

Visual Acuity Recovery After Macular Hole Closure Associated With Foveal Avascular Zone Change

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Purpose: To evaluate changes in the foveal avascular zone (FAZ) area during the postoperative period of macular hole (MH) surgery using the optical coherence tomography angiography (OCTA) and to investigate its relationship to visual acuity (VA).

Methods: Consecutive unilateral MH patients who underwent successful MH closure with at least a six-month observation period were studied retrospectively. To evaluate the FAZ area, OCTA images were obtained at the preoperative visit, the first postoperative visit, and the six-month visit. Main outcome measures were postoperative FAZ change and its relationship to VA change after MH closure.

Results: Fifty-one cases were studied. The FAZ area was $0.42 \pm 0.11 \text{ mm}^2$ at the preoperative visit, $0.25 \pm 0.091 \text{ mm}^2$ at the first postoperative visit and $0.31 \pm 0.11 \text{ mm}^2$ at the six-month visit. FAZ area at the first postoperative visit was significantly smaller ($P < 0.0001$) than at the preoperative visit. FAZ area at the six-month visit was significantly greater ($P < 0.0001$) than at the first postoperative visit, but still significantly smaller ($P = 0.0002$) compared to the normal fellow eye. The postoperative FAZ area enlargement from the first postoperative visit to the six-month visit was significantly correlated with the postoperative VA recovery ($P = 0.0322$) and the postoperative photoreceptor reconstruction ($P = 0.0213$).

Conclusions: The FAZ area once decreases along with MH closure; it thereafter increases toward the normal value over time. The postoperative FAZ change was correlated with the VA recovery.

Translational Relevance: This study suggests that the postoperative FAZ area enlargement might be a potential biomarker indicating foveal reconstruction after MH closure.

Introduction

Macular hole (MH) is a cause of decreased vision among older populations.^{1–3} Since the surgical procedure: pars plana vitrectomy (PPV) with internal limiting membrane (ILM) peeling and gas tamponade was established, the success rate of MH closure and visual outcome have been improved.^{4–8} It has been suggested that the release of vitreoretinal traction by ILM peeling allows the flexible retina to retract toward the optic disc.⁹ Retinal displacement after surgery was reported using fundus photographs and optical coherence tomography angiography (OCTA).^{10,11} In addition, the foveal avascular zone (FAZ) area decreased signifi-

cantly after a successful MH closure.^{11–13} These results suggest that centripetal contraction primarily leads the MH closure after surgery.

The variety of features of macular hole closure in the early postoperative period was reported using optical coherence tomography (OCT).^{14–16} Subfoveal fluid or lucencies, which is a hyporeflective space underlying the fovea with continuity of the inner retinal layers, were often observed after a successful MH closure.^{17–19} These subfoveal fluids gradually decrease and eventually resolve with time. In addition, continuous reconstruction of the foveal microstructure was observed throughout a long follow-up period after the MH was closed successfully.^{20,21} Considering the postoperative foveal structure changes as previously

reported,^{14–21} hypothetically the FAZ area may have continuous changes owing to the foveal reconstruction after an MH closure, and the postoperative changes in the FAZ area might be associated with the visual acuity recovery. In this study, we evaluated the FAZ area using OCTA to determine its change after surgery and its relationship with the visual acuity in cases with MH.

Methods

Study Population

This retrospective observational study, which adhered to the tenets of the Declaration of Helsinki, included unilateral, consecutive idiopathic MH patients who had undergone successful MH closure by PPV with ILM peeling at the Aichi Medical University Hospital in Japan from December 1, 2016, to April 30, 2019. The institutional review board of Aichi Medical University approved the study protocol.

Inclusion criteria were as follows. All participants were idiopathic MH patients with at least a six-month observation period after surgery, and OCTA images were obtained at the preoperative visit, first postoperative visit which was between 2 weeks and 1 month when the intraocular gas disappeared, and the six-month visit postoperatively. Patients were excluded if scans had a poor image quality (marked motion artifacts, unfocused, off-center, or low signal strength). Patients were also excluded if they had an axial length of more than 26-mm or due to the presence of other retinal diseases, such as rhegmatogenous retinal detachment, epiretinal membrane, age-related macular degeneration, choroidal neovascularization, and diabetic retinopathy.

General Examinations

All patients underwent a comprehensive ocular examination, including measurement of the best-corrected visual acuity (BCVA), evaluations by indirect ophthalmoscopy, axial length measurement using AL-scan (Nidek, Gamagori, Japan). Optical coherence tomography (OCT) was performed using a spectral-domain OCT (RTVue XR Avanti, Optovue, Inc., Fremont, CA, USA).

Anatomic Assessment of the Macular Hole

MH was assessed using OCT at each visit. At the preoperative visit, minimum MH size and basal MH size were evaluated. At the postoperative visits, central retinal thickness (CRT), which was defined as

the average retinal thickness between ILM and the inner surface of the retinal pigment epithelium (RPE) within a 1-mm circle centered on the fovea. Restoration of the photoreceptor layer was defined as the continuous back-reflection line corresponding to the external limiting membrane (ELM) and ellipsoid zone (EZ). To compare the postoperative FAZ change with the photoreceptor integrity change, the photoreceptor integrity score was defined as follows: 2 = ELM(+) and EZ(+), eyes with a reconstructed ELM and EZ; 1 = ELM(+) and EZ(–), eyes with a reconstructed ELM, but with a disrupted EZ; and 0 = eyes with a disrupted ELM and EZ.

