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Original Article

Temporal Inverted Internal Limiting Membrane Flap Technique for the Treatment of Macular Holes

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ABSTRACT

Objective: To determine the anatomic and functional outcomes of macular hole surgery with the temporal inverted flap technique.

Methods: In this retrospective study, 9 eyes of 9 patients, who were treated with pars plana vitrectomy using the temporal inverted flap technique and had at least 6 months of postoperative follow-up were enrolled. Best-corrected visual acuity and spectral-domain optical coherence tomography images were determined before and after surgery.

Results: The primary disorders were idiopathic macular holes. The mean minimum macular hole diameter was 456.7 ± 150.0 µm (221-622). In all patients, macular hole closure was performed successfully. The final U-shaped foveal contour type was achieved in 77.7% (7/9 eyes) of the patients and V-shape in 22.2% (2/9 eyes). None of the patients had W-shaped closures or flat/open-type contour. Mean best-corrected visual acuity increased from 1.47 ± 0.40 logarithm of the minimal angle of resolution to 0.8 ± 0.41 logarithm of the minimal angle of resolution at the last follow-up visit ($P < .001$).

Conclusion: Temporal inverted flap technique may be an effective method for treating macular holes with different etiologies to minimize the microsurgical trauma. Further large-scale studies are required to assess the efficacy and safety of this technique.

Keywords: Internal limiting membrane, inverted flap, macular hole, pars plana vitrectomy, temporal inverted flap

INTRODUCTION

Since the last 3 decades, pars plana vitrectomy (PPV) with internal limiting membrane (ILM) peeling has been used to treat idiopathic macular hole (MH) with a favorable success rate approaching 98%.[1-3] However, in a lower percentage of patients, surgical closure cannot be achieved, which necessitates additional interventions. In addition, suboptimal closure configuration of the MHs, causing a decrease in visual acuity, like flat-open shape is not uncommon postoperatively.[4,5] As a result, several surgical strategies have been recently developed to improve postoperative outcomes for the treatment of the aforementioned challenging situations. Previously, Michalewska et al[6] first defined the inverted ILM flap technique to treat the idiopathic large MHs and later modifications were done to treat myopic MHs, repeat MH surgery, and treat large MHs as well.[7-11]

Recently, removal of the ILM was suggested to be related to dissociated optic nerve fiber layer (DONFL) and minimal iatrogenic trauma to the retina.[12] To avoid this problem, Michalewska et al[13] reported a modification of the classical inverted ILM flap technique, known as the temporal inverted ILM flap technique, by decreasing the area of peeled ILM. This modification was found to have similar MH closure rates and visual function improvements compared with the inverted flap technique. According to this technique, ILM was peeled on the temporal side of the fovea only and inverted to the MH. With this procedure, a lower incidence of DONFL with satisfactory anatomic and functional outcomes was reported. However, there is not enough data evaluating the anatomic and functional outcomes of the temporal inverted flap technique for large idiopathic MHs and in particular, no previous report regarding the outcomes of the new technique on the different MH stages. In the light of these data, the aim of the present study is to report the outcomes of the patients who underwent PPV with temporal inverted flap technique for the treatment of MHs and to investigate the restoration of foveal anatomy by using spectral-domain optical coherence tomography (SD-OCT).

METHODS

Study Population

In this retrospective study, we reviewed the medical database of the patients with MH who were operated on by 1 experienced surgeon (YT) between January 2018 and January 2019. The patients who had PPV using the temporal inverted ILM flap technique with a follow-up duration of at least 6 months after surgery were included. Exclusion criteria were a history of

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previous vitreoretinal surgery, retinal vascular disease, or age <18 years old.

