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Surgical treatment of idiopathic macular holes with a fovea-sparing technique and 20% SF_6 gas tamponade

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Purpose: *To assess the macular hole (MH) closure rate and final visual acuity after idiopathic MH treatment with a modified fovea-sparing technique and 20% SF6 gas tamponade.*

Material and Methods: *Fifteen patients (16 eyes; 12 women and 3 men; mean age (standard deviation or SD), 65.5 (5.90 years)) with Gass stage 2 to stage 4 MHs were involved in the study. Before surgery, mean best-corrected visual acuity (BCVA) (SD) was 0.15 (0.09), and mean MH diameter (SD), 437.2 (164.7) µm. Patients underwent surgical treatment with the modified fovea-sparing technique and 20% SF6 gas tamponade of two-week duration and were instructed to maintain a face-down position for a week after surgery.*

Results: *At 1 month after the first surgery, MHs were closed in 11/16 eyes (68.75%). In addition, mean BCVA (SD) in eyes with closed MHs improved significantly from 0.15 (0.09) to 0.48 (0.16) (p = 0.000000). Of the five eyes in which the MH had failed to close after primary fovea-sparing surgery, two received a gas fluid exchange gas tamponade with 15% C3F8, and these patients were advised to maintain a face down position for 3 more weeks. In addition, in another two eyes, the vitreous cavity was revised, and the internal limiting membrane (ILM) was removed by a conventional technique with 15% C3F8 gas tamponade. Moreover, one patient rejected repeat intervention. In the four eyes in which the MH had failed to close after primary fovea-sparing surgery, after a repeat intervention, the MH was closed, and mean BCVA (SD) improved to 0.35 (0.04). There was no significant difference between the eyes in which the MH failed to close and the eyes in which the MH did close after primary surgery in terms of mean MH size (SD) (455 (203) µm versus 415 (155) µm, p = 0.66) or MH duration.*

Conclusion: *A long gas tamponade (longer than 1 week) is required to improve the closure rate with the fovea-sparing ILM peeling technique for idiopathic MHs.*

Keywords:

idiopathic macular holes, internal limiting membrane, vitrectomy, ILM peeling, fovea-sparing technique

Introduction

Macular hole (MH) was first described by Knapp in 1869 in a patient with blunt ocular trauma [1]. Non-traumatic macular holes have been named idiopathic. A study in the United States reported that idiopathic MHs affect 7.8 people per 100,000 population per year. The female to male ratio was determined to be 3.3 to 1, and bilateral idiopathic macular holes occurred in 11.7% of patients and accounted for 20.9% of the affected eyes. Idiopathic MHs are most commonly seen in older adult women usually in the seventh and eighth decades of life [2, 3].

In 1991, Kelly and Wendel first demonstrated the efficacy of pars plana vitrectomy in the treatment of idiopathic MHs. In 30 (58%) of 52 patients, they were able to reattach successfully the detached macula with their surgical procedure. In 22 (73%) of the 30 patients in whom the macula was successfully reattached, there was an improvement in visual acuity [4]. In 1997, Eckardt and colleagues [5] reported on clinical results of vitrectomy with posterior hyaloid removal and internal limiting membrane (ILM) peeling for idiopathic MHs, and noted that the technique enabled anatomic and functional success. Further clinical studies reported that, although macular hole surgery with ILM peeling leads to very good and stable functional and anatomical results [6], it has shortcomings, and may lead to an abnormal interrelationship between outer and inner segments of photoreceptors; defects in the photoreceptor layer; cysts in the outer retinal layers; abnormal blood supply to the internal retinal layers, etc. [7-11].

A number of fovea-sparing techniques for the surgical treatment of macular holes have been proposed. In these techniques, at least part of the ILM around the MH is preserved to reduce trauma to the perifoveal retinal and Muller cells [12-13].

The purpose of the study was to assess the macular hole (MH) closure rate and final visual acuity after idiopathic MH treatment with a modified fovea-sparing technique and 20% SF6 gas tamponade.

Material and Methods

This was a prospective, open label, interventional study.

The study followed the ethical standards stated in the Declaration of Helsinki. Informed consent for the surgical procedure (vitrectomy) was obtained from the subjects after explanation of the nature of the study.

Fifteen patients (16 eyes) received the modified fovea-sparing technique. Of these, 3 were men and 12, women, including a woman who received surgery on both eyes. Patient age ranged from 50 to 74 years, and the mean age (SD) was 65.5 (5.9). Inclusion criteria were the presence of stage 2 to stage 4 holes as per the classification by Gass; the capacity to follow recommendations, and clear optic media. Exclusion criteria were history of vitrectomy, myopia higher than -6.0 diopters (D), or the presence of age-related macular degeneration, glaucoma, diabetic retinopathy or other retinal or choroidal vascular disorders.