Optical Coherence Tomography Angiography

The 3- × 3-mm OCTA scans centered on the fovea were acquired using a commercial 70-kHz spectral-domain OCT device (RTVue XR Avanti; Optovue, Inc) with center wavelength of 840 nm at the preoperative visit, first postoperative visit and the six-month visit, postoperatively. The FAZ area was analyzed using the Angio Vue software (Version 2017.1.0.131; Optovue). The FAZ area was calculated automatically in the inner retinal slab, which was between ILM and 9 μm below the outer plexiform layer. If the FAZ detection was inaccurate, the FAZ area was manually corrected by the retinal specialist (K.T.).

Surgical Procedures

Twenty-five-gauge or twenty-seven-gauge vitrectomy was performed with the patient under local anesthesia by any of the five surgeons using the surgical vitrectomy systems (Constellation Vision System; Alcon Laboratories, Inc., Fort Worth, TX, USA; or EVA Phaco-Vitrectomy System; DORC, Zuidland, Netherlands). Phacoemulsification and intraocular lens implantation were performed in all phakic eyes. Core vitrectomy after the creation or confirmation of a posterior vitreous detachment (PVD) was performed with the vitrectomy probe. Triamcinolone acetonide (MaQaid; Wakamoto Pharmaceutical, Tokyo, Japan) was injected into the vitreous cortex as needed. In all cases, ILM peeling was performed within a 3-mm (2-disc diameter) center on the fovea using Brilliant Blue G (ILM blue; DORC). Fluid-air exchange was performed and if needed, a long-acting gas, such as 20% sulfur hexafluoride or 6% perfluoro propane, was applied to the vitreous cavity.

Statistical Analysis

All data were analyzed using JMP version 13.1.0 (SAS Institute, Inc., Cary, NC, USA). The data are expressed as the mean, standard deviation (SD), and range as appropriate. The BCVA was measured using Landolt C acuity charts, and the decimal BCVA was converted to the logarithm of the minimal angle of resolution (LogMAR) units for statistical analyses. To compare between operated eyes and fellow eyes, the ratios of FAZ area at each timepoint to those of the fellow eye were calculated. FAZ area, LogMAR BCVA, CRT, and ratio of the FAZ area at each timepoint were analyzed by paired *t*-test for normally distributed data and Wilcoxon signed-rank test for nonnormally distributed data and Bonferroni correction for multiple comparisons. The correlations between the postoperative change in the FAZ area and the postoperative change in LogMAR BCVA, CRT, and photoreceptor integrity change were analyzed by Spearman's rank correlation coefficient. Univariate regression was used to investigate associations between postoperative FAZ area change and age, gender, MH stage, axial length, basal MH size, minimum MH size, FAZ area at preoperative and first postoperative visit, and CRT at the first postoperative visit, to determine whether they were predictive of postoperative FAZ area change. All independent variables from the univariate analyses with a *P* value of less than 0.10 or potential factors based on previous knowledge were included in the multivariate analysis. A *P* value less than 0.05 was considered as significant. In multiple comparison, we used a significant *P* value as less than 0.05/*N* (the number of comparison).

Results

Patients Characteristics

Seventy-three eyes of 73 consecutive patients were enrolled initially. Of these, 22 eyes were excluded: 10 for low signal strength caused by severe cataract before surgery and postoperative severe inflammation or corneal edema, 10 for axial length greater than 26-mm, and two for epiretinal membrane. Fifty-one eyes of 51 cases were then included in this study. Thirty-two (63%) cases were females. Mean age was 66.4 ± 8.1 years (range 46–83 years). Axial length was 24.0 ± 0.84 mm (range 21.89–25.91 mm). Basal MH size was 756 ± 269 μ m (range 174–1420 μ m), and minimum MH size was 341 ± 142 μ m (range 68–689 μ m). [Table 1](#) summarized the preoperative and intraoperative characteristics of the patients.

Table 1. Preoperative and Intraoperative Parameters

Parameter	Value
Number of eyes	51
Preoperative patient characteristics	
Age, Years, (SD)	66.4 (8.1)
Female, n, (%)	32 (63)
Right eye, n (%)	29 (57)
LogMAR BCVA, (SD)	0.62 (0.29)
Axial length, mm, (SD)	24.0 (0.84)
Parameters related to MH surgery	
MH stage 2:3:4, n	18:16:17
Basal MH size, μ m, (SD)	756 (269)
Minimum MH size, μ m, (SD)	341 (142)
Phakia:IOL, n	46:5
Gas tamponade Air:SF6:C3F8	6:12:33

SD, standard deviation; IOL, intraocular lens, SF6, sulfur hexafluoride; C3F8, perfluoropropane.

The Changes in FAZ Area, VA, and CRT During Follow-up Period

FAZ area at each timepoints are shown in [Figure 1](#). The FAZ area was 0.42 ± 0.11 mm² (range 0.18–0.61 mm²) at the preoperative visit, 0.25 ± 0.091 mm² (range 0.10–0.55 mm²) at the first postoperative visit, and 0.31 ± 0.11 mm² (range 0.097–0.62 mm²) at the six-month visit. The FAZ area at the first postoperative visit was significantly smaller than at the preoperative visit (*P* < 0.0001), and the FAZ area at the six-month visit was significantly greater than at the first postoperative visit (*P* < 0.0001). However, the FAZ area at the six-month visit was still significantly smaller than at the preoperative visit (*P* < 0.0001). Representative cases with and without postoperative FAZ area changes are shown in [Figures 2](#) and [3](#).

