Tapping of Macular Hole Edges: The Outcomes of a Novel Technique for Large Macular Holes

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Purpose: To describe the novel technique of tapping macular hole edges for holes with low macular hole index (MHI) and assess its outcomes.

Design: A prospective interventional study.

Methods: Twenty-eight consecutive eyes with idiopathic large macular holes (MHI < 0.5) were enrolled. A standardized surgical protocol was performed using vitrectomy with brilliant blue G dye-assisted large internal limiting membrane peeling, intraocular gas tamponade with 18% C3F8, and strict postoperative prone positioning for 5 days. Tapping of macular hole edges was performed on all sides using 23-gauge GreenTip soft tip cannula. Hole closure was examined postoperatively using optical coherence tomography.

Results: There were 16 females and 12 males aged 63 ± 14.38 years. The mean MHI was 0.32. Hole closure was seen in 25 eyes (89.29%). MHI was less than 0.25 in the 3 eyes with failed macular hole surgery. Epiretinal membrane (ERM) was present in 22 eyes (78.57%). The presence of ERM did not correlate with hole closure (P = 1.00). Continuity of external limiting membrane was a better predictor of functional success than inner segment/outer segment continuity (P < 0.05). Type I hole closure was seen in 20 (80%) of 25 eyes while the remaining 5 eyes (20%) had type II hole closure on optical coherence tomography. Corrected distance visual acuity improved significantly from 0.86 ± 0.2 logMAR preoperatively to 0.43 ± 0.22 logMAR postoperatively (P < 0.0001).

Conclusions: Newer technique of tapping macular hole edges provides acceptable anatomical and functional success rates even in large macular holes (MHI < 0.5).

Key Words: macular hole index, large macular holes, macular hole surgery

Since the initial reports by Kelly and Wendel who documented 58% anatomical success in macular hole surgery, various recent series suggest improved anatomical success rate of up to more than 90%. The surgical success rate may depend on various factors including duration of symptoms, stage of hole, adequacy of internal limiting membrane (ILM) peel around the hole, duration of gas tamponade, and diligent postoperative positioning.

Based on optical coherence tomography (OCT), macular hole index (MHI) has been proposed as an index reflecting macular deformation and includes both the horizontal and vertical dimensions of the macular hole representing tangential and anteroposterior vitreomacular traction. It was suggested that an MHI value of greater than 0.5 could be used to predict postoperative outcomes. In our series, we included patients with large macular hole with low MHI (MHI < 0.5) and analyzed their anatomical and functional success.

Materials and Methods

The study was performed in accordance with the ethical standards laid down in the Declaration of Helsinki. Informed consent was given by all participants prior for their inclusion in the study.

Twenty-eight consecutive patients with idiopathic large macular hole (MHI < 0.5) and symptoms of less than 12 months duration underwent macular hole surgery. A complete preoperative ophthalmologic examination including intraocular pressure measurement, lens status evaluation, refraction, and biomicroscopic examination of fovea and vitreous was done. Corrected distance visual acuity was measured using the Snellen visual acuity chart. Visual acuity was converted to logarithm of minimum angle of resolution (logMAR) scale for analysis. Biomicroscopic evaluation and Cirrus spectral domain optical coherence tomography (Carl Zeiss Meditec, Dublin, CA) of the macula was done. The height and base of macular hole were measured on OCT to enable us to calculate the MHI. The center of the macular hole was taken as the center of the base diameter (depicted in red) of the macular hole (Fig. 1).

Patients were examined 6 months postoperatively. Optical coherence tomography was repeated to look for hole closure. In the immediate postoperative visit (day 1), the presence of C3F8 gas precluded OCT examination. Hole closure was classified as type 1 closure or type 2 closure. Type 1 closure indicates that there is no interruption in the continuity of foveal tissue above the retinal pigment epithelial layer after surgery for macular hole. The normal foveal contour is usually encountered in type 1 closure. Type 2 closure indicates that there is an interruption in the continuity of foveal tissue after surgery. Thus, the retinal pigment epithelial layer is denuded. The hole edge is thinned and attached to the underlying retinal pigment epithelial layer. Continuity of inner segment/outer segment (IS/OS) junction and external limiting membrane (ELM) were also noted on OCT at all follow-up visits.