Preoperatively, patients underwent a routine eye examination, including refractometry, visual acuity assessment, tonometry, biomicroscopy, binocular ophthalmoscopy with dilated pupils and a 90D lens, and optical coherence tomography (OCT) of the macula. For the clinical analysis, macular hole size was measured using callipers in the 'retinal thickness analysis' mode, the scan with the largest distance between edges of the hole was taken to be the most accurate. From the chosen scan the shortest distance across the full-thickness defect was defined as the size of the hole.

A three-port pars plana vitrectomy was performed under visualization using a wide angle non-contact BIOM system with a Constellation 25-G instrument (Alcon, TX, USA). All eyes had a natural lens, but phacoemulsification was not performed, since visualization was sufficient for performing vitrectomy. After the posterior hyaloid membrane was separated from the retinal surface and removed, the ILM was exposed to the TwinTM dye (Alchimia, Ponte San Nicolò, Italy; composed of 0.18% Trypan Blue + 0.03% Blulife dye) for about 20-30 seconds. An ILM flap was created about 1.5 disc diameter (DD) temporally from the IMH, thus leaving a 0.3-0.5-DD piece of the ILM attached to the edge of the IMH. The flap was folded over the hole to block it. A viscoelastic drop was introduced to stabilize the flap, if required. The Michalewska and colleagues (2015) method [14] was used as a prototype, although in their method, peeling of the ILM was restricted to the temporal margin of the macular hole only [14]. Fig. 1 shows the steps in the formation of the flap.

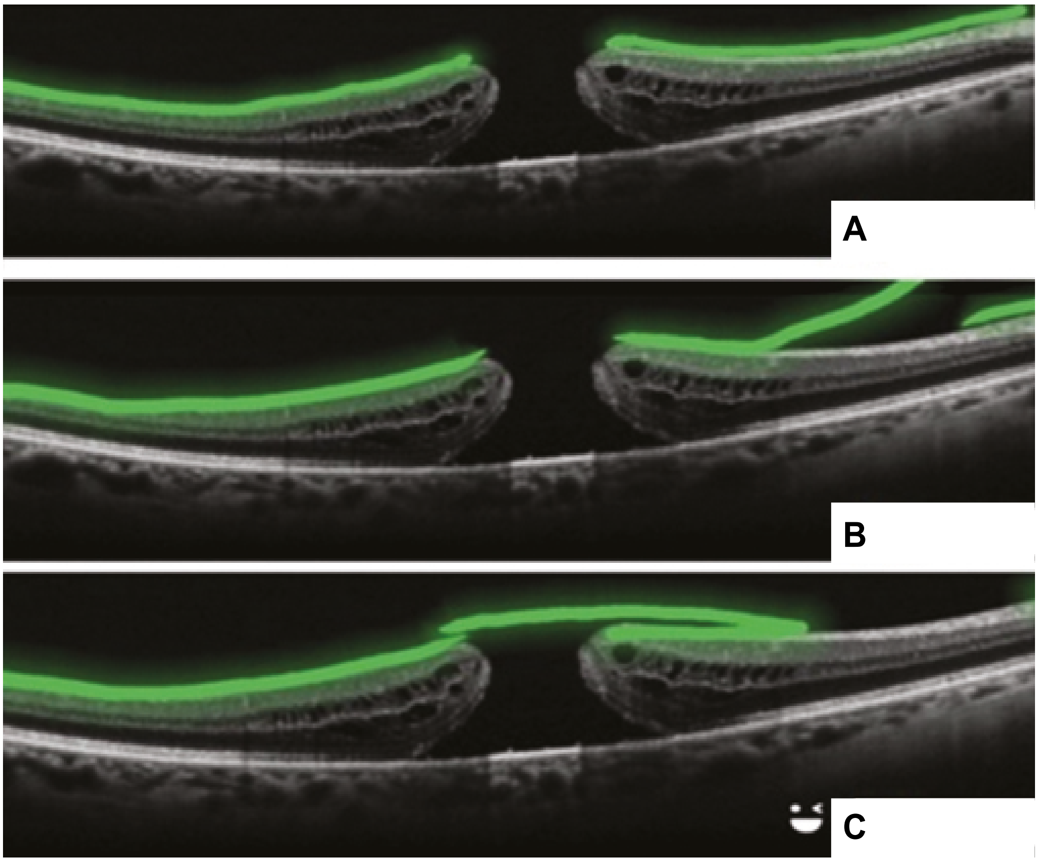

Fig. 1. Steps in the formation of the inverted inner limiting membrane (ILM) flap. A. Stained ILM. B. Initiation of the formation of the ILM flap. C. The newly formed ILM flap is not removed from the edge of the macular hole and is folded over the hole to block it

In addition, 20% SF6 endotamponade was performed, and, postoperatively, patients were asked to maintain a face down position for a week. The gas bubble vanished over about two weeks.