The LogMAR BCVA was 0.62 ± 0.29 (range 0.15–1.30 LogMAR) at the preoperative visit, 0.45 ± 0.48 (range 0–2.6 LogMAR) at the first postoperative visit, and 0.15 ± 0.20 (range –0.18–0.70 LogMAR) at the six-month visit. The LogMAR BCVA at the first postoperative visit and six-month visit were significantly improved than at the preoperative visit (*P* = 0.0108 and *P* < 0.0001, respectively) and the LogMAR BCVA at the six-month visit was also significantly improved than at the first postoperative visit (*P* < 0.0001). There were no relationships between FAZ area and LogMAR BCVA at all the time points (preoperative visit; *R* = –0.0275, *P* = 0.8494, first postoperative visit; *R* = 0.1225, *P* = 0.4368, six-month visit; *R* = –0.0229, *P* = 0.8743).

CRT was 288 ± 31 μ m (range 204–363 μ m) at the first postoperative visit and 280 ± 30 μ m (range 211–

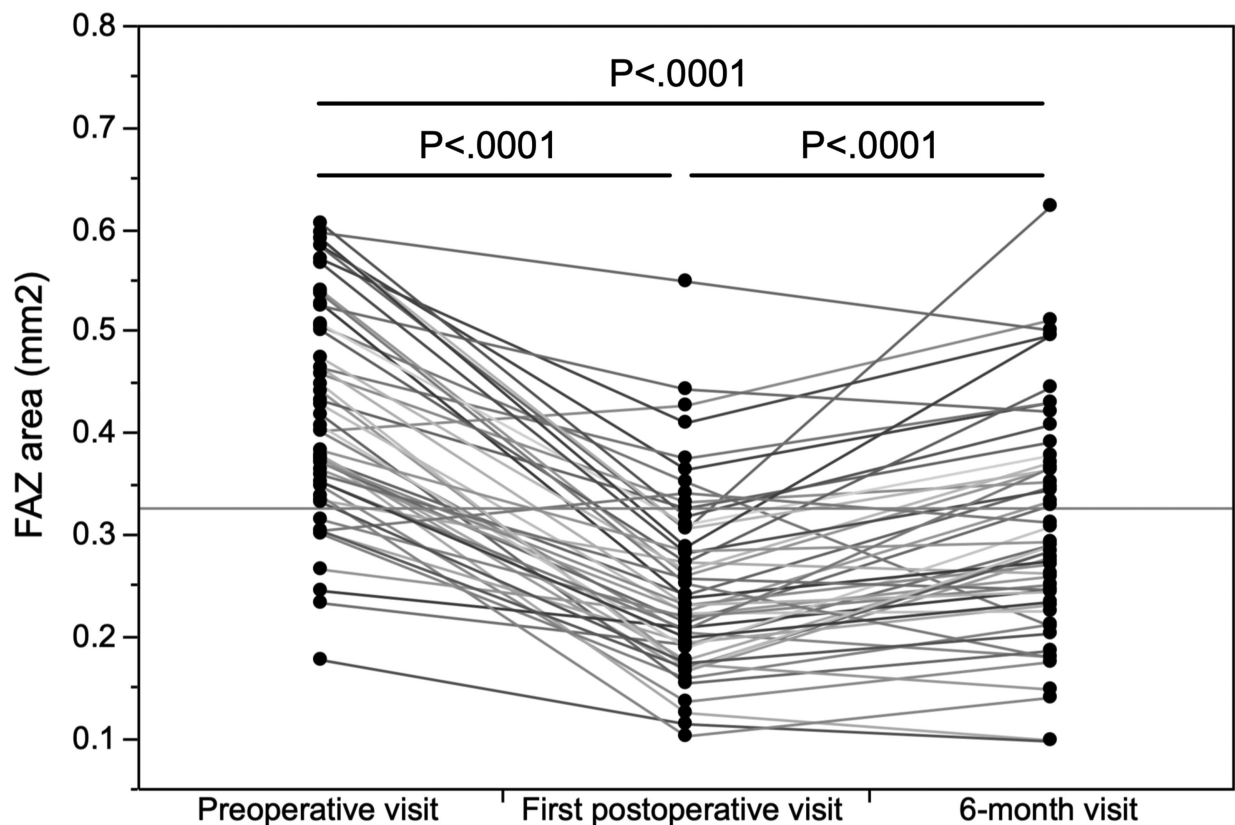


Figure 1. Paired line plot of FAZ areas at each timepoints. Significant *P* values after Bonferroni correction for the Wilcoxon signed-rank test were shown.

352 μm) at the six-month visit. CRT at the six-month visit was significantly thinner than at the first postoperative visit (*P* = 0.0017).

P = 0.1651) at the preoperative visit, 0.63 (compare to 1, *P* < 0.0001) at the first preoperative visit, and 0.77 (compare to 1, *P* = 0.0001) at the six-month visit (Fig. 4).

Reconstruction of Foveal Microstructure

Reconstruction of the ELM by centripetal bridging was first observed before reconstruction of the EZ. Reconstruction of the ELM was seen in 37 eyes (74%) at the first postoperative visit and 48 eyes (96%) at the six-month visit. The EZ was reconstructed centripetally after ELM bridging. Reconstruction of the EZ was observed in no eyes (0%) at the first postoperative visit and 13 eyes (26%) at the six-month visit.