The medical records including age, gender, lens status, intraocular tamponade usage, and intraoperative and postoperative complications were reviewed for each patient. In every patient, comprehensive ophthalmological examinations including Snellen's best-corrected visual acuity (BCVA), slit-lamp biomicroscopy, and fundoscopy were performed. Spectral-domain optical coherence tomography (Heidelberg Engineering, Heidelberg, Germany) examinations were conducted preoperatively and at each follow-up visit. Macular hole configuration, MH diameter, the presence of external limiting membrane, the success of MH closure, the reoccurrence of MH, and final foveal contour type (U-, V-, or W-type) were assessed using SD-OCT. Full-thickness MH (FTMH) was defined as the presence of a full-thickness neurosensory defect. Lamellar MH was defined as a defect with an irregular fovea contour with dehiscence of the inner from the outer layers in the fovea confirmed by SD-OCT.[14] Optical coherence tomography-based anatomic classification was used for classification into small (≤250 µm), medium (>250 µm and ≤400 µm), and large (>400 µm) based on the horizontally measured linear width at the narrowest point of the hole, as described before.[15] Macular hole closure configuration was characterized as U-shape, V-shape, W-shape (irregular), flat open, and flap closure.[4,16]

Before the procedure, informed consent was taken from every patient. The study was in compliance with the principles outlined in the Declaration of Helsinki and approved by Institutional Ethics Committee of Ankara Yıldırım Beyazıt University, (Date: January 9, 2019, Decision no: 26379996/01).

Surgical Technique

Under retrobulbar anesthesia, a standard PPV was achieved using a conventional 25-gauge 3-port system with the Constellation Vision System (Alcon Laboratories, Inc., Fort Worth, Tex, USA) with a cutting speed of 7500 cuts per minute. A non-contact visualization system (Eibos system, Moller-Wedel International, Wedel, Germany) was used for endo-ocular visualization. Phacoemulsification and intraocular lens implantation were performed simultaneously on phakic eyes according to the surgeon's discretion. Using triamcinolone-assisted visualization, the central core vitrectomy and posterior vitreous detachment were performed. Membrane Blue-Dual (DORC, Zuidland, Netherlands) was performed for staining of the ILM around the fovea to remove the ILM. The temporal inverted ILM flap technique was accomplished as described previously.[13] In brief, the ILM at the temporal side of the fovea was peeled in a circular manner at least 2-disk diameter around the MH by about 180° and was prepared as a semicircular flap. Thereafter, the inverted flap was flipped over the fovea and was placed gently over the nasal side of the fovea to cover the MH. To avoid losing the flap, the surgeon turned off the infusion line when the flap was placed to the macular area. After ensured for the proper placement of the flap on the macula surface, fluid–air exchange was performed with a backflush needle placed on the nasal part of the optic nerve. To canalize the fluid flow to the optic nerve, the globe was rotated a little to the nasal direction, keeping the backflush needle away from the flap on the optic nerve surface. At the end of the surgery, 20% sulfur hexafluoride was injected as endotamponade, and patients were requested to take a prone position for 3 days.

Main Points

- Conventional internal limiting membrane (ILM) peeling is associated with mechanical and subclinical traumatic changes to the retinal layers.
- The risk of iatrogenic trauma in the area of papillomacular bundle was lower while using the temporal inverted ILM flap technique than conventional ILM peeling.
- The temporal inverted ILM flap technique is a safe and successful procedure for treating large idiopathic full-thickness macular holes (MHs) and myopic MHs.
- It is an effective method for treating MHs not only for challenging cases but also in the case of smaller MHs to minimize the microsurgical trauma.

Statistical Analysis

Decimal acuity values were converted to logarithm of the minimal angle of resolution (logMAR) for statistical analysis. Finger counting vision was defined as 20/2000 (2.0 logMAR), and hand motion was described as 20/20000 (3.0 logMAR).[17] A paired *t*-test was used to compare the preoperative and postoperative outcomes with a significance level set at $P < .05$. All statistical analyses were performed using Statistical Package for the Social Sciences Version 22.0. (IBM SPSS Corp.; Armonk, NY, USA).