Patients were followed at 1 month and 2 months after surgery to assess the state of the macular area and visual acuity. We also assessed possible correlations of the final visual acuity with preoperative clinical characteristics.

Statistical analyses were conducted using Statistica 8 (StatSoft, Tulsa, OK, USA) software. Data are presented as mean (with standard deviation (SD) in parentheses). Student t-test for dependent samples was used to determine statistical significance. The level of significance $p \leq 0.05$ was assumed. Spearman rank-order correlation was used to assess associations.

Results

Before surgery, best-corrected visual acuity ranged from 0.02 to 0.25 (mean (SD), 0.15 (0.09); minimum MH diameter, from 197 µm to 769 µm, (mean (SD), 437.2 (164.7) µm); and MH duration, from 2 weeks to 3 years (mean (SD), 7.84 (8.84) months). Particularly, in 4 of the 16 study eyes, MH duration before surgery was at least a year.

At 1 month after the first surgery, MHs were closed in 11/16 eyes (68.75%). In addition, mean BCVA (SD) in eyes with closed MHs improved significantly from 0.15 (0.09) to 0.48 (0.16) ($p = 0.000000$). It is noteworthy that, even in eyes with an open MH after primary surgery, there was a non-significant reduction in MH size, and mean BCVA (SD) somewhat improved from 0.09 (0.08) to 0.2 (0.6). Figure 2 shows an MH that failed to close after the first fovea-sparing procedure.

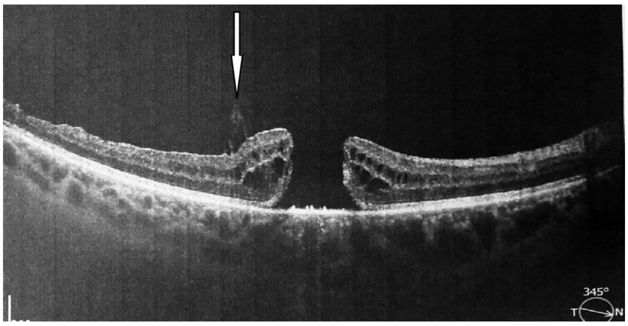

Fig. 2. Non-closure of the macular hole. A white arrow points to the ILM flap that is seen turned away from, and does not cover the hole.

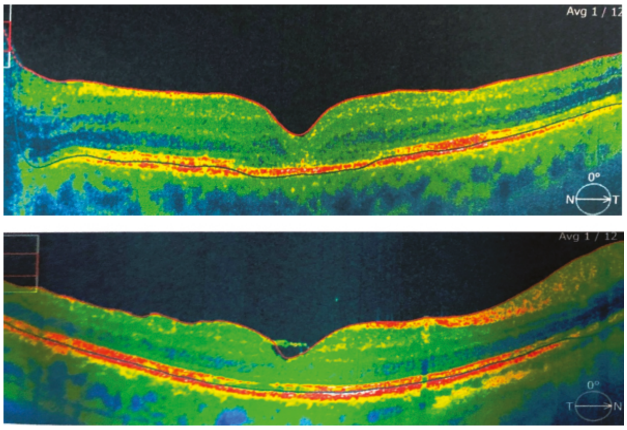

Fig. 3. Variants of macular hole closure. A, a macular hole closure with the preserved internal and external retinal layers, but the ILM flap is not seen on OCT. B, a macular hole closure with the preserved internal and external retinal layers. The ILM flap is seen above the foveola.

We believe that the MH failed to close after the first fovea-sparing procedure due to fast gas absorption in 2 eyes, and due to non-compliance with the requirements for maintaining a face down position for a week in 3 patients.

The two patients with fast gas absorption received a gas fluid exchange gas tamponade with 15% C3F8 according to our previously reported method [15], and were advised to maintain a face down position for 3 more weeks. This resulted in MH closure in the two eyes. In another two patients in whom the macular hole failed to close after the first procedure, the vitreous cavity was revised, and the ILM was removed by a conventional technique with 15% C3F8 gas tamponade and recommendations to maintain a face down position for 2-3 more weeks. This also resulted in MH closure in the two eyes. One patient rejected repeat surgery. Therefore, the percentage of MH closure after the initial surgery or re-surgery was 93.75%.

There was no significant difference between eyes in which the MH failed to close and eyes in which the MH did close after primary surgery in terms of MH size (mean (SD), 455 (203) µm versus 415 (155) µm, $p = 0.66$) or MH duration (MH duration was not longer than 1 month in 4 eyes, and was 1 year in only one eye). It is noteworthy that, in all eyes, macular hole closure pattern (MHCP) was 1A as per the classification by Rossi and colleagues (2020) [16], that is, with reconstitution of all (inner and outer) retinal layers [16]. Figure 3 shows variants of IMH closure after the described procedure.