Comparison of FAZ Area Between the Operated Eye and Fellow Eye

Thirty fellow eyes of 51 cases obtained a sufficient quality of OCTA images without any abnormalities. FAZ area of the fellow eye was 0.39 ± 0.096 mm² (range 0.22–0.64 mm²). The ratio of FAZ area of the operated eye to the fellow eye was 1.05 (compare to 1,

Relationship Between Postoperative FAZ Change and Parameters

Between the first postoperative visit and the six-month visit, postoperative FAZ change was 0.055 ± 0.075 mm² (range –0.142 to 0.318 mm²), postoperative LogMAR change was –0.28 ± 0.38 (range –2.2 to 0.067 LogMAR), and postoperative CRT change was –3.5 ± 15 μm (range –54 to 33 μm).

Postoperative FAZ change was significantly correlated with the changes in LogMAR BCVA during the same period (*R* = –0.30, *P* = 0.0332) (Fig. 5). There was significant quadratic relationship between visual acuity at the first postoperative visit and postoperative FAZ change (*R*² = 0.40, *P* < 0.0001) (Fig. 6). Postoperative FAZ change was also significantly correlated with the changes in CRT during the same period (*R* = –0.30, *P* = 0.0337) (Fig. 5). Photoreceptor integrity

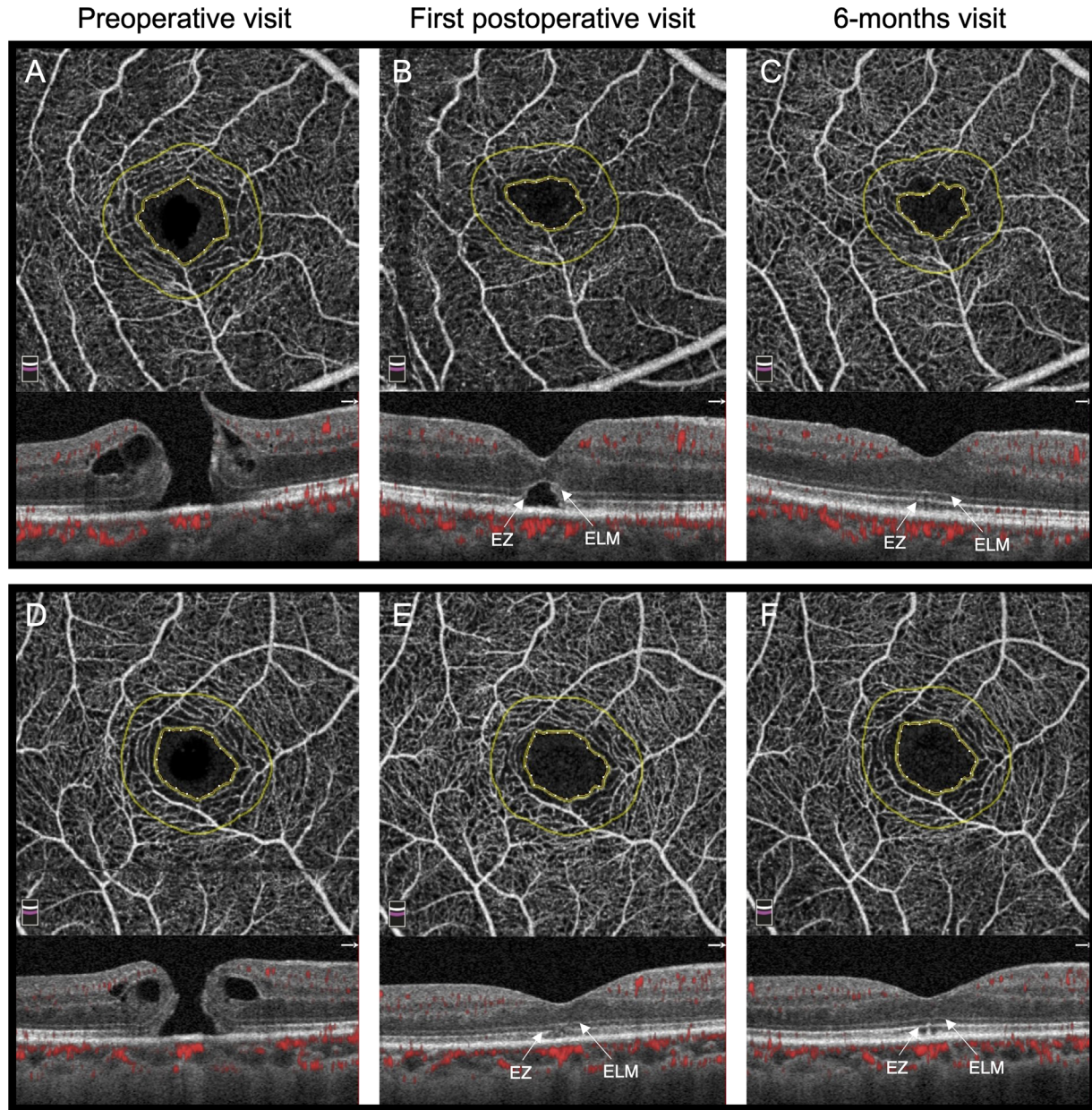


Figure 2. Representative cases with non-postoperative FAZ area enlargement. (A–F) En face OCTA images and B-scan images. (A–C) A 60-year-old female with stage 2 MH, basal MH size was 527 μm , and minimum MH size was 269 μm . (A) FAZ area was 0.401 mm^2 at the preoperative visit, (B) 0.204 mm^2 at the first postoperative visit, and (C) 0.180 mm^2 at the six-month visit. (B) At the first postoperative visit, the ELM was restored with bridging formation, but the EZ was disrupted. (C) At the six-month visit, the ELM and EZ were restored. Visual acuity was 0.1 at the preoperative visit, 0.15 at the first postoperative visit, and 0.6 at the six-month visit. (D–F) A 73-year-old female with stage 4 MH, basal MH size was 500 μm , and minimum MH size was 191 μm . (D) FAZ area was 0.304 mm^2 at the preoperative visit, (E) 0.341 mm^2 at first postoperative visit and (F) 0.312 mm^2 at the six-month visit. (E) At the first postoperative visit, the ELM was restored with bridging formation, but EZ was disrupted. (F) At the six-month visit, the ELM and EZ were restored. Visual acuity was 0.4 at the preoperative visit, 0.9 at the first postoperative visit, and 1.0 at the six-month visit.

score change between the first postoperative visit and six-month visit was 0.51 ± 0.64 (range 0–2). Postoperative FAZ change was significantly correlated with the change in the photoreceptor integrity score ($R = 0.33$, $P = 0.0213$) (Fig. 5).

