Surgical Technique

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Modification of the Inverted Internal Limiting Membrane Flap Technique for the Treatment of Chronic and Large Macular Holes

Surgical strategies for the treatment of macular holes aim to relieve vitreo-foveal traction and promote flattening and reapposition of the macular hole edges by intraocular gas tamponade. Surgical treatment of an idiopathic macular hole is one of the most successful operations in vitreo-retinal surgery with closure rates of 90% to 98%.[1] However, this is dependent on factors such as the macular hole diameter, duration, age, and associated pathology.[2] Chronic and large macular holes have the poorest surgical outcomes with closure rates of 40% to 83%.[3,4] Different techniques have been used to improve the closure rates of such holes with variable success.[5,6]

In 2010, an inverted internal limiting membrane (ILM) flap technique was reported to increase the anatomical closure rates of large macular holes (minimum diameter > 400 μm) to 98% with corresponding functional improvement.[7] This technique is thought to prevent the postoperative development of a flat-open configuration that is common with large macular hole closure and limits visual outcome. This technique; however, is associated with a steep learning curve, and is limited by difficulty in maintaining the inverted ILM flap inside the hole during fluid-air exchange.[7] We describe here a technique that uses the principle of ILM folding to aid macular hole closure, with modifications that improve retention of the ILM flap on the macular surface, and that render the procedure suitable for redo cases where there is no ILM bordering the macular hole.

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Methods

The associated **Supplemental Digital Content 1** (see **Video**, http://links.lww.com/IAE/A419) demonstrates the key steps of the procedure. Intraoperative cross-sectional anatomy is highlighted with Intraoperative optical coherence tomography (Zeiss Rescan 700, Jena, Germany). Combined phacoemulsification and intraocular lens implantation is performed if the patient has significant lens opacity. A standard 3-port 25-gauge pars plana vitrectomy is completed. Unless it is preexisting, posterior hyaloid separation is induced and the posterior hyaloid is completely removed using triamcinolone-assisted visualization. Brilliant Blue G dye (Brilliant Peel; Geuder, Heidelberg, Germany) is injected over the macular through a 25-gauge soft tip cannula to stain the ILM for approximately 1 minute. Any epiretinal membrane is peeled away. The ILM is grasped with ILM forceps at a point away from the papillomacular bundle and an ILM-rhexis of approximately two disk diameters is peeled around the macular hole. Care is taken to ensure that the ILM-rhexis does not rupture while circumnavigating the hole and that a small attachment connecting the free ILM to the hole edge is preserved. This can be achieved by advancing the rhexis around the perimeter rather than near the margin of the hole and regrasping at the advancing edge of the peeled ILM.

The result is an ILM flap tethered to the hole's margin by an "ILM hinge." The area of the ILM peel is then extended to the major vascular arcades and to a distance of two disk diameters from fixation temporally. This ILM is discarded. The infusion port is turned off so that fluid currents do not agitate the ILM flap. The ILM flap is folded into the macular hole bed to fill the defect completely. In contrast to the technique described by Michelewska et al,[7] we use a simplified folding method whereby the mobilized ILM is placed into the bed of the macular hole by allowing it to crease and fold on itself in any orientation, thus obviating the need to ensure the flap is inverted inside the hole.

With the infusion still off, viscoelastic (OcuCoat; Bausch & Lomb, Rochester, NY) on a 25-gauge soft tip cannula is introduced into the vitreal cavity.

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Approximately 0.2 mL of viscoelastic is injected over the ILM flap, forming a "viscoelastic cap." Fluid-air exchange is performed using a 25-gauge soft tip cannula held nasal to the disk to reduce the risk of dislodging the viscoelastic cap. The procedure is completed with gas exchange to an isovolumetric concentration of perfluoropropane. All ports are checked for leakage and sutured if required. This technique can also be used in "redo" macular hole repairs after previous ILM peeling. In these cases, free fragments of ILM are placed inside the macular hole and secured there with a viscoelastic cap.

Postoperatively, the patient is advised to posture for 7 days to 10 days; face-down for 30 minutes of every hour during the day, sleeping on alternate sides at night. We obtained pre and postoperative best-corrected visual acuity, fundal photos, and spectral domain optical coherence tomography (SDOCT).

