclusion

This study had the limitations of a small, uncontrolled, retrospective study. Therefore, we cannot claim that all idiopathic macular holes are horizontally oval. However, small macular holes close well with conventional ILM peeling; therefore, shape considerations are only empirical in them. Use of a long-acting gas prolonged the time to visual rehabilitation but was considered necessary in view of the hole size, as endorsed by a recent large study.[10] However, in this proof-of-concept study, we were able to demonstrate the horizontally oval shape of large idiopathic macular holes, and temporal extension of the ILM rhexis as an intuitive and successful treatment for the same. We are unaware of any previous report in the literature focusing on the shape of macular holes and treatment implications thereof. This technique needs to be validated by larger, prospective controlled trials against conventional, as well as popular modifications of ILM peeling for large macular holes.

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Conflicts of interest

There are no conflicts of interest.

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