Statistical analysis was performed using STATA software (Statacorp, College Station, TX) and SPSS version 17.0 (SPSS, Chicago, IL). The arithmetic means, SDs, and frequency distribution were calculated for all the descriptive parameters. The χ² test and Fisher test (wherever applicable) were used to determine the significance of association between a risk factor and hole closure rate. P < 0.05 was considered to be statistically significant.

Surgical Procedure

The surgical technique consisted of standard 3-port pars plana vitrectomy and brilliant blue G dye-assisted ILM peel using intravitreal ILM forces (DORC, Zuidland, Netherlands). Arcade-to-arcade ILM peeling was done to include the entire...
macular area so as to maximize removal of tangential traction. Any epiretinal membrane (ERM), if present, was also peeled, which was highlighted after brilliant blue G instillation (negative staining).

An additional procedure of tapping of macular hole edges in all quadrants using 23 gauge GreenTip soft tip cannula/Tano diamond dusted soft silicone tip (DDMS; Synergetics, Inc, O’Fallon, MO) was performed under high magnification using irrigating plano-concave Machemer style contact lens (Fig. 2). This facilitates an intraoperative increase in the height of macular hole. Because MHI is defined as ratio of height to base, this maneuver translates into increased MHI and thus can contribute to macular hole closure even in cases of large holes. Peripheral vitrectomy was completed, and fluid-air exchange was performed. Eighteen percent of C3F8 gas was used for tamponade in all cases at the end of the surgery. No intraoperative or postoperative laser photocoagulation was applied to the hole margin or to the central retina. Patients were advised to maintain strict face down position for 5 days for 14 to 16 hours per day.

**RESULTS**

The mean (SD) age of the patients was 63 (14.38) years. There were 12 males and 16 females. Eighteen participants were pseudophakic, and 10 were phakic. The mean (SD) preoperative logMAR visual acuity was 0.86 (0.2), and mean (SD) postoperative logMAR visual acuity was 0.43 (0.22) \( (P < 0.0001; \) Fig. 3). The mean number of lines of improvement was 2.53 at 6 months postoperative period. Stage 3 macular hole was present in 19 eyes, and stage 4 macular hole, in 9 eyes. The mean MHI was 0.32.

**FIGURE 1.** A, Center of the macular hole was taken as the center of the base diameter (M) of the macular hole. B, Spectral-domain optical coherence tomography line scan image of a patient with large macular hole.

**FIGURE 2.** Intraoperative clinical photograph demonstrating tapping of the inner edges of the macular hole using Tano diamond dusted soft silicone tip (DDMS; Synergetics, Inc).
Participants were divided into 2 groups of anatomical success (As) and anatomical failure (Af) based on the postoperative closure of macular hole on OCT. Anatomical closure (As) was seen in 89.29% patients (25 eyes) including type 1 macular hole closure in 20 eyes (71.43%) and type 2 hole closure (flat-open) in the remaining 5 eyes (17.86%) with MHI values ranging from 0.25 to 0.44 (Fig. 4). In 3 eyes, macular hole failed to close (Af). The comparative parameters between the 2 groups, pertaining to mean age (in years), sex distribution, stage of macular hole, mean MHI, presence or absence of ERM, continuity of ELM, and IS/OS junction at 6 months are as shown in Table 1. Of the 25 eyes in group As, type I hole closure was seen in 20 eyes (80%), and type II hole closure, in 5 eyes (20%). None of the eyes in group Af had an MHI value of greater than 0.25. The mean (SD) number of lines of improvement at 6 months was 2.84 (0.85) in group As, whereas no improvement was seen in group Af (P = 0.004). The mean (SD) corrected distance visual acuity (log MAR) was 0.37 (0.14) in group As and 0.93 (0.13) in group Af (P = 0.004). ERM peeling was required in 22 (78.57%) of 28 eyes. Of these, 19 eyes were in the As group. ERM peeling was not found to be statistically correlated to the closure of macular holes (P = 1.00).