Discussion

To date, we have performed the modified ILM flap technique on 24 chronic large macular holes (duration >12 months, mean aperture diameter 527.7 μm). All macular holes (100%) were closed after a single procedure. Preoperative mean best-corrected visual acuity was 20/160. After a mean follow-up of 12 months, the mean best-corrected visual acuity was 20/60 ($P <$ 0.0001). At last follow-up, 23 eyes (95.8%) had experienced an improvement in best-corrected visual acuity and 87.5% of eyes achieved halving of the minimum angle of resolution. Figure 1 shows color fundus photographs and spectral domain optical coherence tomography scans of the preoperative appearance and the postoperative evolution of a macular hole in a patient who underwent surgery with this technique. The preoperative visual acuity was count fingers at 30 cm. At 2 months postoperatively, the folded ILM flap is visible as hyper-reflective tissue within the macular hole and the visual acuity is 20/200 (C). At 6 months postoperatively, there is further approximation of the edges of the neurosensory retina (D). The closed macular hole at this time point has a "U"-shaped configuration (the physiologic foveal contour), and the patient's visual acuity has improved to 20/80.

One of the difficulties in the inverted ILM flap technique described by Michalewska et al[7] was the high rate of accidental ILM detachment during the procedure. The advantages of our technique are conferred using a viscoelastic cap to improve retention of the ILM flap within the macular hole. Originally developed as a substitute replacement for vitreous, ophthalmic viscosurgical devices (OVDs) are composed of either sodium hyaluronate, chondroitin sulfate (biopolymers found in connective tissues), or hydroxypropyl methycellulose (a component of plant fibers). The physical properties of OVD vary with respect to their viscosity, viscoelasticity, pseudoplasticity, and surface tension depending on the molecular weight, size, and concentration of the constituents. Although the use of OVDs is established in anterior segment surgery, they have been less widely used in the posterior segment. Sodium hyaluronate has been used for viscodissection and viscodelamination in diabetic vitrectomy.[8] OVD has also been applied to the posterior pole to protect the retina from mechanical damage during fragmentation removal of a luxated crystalline lens or from chemical damage by indocyanine green during macular hole repair. Thus far, there have been no reports of toxic or other adverse effects of OVDs on the retina.

We used OcuCOAT, which is an isotonic, nonpyrogenic, dispersive OVD containing highly purified 2% hydroxypropylmethylcellulose with a molecular weight greater than 80,000 daltons. Its rheologic characteristics of moderate viscoelasticity, low surface tension, and low viscosity helps to retain the ILM inside the macular hole during fluid-air exchange. Other OVDs may be used, although dispersive OVDs are most suitable because of better retentiveness and ability to coat and adhere to tissues. In contrast to the technique described by Michalewska et al,[7] the viscoelastic cap allows our modified technique to be used even if the ILM hinge is broken during ILM-rhexis and in macular hole reoperations after a previous ILM peel.

The position of the ILM hinge can be allowed to vary on a case-by-case basis depending on the ease at which the ILM-rhexis is performed. We have not noted any particular location of the hinge to be superior. The function of the ILM hinge is to tether the ILM flap to the hole if it extrudes during fluid-air exchange. However, the viscoelastic cap alone is usually sufficient to secure the ILM flap inside the macular hole, as occurs in macular hole reoperations.

The improvements seen in macular hole closure rates and postoperative visual acuity is attributed to the fact that the ILM flap technique seems to promote a more favorable postoperative contour of large macular hole closure, in the form of a U-shape closure that is associated with better functional outcomes. It is thought that the presence of the ILM flap acts as a scaffold for glial cell proliferation within the hole, which subsequently stimulates some migration of photoreceptor cells toward the fovea.[7]

In conclusion, we present a modified ILM flap technique to improve retention of the ILM flap within the macular hole and improve the reliability and reproducibility of the operation. From our experience,