The relationship between postoperative FAZ change (difference in area between the first postoperative visit and six-month visit), and preoperative and first postoperative visit parameters are summarized in Table 2. The univariate regression analyses identified

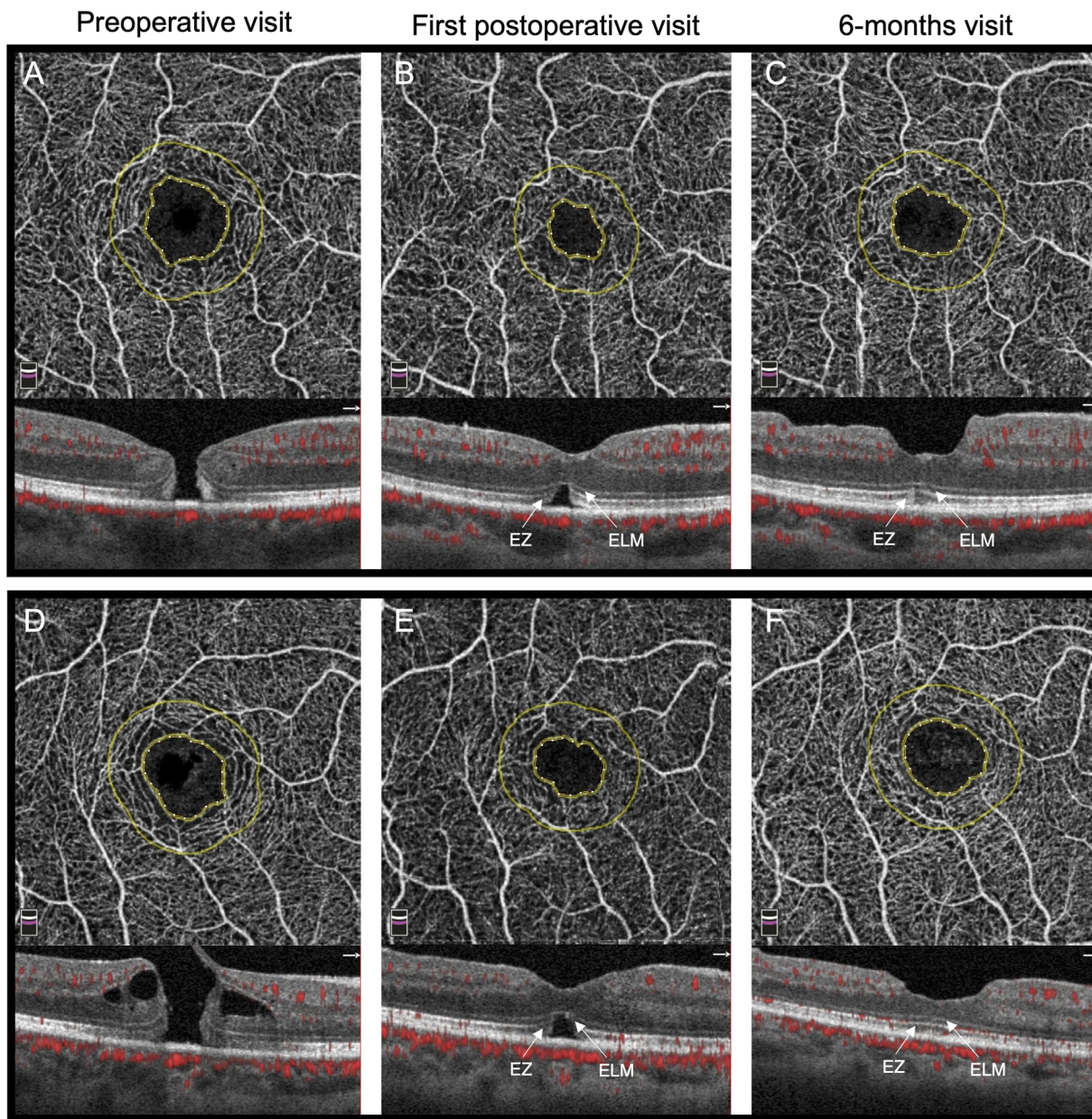


Figure 3. Representative cases with postoperative FAZ area enlargement. (A–F) En face OCTA images and B-scan images. (A–C) A 69-year-old female with stage 3 MH, basal MH size was 259 μm and minimum MH size was 177 μm . (A) FAZ area was 0.376 mm^2 at the preoperative visit, (B) 0.166 mm^2 at the first postoperative visit and (C) 0.278 mm^2 at the six-month visit. (B) At the first postoperative visit, the external limiting membrane (ELM) was restored with bridging formation, but EZ was disrupted. (C) At the six-month visit, the EZ was still disrupted. Visual acuity was 0.1 at the preoperative visit, 0.4 at the first postoperative visit and 0.5 at the six-month visit. (D–F) A 53-year-old female with stage 2 MH, basal MH size was 504 μm , and minimum MH size was 285 μm . (D) FAZ area was 0.364 mm^2 at the preoperative visit, (E) 0.225 mm^2 at the first postoperative visit, and (F) 0.333 mm^2 at the six-month visit. (E) At the first postoperative visit, the ELM was restored with bridging formation, but EZ was disrupted. (F) At the six-month visit, the ELM and EZ were restored. Visual acuity was 0.5 at the preoperative visit, 0.4 at the first postoperative visit, and 1.2 at the six-month visit.