RESULTS

Basal Characteristics

In our study, 9 eyes of 9 patients were included. The mean age of the patients was 70 ± 7 years (62-85). The mean minimum MH diameter was 456.7 ± 150.0 µm (221-622). The mean base diameter was 1126.64 ± 228.9 µm (724-1603). The mean follow-up period was 6.8 ±1.5 (6-10) months. The primary diseases of the patients were idiopathic MH. According to the baseline OCT characteristic, 2 (22%) eyes were small MH, 1(11%) eyes were medium-size MH, and 6 (66%) were large MH. Cataract surgery was simultaneously conducted in 3 patients (33%). Characteristics of the 9 eyes included in the study were shown in Table 1.

Anatomic Results and Functional Outcomes

All eyes achieved complete closure of MH at the first-month follow-up. During the follow-up, there was no reopening of the MH. According to the closure patterns on SD-OCT, the final U-shaped foveal contour type was achieved in 77.7% (7/9 eyes) of the patients and V-shape in 22.2% (2/9 eyes). In none of the patients, the W-shaped closures or flat/open-type contour were detected. On postoperative SD-OCT, an ILM flap was visible in 22.2% (2/9 cases) of the patients (case 1 and case 7 in Figure 1). In addition, epiretinal membrane formation was detected in only 1 (11.1%) patient on postoperative SD-OCT (case 2 in the Figure). The mean BCVA recovered significantly from 1.47 ± 0.40 logMAR at baseline to 0.8 ± 0.41 logMAR at last visit ($P < .001$). Visual improvement was noted in all eyes (100%). Visual acuity of

Table 1. Baseline Characteristics of the Study Population

Case	Age (Years)/Sex (F/M)	Lens Status	Minimum Diameter, µm	Basal Diameter, µm	Cataract Surgery	Preoperative BCVA, Snellen (logMAR)	Postoperative BCVA, Snellen (logMAR)	Follow-up, Months
1	73/M	Pseudophakic	601	1603	No	20/400 (1.3)	20/60 (0.5)	9
2	74/M	Phakic	519	1225	Yes	20/2000 (2)	20/200 (1)	6
3	67/M	Pseudophakic	248	724	No	20/400 (1.3)	20/30 (0.2)	6
4	85/F	Pseudophakic	465	1113	No	20/2000 (2)	20/400 (1.3)	6
5	63/F	Phakic	386	1000	No	20/2000 (2)	20/400 (1.3)	7
6	62/M	Pseudophakic	439	1155	No	20/200 (1)	20/40 (0.3)	10
7	74/M	Pseudophakic	622	1115	No	20/400 (1.3)	20/200 (1)	6
8	71/M	Phakic	221	1130	Yes	20/250 (1.1)	20/80 (0.6)	6
9	69/F	Phakic	610	1069	Yes	20/400 (1.3)	20/200 (1)	6

BCVA, best-corrected visual acuity.

20/40 was achieved in 2 eyes (22%). Representative cases of MH are presented in Figure 1.

Adverse Events

The surgery was done successfully in all cases and no intraoperative and postoperative complications were recorded. A missing flap was not observed in any patient.