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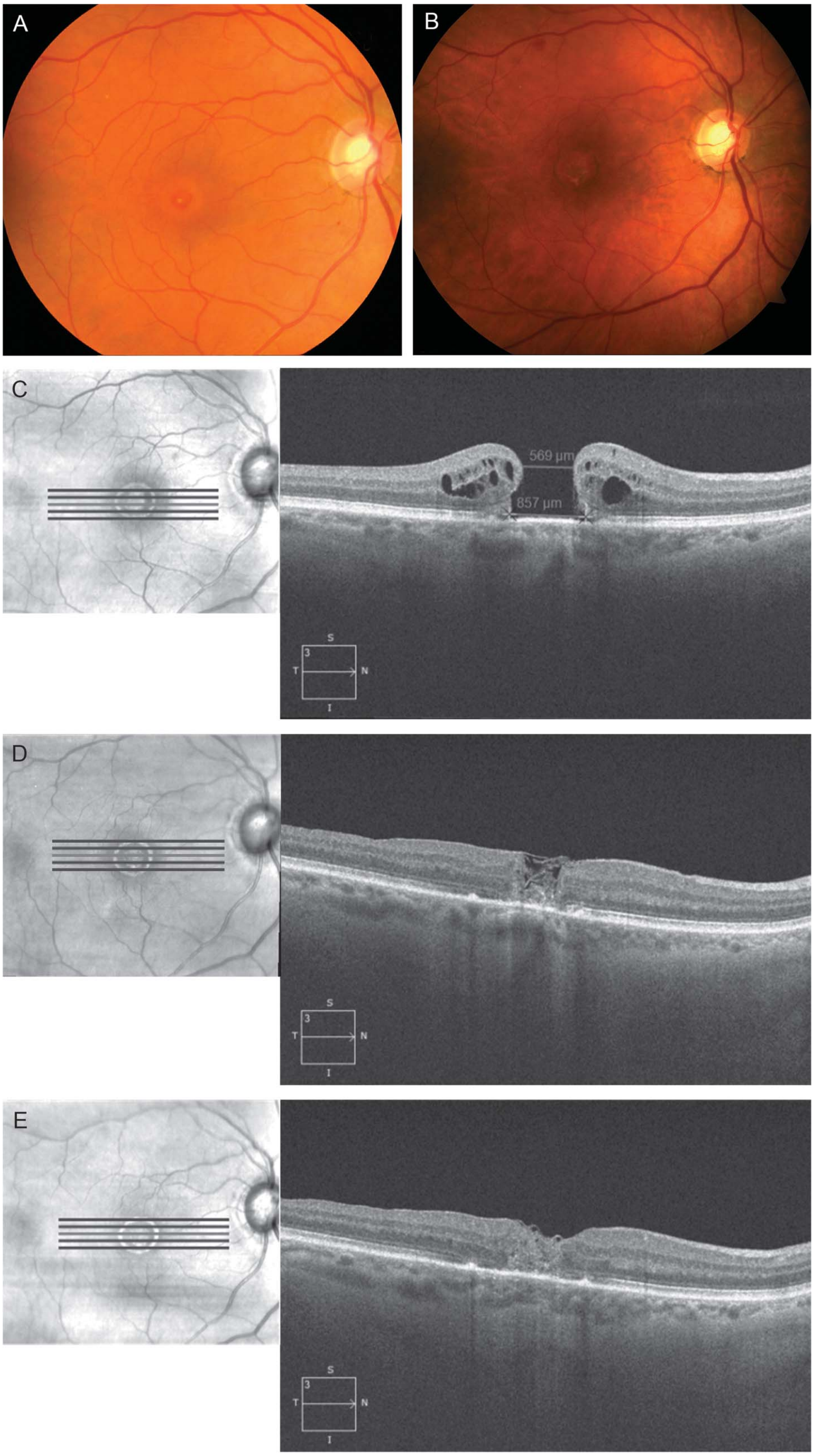

Fig. 1. Large macular hole of 13 months' duration in a 67-year-old woman treated using our modified ILM flap technique. Preoperative (**A**) and postoperative (**B**) color fundus photographs. **C–E.** Eye-tracked spectral domain optical coherence tomography raster images preoperatively (**C**) and at 2 months (**D**) and at 6 months (**E**) postoperatively. At 2 months, the folded ILM is visible as hyper reflective tissue. At 6 months, the macular hole has closed with a "U"-shaped foveal contour. Visual acuity improved from count fingers preoperatively to 20/80 at 6 months.

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folding of the ILM into the macular hole achieves good closure rates of large and chronic macular holes with associated visual improvement. Further long-term analysis and larger samples will help to determine the efficacy of this technique for the treatment of large chronic macular holes.

Key words: internal limiting membrane, macular hole, surgical technique.

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