that only the female gender ($P = 0.0111$) was significantly associated with postoperative FAZ change. In addition to sex, we also included the axial length (univariate analysis, $P = 0.1043$) to the multivariate analysis, because previous studies suggested that the

axial length was a risk factor of MH formation^{22,23} and was also associated with the retinal structures.²⁴ The multivariate analysis also identified that only the female gender ($P = 0.0380$) was significantly associated with postoperative FAZ change.

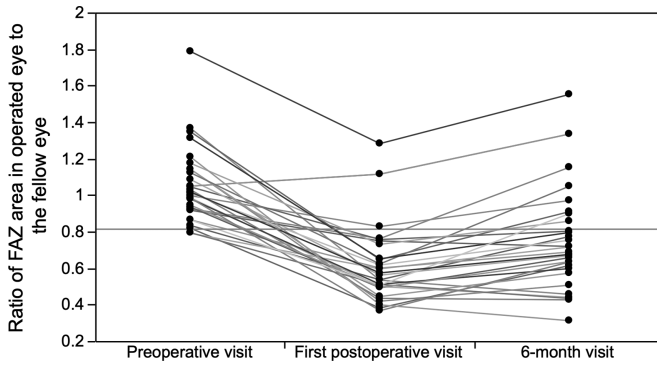


Figure 4. Ratio of FAZ area in operated eye to the fellow eye at each timepoint. The ratio of FAZ area of the operated eye to the fellow eye was significantly smaller at the preoperative, first visit, and six-month visit (both compare to 1, $P < 0.0001$ and $P = 0.0002$, respectively).

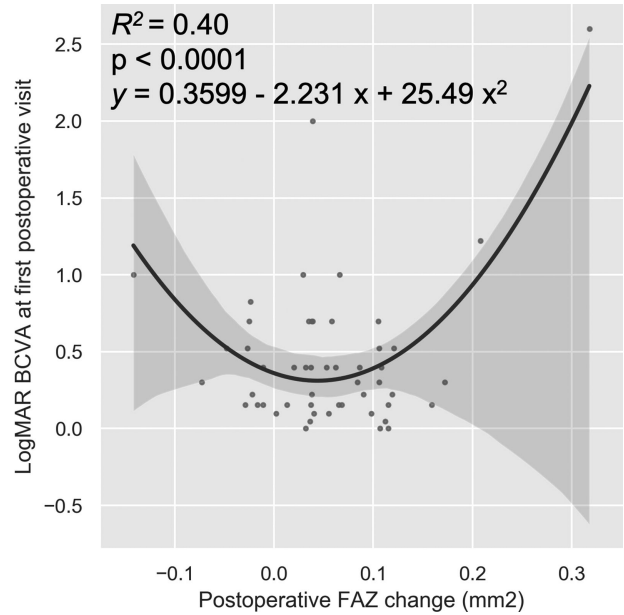


Figure 6. Association between postoperative foveal avascular zone change and visual acuity at the first postoperative visit. A quadratic regression function was shown.

Discussion

It is well known that the centripetal movement of the retinal tissue is observed after successful macular hole closure. This mechanism has been well studied using fundus photo, OCT, and OCTA.^{10–13,25} Due to this mechanism, OCTA studies showed that FAZ area was significantly decreased after surgery compared with the preoperative FAZ area.^{11–13} However, it is still unknown whether FAZ area would change after MH closure. In this study, we showed that once the FAZ area decreases along with MH closure, it thereafter increases toward the normal value over time. The postoperative change in FAZ area was significantly correlated with the photoreceptor recovery and the visual acuity recovery. These results suggest that the FAZ area enlargement may indicate the foveal reconstruction after MH surgery.

In this study, the FAZ area once decreased along with MH closure, thereafter increased during the postoperative period. Compared with the normal fellow eye, the FAZ area in the operated eye was initially smaller (ratio to the fellow eye; 0.63 at the first postoperative visit), then increased toward the normal value (ratio to the fellow eye; 0.77 at six-month visit). The FAZ area change was negatively correlated with the CRT change. Previous literature reported the negative correlation between the FAZ area and retinal thickness.^{13,26,27} In MH cases, the central retina was thickened during the early postoperative period, subsequently, the CRT decreased toward the