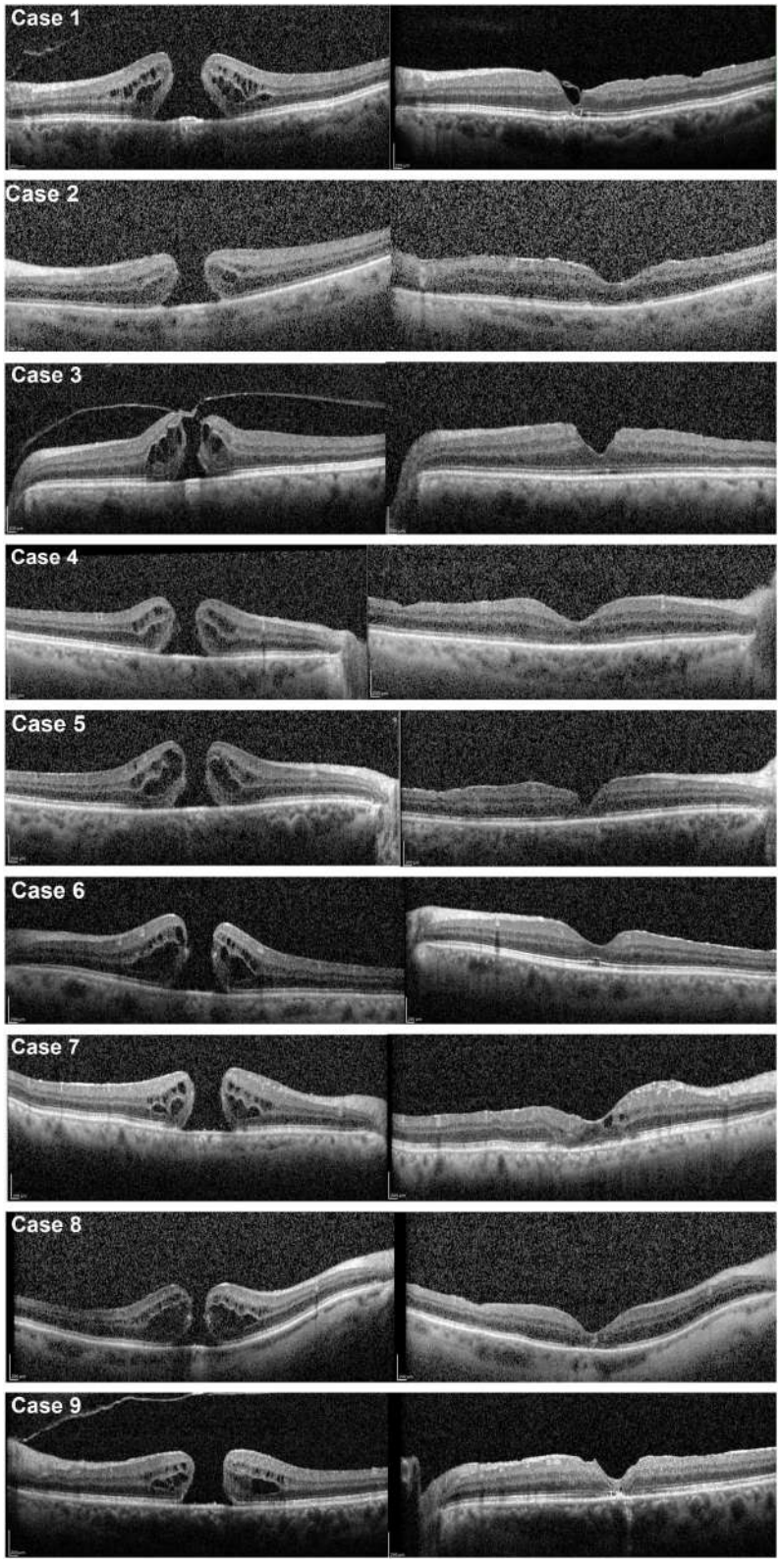
DISCUSSION

Our findings demonstrated that all 9 eyes with MH were successfully treated with PPV by the temporal inverted flap technique. Using this method, complete MH closure was accomplished in all eyes and U-type closure was demonstrated on OCT examinations of most eyes. In addition, significant improvement was also observed in visual acuity. As in line with previously reported data, our findings indicated that the temporal inverted flap technique leads to reasonable anatomical and functional outcomes in patients with MHs.

Previous studies showed that ILM peeling is associated with mechanical and subclinical traumatic changes to the retinal nerve fiber layer and a decline in the thickness of the nerve fiber layer, the ganglion cell layer, and inner retinal layer.[18,19] Using the temporal inverted ILM flap technique in which the ILM is removed from the temporal side of the macula, Michalewska et al[13] reported that the risk of iatrogenic trauma in the area of papillomacular bundle was lower than conventional ILM peeling and had a lower incidence of the DONFL appearances. The temporal inverted flap technique was used by different operators for improving surgical outcomes in challenging situations like large MHs and myopic cases.[13,20,21] However, in our study, in addition to challenging MH cases, we also enrolled small and medium-size MHs in order to minimize the risk of surgical trauma in the papillomacular bundle area as well as DONFL appearance.