The results of surgical treatment are presented in Table 1.

With additional interventions in 5 eyes, 15 eyes had their macular holes closed, and mean BCVA (SD) significantly improved to 0.45 (0.16) ($p=0.000000$).

We found a statistically significant correlation of the final BCVA with the preoperative BCVA ($r = 0.72$ $p < 0.05$), but not with the MH size, patient age, or MH duration.

Discussion

The photoreceptor layer at the foveola is entirely cones, and axons from these densely packed central photoreceptors are laterally displaced. Where they meet their corresponding bipolar cells and subsequent ongoing connections, they form a thickened rim to the central pit. The displacement of fibres away from the foveal centre is hypothesised to have occurred phylogenetically to reduce light obstruction to the central densely packed cones to maximize visual acuity. Muller cells ensheath the cone

Table 1. Baseline characteristics and treatment outcomes of patients with macular holes

№	Male/Female	Age (years)	Minimum hole diameter (μm)	BCVA before surgery	Hole closure	BCVA before repeat intervention	BCVA after hole closure
1.	Male	72	198	0.25	+		0.6
2.	Male	65	420	0.17	+		0.45
3.	Male	65	255	0.04	-	0.25	0.4
4.	Female	68	380	0.2	+		0.7
5.	Female	65	755	0.03	+		0.3
6.	Female	65	377	0.3	+		0.7
7.	Female	50	658	0.2	+		0.7
8.	Female	69	350	0.1	+		0.4
9.	Female	58	550	0.17	+		0.3
10.	Female	58	450	0.2	+		0.4
11.	Female	59	511	0.12	+		0.5
12.	Female	71	332	0.2	-	0.25	0.35
13.	Female	60	371	0.04	+		0.25
14.	Female	74	345	0.12	-	0.17	0.35
15.	Female	64	769	0.02	-	0.12	0.3
16.	Female	60	375	0.04	-	0.08	

Note: BCVA, best-corrected visual acuity; ILM, internal limiting membrane

axons anatomically and also support their physiological functions [17]. The increasing refractive index together with their funnel shape at nearly constant lightguiding capability make Muller cells ingeniously designed living optical fibers in the retina [18].

Therefore, these anatomic interrelationships should be preserved to restore optimal vision after macular hole surgery. When the ILM is peeled, some end feet are avulsed with Muller cell damage [19, 20]. During MH formation the foveal centre cones are avulsed from the RPE and extend up the sides of the MH, but still maintain their Muller cell sheaths and therefore remain connected with the perimacular hole ILM. By avoiding peeling this important region of ILM, we hypothesize that Muller cell integrity is better maintained and allows improved foveal shape reformation, and superior postoperative visual acuity as a consequence.

In most reports on various techniques of foveal sparing ILM peeling for IMH, 20% SF6 gas was used as a postopetative tamponade agent, and patients were instructed to position face down for not more than 7 days [12, 13]. In addition, 20% SF6 gas tamponade is believed to be more effective in classical ILM peeling [21]. We also decided to use a routine 20 % SF6 tamponade, but, with this tamponade, only 11 of the 16 eyes (68.75%) exhibited macular hole closure.

In a study by Ho and colleagues [12], all patients included in the study were diagnosed with early stage 2 idiopathic MH according to the Gass classification. MH closure was achieved in 14/14 eyes in the foveolar ILM non-peeling group, and restoration of the umbo light reflex was found in 12 of 14 eyes in this group (86 %) but none in the total peeling of foveal ILM group. It is noteworthy that, in a study by Morescalchi and colleagues (2020) [12], in the fovea-sparing group, although MH closure was seen in 22 eyes (100%), separation of the neuroepithelium from the RPE was observed in 14/22 eyes, and resolved spontaneously within 4 months to 12 months [13]. Therefore, it is possible that, in eyes with foveal-sparing ILM peeling for IMHs, in addition to exerting a protective effect, ILM remnants in the foveal region relieve tangential traction to a lesser extent, and, consequently, require longer gas tamponade. This is confirmed by the fact that an additional 21 day-long tamponade (without a repeat transvitreal surgery) enabled achieving MH closure in the two eyes in which the MH had failed to close after primary fovea-sparing surgery. In addition, we believe that a longer acting gas tamponade allows keeping the flap in the correct position for a sufficiently long time for MH closure.

Conclusion

First, the foveal-sparing technique using the ILM folded flap for IMH closure allows obtaining an adequate pattern of MH closure. Second, the rate of IMH closure after the modified foveal-sparing ILM peeling technique with 20% SF6 gas tamponade was 68.7%, which is not adequate. Finally, a long gas tamponade (longer than 1 week) is required to improve the efficiency of the technique.

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Disclosures

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Abbreviations: *BCVA, best-corrected visual acuity; ILM, internal limiting membrane; IMH, idiopathic macular hole; DD, optic disc diameter*