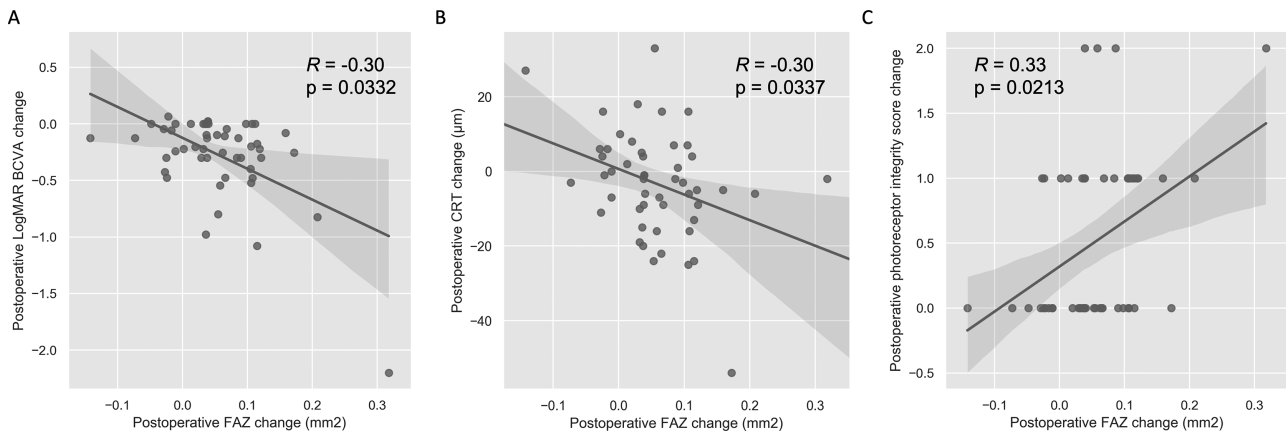


Figure 5. Spearman's rank correlation coefficient between postoperative foveal avascular zone change and postoperative changes in (A) visual acuity, (B) central retinal thickness, and (C) photoreceptor integrity score.

Table 2. Univariate and Multivariate Regression Analysis of Association Between Postoperative FAZ Change and Parameters

Parameters	Univariate Analysis		Multivariate Analysis		
	Correlation Coefficient	P Value*	Estimated Value	95% CI	P Value†
Preoperative visit					
Age	0.0899	0.5306			
Sex (male=0, female=1)	0.3527	0.0111	0.048	0.0028–0.092	0.038
Eye (left=0, right=1)	−0.0565	0.6938			
MH stage (2,3,4)	0.1162	0.4168			
Axial length	−0.2325	0.1043	−0.0042	−0.026–0.017	0.6934
Basal MH size	−0.1031	0.4717			
Minimum MH size	0.1267	0.3755			
FAZ area	0.1283	0.3695			
Postoperative first visit					
FAZ area	−0.0274	0.8484			
CRT	−0.1607	0.26			

*P values for univariate analyses were calculated using the Spearman’s rank correlation coefficient.

†P values for multivariate analyses were calculated using the least squares method.

normal values.²⁰ Our cases also showed that foveal thinning was observed in FAZ enlargement cases (Fig. 3), but was not obvious in FAZ nonenlargement cases (Fig. 2). Together with these results, the FAZ area can become smaller along with the thickened central retina at the early postoperative period owing to the excessive centripetal movement of the retinal tissue.

Subsequently, the smaller FAZ and thickened central retina gradually enlarges and thins along with reconstruction toward the normal over the postoperative period (Fig. 7). Therefore the FAZ area significantly increased during the postoperative period.

Our result showed that FAZ area itself was not correlated with the visual acuity at all timepoints. One

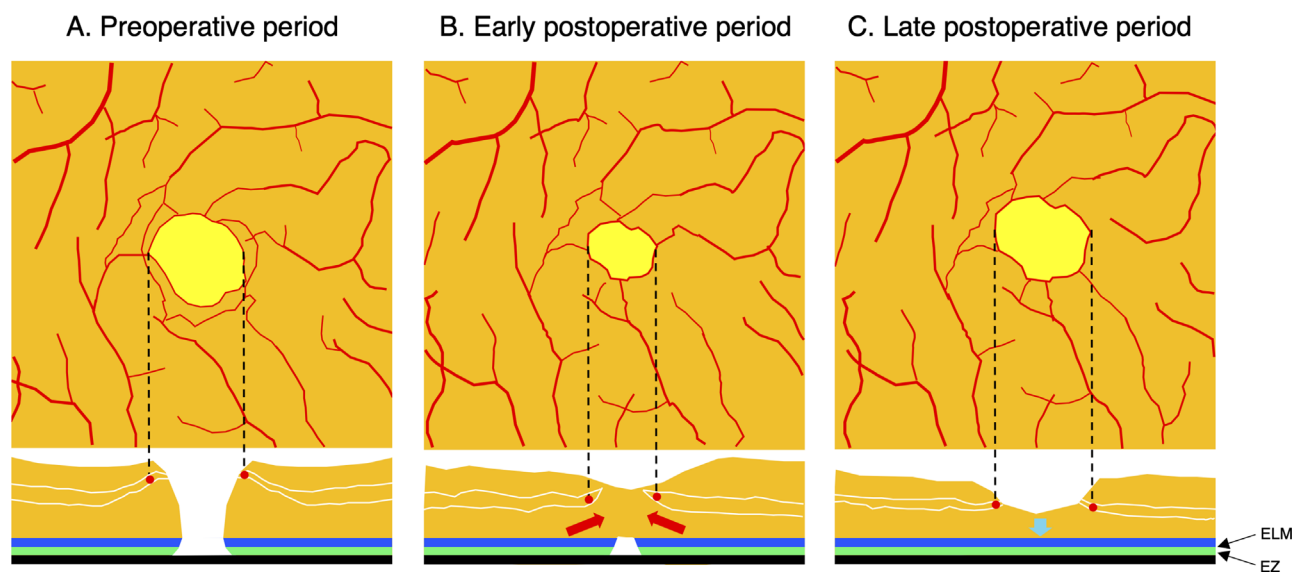


Figure 7. Schematic representation of the relationship between MH and FAZ. External limiting membrane (ELM) line is shown in blue and ellipsoid zone (EZ) line is shown in green. (A) Preoperatively, innermost capillary (red dots) constituting the FAZ are moving away from the center of the fovea. (B) Bridging formation with centripetal tissue moving (red arrows) leads to MH closure along with a decrease in the FAZ area and the central retina thickening during the early postoperative period. (C) Foveal reconstruction with retinal tissue moving toward the normal foveal configuration (blue arrows) leads the FAZ area enlargement and photoreceptor recovery during the postoperative period.

possible reason is that there is greater individual variation in FAZ area.²⁷ Thus it is difficult to use FAZ area as a biomarker of visual acuity. However, FAZ change was not affected by the individual variation in FAZ area.