The general success rate of MH closure with surgery is greater than 90%.[22] According to the study by Michalewska et al.[13] the temporal inverted flap technique had a 93% anatomical success in large MHs, which was found superior to the conventional ILM peeling technique and non-inferior to the inverted flap technique. In our experience, the MH closure rate was 100% with temporal inverted flap technique for the treatment of all MH sizes, which was also higher than the generally accepted anatomical success rate. In addition, postoperative MH closure morphology is an important determinant of the postoperative outcomes, where U-shaped closure is associated with better results.[16] In the present study, according to the anatomical closure morphology, the proportion of U-shaped closure was 77.7% and the other remaining cases had V-shaped configuration at the last follow-up visit. This percentage was higher than the U-shaped closure rate of 64% in the study by Michalewska et al[13] at the postoperative sixth month. Moreover, according to the previous reports with conventional ILM peeling techniques, flat-open type MH closure was observed in 19- 39% of idiopathic MHs,[5,16] whereas none of the patients showed flat-open appearance in our study. The higher frequency of better anatomical success could be attributed to the relatively smaller minimal diameters of MHs in

Figure 1. SD-OCT scans of the preoperative appearance and the postoperative evolution of macular hole in patients who underwent PPV with temporal inverted flap technique.
SD-OCT, spectral-domain optical coherence tomography; PPV, pars plana vitrectomy.



our study. In the present study, 36% of the patients were of small-medium-size MH and none of the patients was myopic or a recurrent case. On the other hand, either U- or V-shaped closure was observed in large MHs without any W-shaped closures or flat/open-type contour. Medium-size FTMH (250-400 microns) had a higher success rate with vitrectomy with or without ILM peeling than large MHs.[23] Furthermore, different visual outcomes have been reported depending on the stage of MH. As in line with the previous reports, in our study, the improvement in the visual acuity was observed in all patients.[24-26] These results suggested that the temporal inverted flap method was associated with favorable anatomical and functional outcomes in the case of different MH sizes.

Despite the improvement in surgical outcomes, this novel technical modification is not free of challenging conditions depending on the surgeon's skill. An important issue is preventing the ILM flap retroversion during the fluid–air exchange. Michelega et al[13] reported 7% failure after initial surgery, which was related to the spontaneous retroversion of the flap during fluid–air exchange.[13] To prevent this complication, some authors offered to use low molecular weight viscoelastic material or heavy liquids for stabilization of the flap.[27,28] In the current study, we did not observe any failure of MH closure related to destabilization of the flap on the macula. To avoid flap stabilization failure, the surgeon in our study performed some technical modifications in addition to the original technique to maintain the flap on the nasal side of the macula. First, during ILM flap invertion to the nasal side of the fovea, the fluid aspiration was turned off and then fluid–air exchange was performed. In addition, long-lasting gas was filled to the vitreous cavity to stabilize the flap for a long time. This is different from the original technique in which air was used instead of gas. Moreover, it is important to note that our results were based on the work of an experienced vitreoretinal surgeon. Our findings should be evaluated in the light of previously mentioned patients' characteristics, which include not only challenging cases but also lower-risk patients.

Our findings should be interpreted with caution because of several limitations. First, this was a retrospective study without any control group. Second, the sample size was small with a limited follow-up period. Third, the study population was heterogeneous with a limited number of cases other than large MHs. Despite these limitations, our study presented a comprehensive case series operated with temporal inverted flap technique.

CONCLUSION

Although the temporal inverted flap technique was originally performed in eyes with large MHs and MHs in myopic eyes, to the best of our knowledge, there were no reports investigating the anatomic and functional results in the case of small and medium-size MHs. Our findings demonstrated that the temporal inverted flap technique may be an effective method for treating MHs not only for challenging cases but also in the case of smaller MHs to minimize the microsurgical trauma. Further large-scale, prospective, randomized studies with long-term follow-up are needed to determine the actual benefits for temporal inverted flap technique and use in different settings.

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