Both IS/OS and ELM were continuous in 6 eyes (CC), IS/OS was discontinuous and ELM was continuous in 16 eyes (DC), and both were discontinuous in 6 eyes (DD). Of the 6 eyes with continuous IS/OS and ELM (CC) and the 16 eyes with discontinuous IS/OS but continuous ELM, all were in group As. Of the 6 eyes where both IS/OS and ELM were discontinuous, in 3 eyes, the macular hole had failed to close (Af); in the remaining 3 eyes, the hole had closed anatomically but both the IS/OS and ELM were discontinuous (P = 0.002). The mean age (in years), mean MHI, and mean number of lines of improvement from baseline in CC, DC, and DD eyes are shown in Table 2. There was no statistically significant difference in these eyes for age (P = 0.30) or MHI at baseline (P = 0.36). When the postoperative gain in visual acuity was compared,
there was a statistically significant difference between groups CC and DD ($P = 0.003$) and between groups DC and DD ($P = 0.03$), but not between groups CC and DC (0.22). No significant complications were noted in any of the study participants during the 6 month follow-up period. Progression of nuclear sclerosis was observed in 2 of the 10 phakic eyes.

**DISCUSSION**

Macular hole index is considered representative of preoperative macular deformation. Kusuhara et al$^3$ have demonstrated significant correlation between the MHI, the base diameter, and the minimum diameter of the hole, which suggests that the MHI value reflects the horizontal extent of the hole and preoperative perpendicular deformation of the macula. Their study has also shown that holes with greater MHI values (>0.5) represent eyes with a limited extent of preoperative macular deformation and therefore would benefit most from surgery and could be used to predict postoperative visual acuity.$^3$

We included all eyes with idiopathic large macular holes with MHI less than 0.5 in our study. Hole closure (type 1 and type 2) was achieved in 25 eyes (89.29%) with MHI values ranging from 0.25 to 0.44. All eyes with anatomical failure had MHI less than 0.25. ERM was present in 22 (78.57%) of the 28 eyes undergoing surgery and may suggest that large holes with large base diameters and small height (low MHI) are frequently associated with ERM. In most cases, tangential macular traction from posterior vitreous cortex is the primary causative factor for idiopathic macular hole formation, whereas ERM seems to be a proliferative response of retinal glial cells, which may contribute to hole enlargement. Cheng et al$^5$ have previously reported a positive association between macular hole size and ERM, suggesting that ERM may develop after macular hole formation and over time the average grade of ERM associated with macular holes increases as the hole size increases. In our series, ERM peeling was not found to be statistically correlated to the closure of macular holes. Consistent with previous studies, significant visual acuity gain was seen in eyes with anatomical success; however, we did not analyze the correlation between MHI and visual acuity gain.

In view of large base diameters and low MHI, we incorporated a new adjuvant surgical maneuver of intraoperative tapping of macular hole edges in all quadrants from the inner side. This facilitates an in situ increase in perpendicular height of macular hole compared with the base diameter, thus translating to an intraoperative increase in MHI. However, there are no available reports in relation to this technique. The edges of macular hole were not grasped. Rather, the edges were tapped from the inner side of the hole. Thus, retinal pigment epithelial defects were not observed in our patients during follow-up as previously reported.$^6$

Various techniques to improve the anatomical and functional outcomes of large macular holes have been described with good results. Charles presented "arcuate partial retinotomy" close to the macular hole. $^7$ This technique was described as a dissection of the nerve fiber layer. Alpatov et al$^8$ reported the mechanical closure of stage II to IV macular holes by mechanically bringing the edges of the macular hole close to each other and compressing the edges using forceps. It was retrospectively compared with an earlier group of patients who had standard vitrectomy and ILM peeling and found improvement in anatomical success from 86% to 92%. Michalewska et al$^9$ have described the inverted ILM flap technique to increase the success rate in cases of large macular hole and have reported type 1 hole closure in most of the cases. All these techniques result in glial cell proliferation facilitating macular hole closure by proliferating cells. In contrast to this, in our technique, we attempt to increase the MHI intraoperatively by mechanically tapping the edges of the macular hole, in addition to inducing glial cell proliferation. It also minimizes structural damage because the edges are not grasped or pulled together and damage to the nerve fiber layer is kept to a minimum.

The ILM represents the structural boundary between the retina and the vitreous and is formed by projections from the Muller cell footplates. The rationale for peeling the ILM is to ensure thorough removal of any tangential tractional component. Internal limiting membrane peeling might also promote glial repair by inducing local expression of growth factors and reduce the possibility of late reopening of surgically closed holes by removal of a potential scaffold for repopulation of myofibroblasts. Thus, an adequate ILM peel in itself may be sufficient to induce glial cell proliferation and repair. In addition, complete ILM removal is important to ensure adequate removal of tangential traction. Thus, arcade-to-arcade peeling of ILM was carried out in all our cases.