Postoperative FAZ area enlargement was positively correlated with the photoreceptor recovery and visual acuity change. Therefore we speculated that the FAZ enlargement was one of the phenomena that show the foveal reconstruction processes after MH closure. In the early postoperative period, a variety of features of macular hole closure were reported.^{14–19} Previous literature reported two types of MH closure: the simple and bridge closure.¹⁴ They reported that the visual acuity improvement starts after the fovea assumes a normal configuration. The subfoveal lucencies, also known as the subfoveal fluid, were common findings after MH surgery, and they gradually decrease and eventually resolve with improvement of the visual acuity.^{17,18,28} The healing process after MH surgery might begin with the inner part of the retina, forming bridge closure or a subfoveal fluid cavity because of the usually larger defects at the basal part of the hole, and with a gradual restoration of the anatomic features of the outer retina.^{17,18,25,29}

Although the pathologic processes of MH closure and foveal reconstruction have not been elucidated yet, a possible mechanism is that the hole closes via a bridging of the inner part of the retina with glial proliferation, probably of Muller cells. The bridging formation leads the centripetal tissue movement, which might cause the FAZ area reduction and thickened retina during the early postoperative period. Thereafter, the normal foveal structures might regenerate by Muller cell proliferation and movement of the photoreceptor cell body toward the foveal center. This causes a reduction in the distance between the central ELM and the RPE, which leads to photoreceptor restoration.³⁰ Foveal reconstruction processes might include not only photoreceptor restoration but also normal foveal configuration such as normal CRT and FAZ areas. Thus the postoperative FAZ area change correlated with the postoperative changes in CRT, photoreceptor integrity, and visual acuity.

In this study, the visual acuity improvement was small in the patients with small FAZ changes and vice versa. We speculated that the reason was that in the patients with small postoperative FAZ change, the FAZ change might have almost finished before the first postoperative visit (two to four weeks after surgery). As the MH closure type and photoreceptor reconstruction period were different among the patients.^{14–19,21} Our results showed a significant association between visual acuity at the first postoperative visit and postop-

erative FAZ change. The patients with small postoperative FAZ changes had good visual acuities at the first postoperative visit, whereas those with greater postoperative FAZ changes had relatively poor visual acuities at the first postoperative visit (Fig. 6). Thus the FAZ area did not change during six months after surgery; consequently, the improvement in visual acuity was also small in these patients.

Our result showed that the female gender was the factor associated with the postoperative FAZ enlargement. Large cohort studies showed that the incidence of MH was higher in females than in males.^{1–3,31} The precise etiologic factors responsible for the increased risk factor of MH in females are unknown. One possible mechanism previously reported was that the women were more prone to PVD compared with male counterparts of similar age.³² Sex differences in the foveal structure were also reported.^{24,33–35} These studies showed that retinal thickness was thinner in the females than in males. Although it is difficult to clarify the reason why females have a greater FAZ area enlargement after MH closure, we speculated that differences in PVD progress, foveal structure, or both might be correlated with the postoperative FAZ enlargement. Further studies with a large sample size are needed to confirm this result.

Data for this study were obtained as part of clinical care rather than as part of a research protocol. Although the limitations of this approach are inherent, many are mitigated by the fact that, in the current study, all technicians followed standard procedures. A research assistant managed the standardized data entry to minimize the data acquisition errors. Eyes included in this study had different surgical procedures, such as 25-gauge and 27-gauge system and types of gas tamponade. Although we unified the size of the ILM peeling: 3-mm center on the fovea in all cases, the surgical procedure variations might still affect the results. In this study, the FAZ area change was small in the patients with good visual acuities at the first postoperative visit because the foveal reconstruction might have already finished before the first postoperative visit. The MH closure type and photoreceptor reconstruction period were different among the patients.^{14–19,21} Therefore, in the patients whose fovea has been reconstructed during the first postoperative visit, the FAZ area change is difficult to use as a biomarker of foveal reconstruction. FAZ evaluation needs cautiousness because of the greater variations among subjects and OCTA limitations.^{36,37} We speculated that the FAZ area enlargement was the process of FAZ area increase toward the normal values compared to the FAZ area of the fellow eyes. Despite that, there were still controversies regarding whether the fellow

eye could be considered a control for FAZ studies.³⁵ In addition, we used a single OCTA image to evaluate the FAZ, which sometimes are imperfect compared to using the multiple averaging technique.^{37–39} Microcapillaries, which constitute the FAZ, sometimes could not be detected by OCTA. Therefore the FAZ area might be overestimated, especially in cases with abnormality, although we carefully checked and modified FAZ segmentation in all OCTA images.

In conclusion, our results show that the FAZ area once decreases along with MH closure and thereafter increases toward the normal over time. The postoperative change in the FAZ was correlated with the visual acuity recovery. The postoperative FAZ area enlargement might indicate the foveal reconstruction after MH closure.

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