In addition, the aforementioned studies have defined "large" macular holes based on the base diameter rather than the MHI, which has been used in the present case series. The MHI is a

### TABLE 2. Preoperative Age, Baseline MHI, and Postoperative Vision Improvement in Eyes With CC, DC, and DD

<table>
<thead>
<tr>
<th>Group</th>
<th>CC</th>
<th>DC</th>
<th>DD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>67.33 (5.24)</td>
<td>59.75 (18.27)</td>
<td>65.67 (0.58)</td>
</tr>
<tr>
<td>MHI</td>
<td>0.37 (0.08)</td>
<td>0.33 (0.07)</td>
<td>0.29 (0.07)</td>
</tr>
<tr>
<td>Lines improved</td>
<td>3.33 (0.52)</td>
<td>2.88 (0.81)</td>
<td>1.67 (0.58)</td>
</tr>
</tbody>
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more sensitive indicator indicating the prognosis as compared with the base diameter alone. Because the MHI is defined as the ratio between height and base diameter, a higher MHI value indicates a smaller horizontal and a greater perpendicular hole dimension, which are more amenable to closure. Despite larger base diameter and shorter perpendicular dimension in our series, the macular holes responded well to surgery, supporting our hypothesis that tapping of the inner edge of the hole may increase the MHI contributing to hole closure.

Furthermore, the importance of posturing with intraocular tamponade cannot be over emphasized in these cases. Intraocular tamponade after vitrectomy for macular holes is believed to facilitate reapposition of the hole edges by providing buoyant forces that push the retina against the underlying retinal pigment epithelium and provide an interface with the vitreous fluid component that serves as a template for a fibrin membrane and glial migration across the macular hole. It is also suggested that the tamponade agent might address intraretinal hydration by preventing subretinal recruitment of vitreous fluid through the hole. We have made use of long-acting gas C3F8 (18%) in all cases to provide a longer tamponade, which may be an important factor contributing to success in these cases with low MHI. The force is greatest at the apex of the arc of contact, and by sustaining an accurate face-down position, the maximum vector forces can be directed against the macular hole.

Face down positioning for a period of 5 days was advised in all our cases. The requirements for postoperative posturing might be decreased proportional to the adequacy of the ILM peel and inversely proportionally to the size of the macular hole. Since our cases had a low MHI, postoperative posturing for a period of 5 days at least for 14 to 16 hours per day was advised in all cases.

Optical coherence tomography was also used to classify cases based on continuity of IS/OS junction and ELM as CC, DC, and DD as described previously. It was seen that eyes where both the IS/OS and ELM were discontinuous had significantly worse visual acuities compared with the other 2 groups. However, visual acuity was not significantly different in eyes with IS/OS discontinuous and ELM continuous as compared with eyes where both were continuous. This implies that continuity of ELM is a more important predictor of functional success represented by postoperative gain in visual acuity than continuity of IS/OS junction. Our results are in agreement with those of Emi Ooka et al., who had shown that the restoration of not only the IS/OS junction but also that the ELM may reflect the morphologic and functional recovery of the foveal photoreceptors in surgically closed macular holes. However, previous studies have reported IS/OS continuity and the size of the IS/OS defect to be associated with visual outcomes after macular hole surgery. In addition, Moshefighi et al in a retrospective review of 2 cases postulated that an outer retinal defect by OCT may occur in the early postoperative period after macular hole surgery, despite which good visual acuity is possible.

The present study also has several limitations. The sample size was small and there were no controls to compare our new technique with. However, before institution of this new technique, the surgical outcomes in patients with large macular holes who were operated on by the same surgeon were not very encouraging. A retrospective review of our previous cases has shown anatomical success in 2 of 10 patients. We also did not have intraoperative OCT for objective documentation of change in MHI. In addition, the flat open and failed macular hole cases were not reoperated. However, there was no deterioration in vision after surgery.

These results and observations demonstrate that with a meticulous surgical technique, good success rate can be achieved even in large macular holes with MHI as low as 0.25. A large number of these cases are often associated with ERMs. The important factors determining anatomical and visual success in these cases may be meticulous removal of the ILM and ERM, tapping of the macular hole edges, and intraocular tamponade with a long-acting gas with diligent postoperative prone positioning for up to 5 days. However, further comparative studies will be required to prove the efficacy of this new maneuver and assess its utility for large macular holes with low MHI.

REFERENCES