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Parameters affecting the anatomical and functional success of macular hole surgery

Makuler hol cerrahisinin anatomik ve fonksiyonel başarısını etkileyen parametreler

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ABSTRACT

Aim: To evaluate the effect of preoperative Spectral Domain Optical Coherence Tomography (SD-OCT) parameters on macular hole surgery (MHS) and their predictive value for postoperative best corrected visual acuity (BCVA).

Materials and Methods: This retrospective study included 30 eyes of 30 patients with macular hole (MH). All patients underwent pars plana 23-gauge vitrectomy. A detailed macular analysis including MH minimum diameter (MD), base diameter (BD), opening diameter (OD), height, nasal arm (NA), temporal arm (TA), macular hole index (MHI), diameter hole index (DHI), tractional hole index (THI), hole form factor (HHF), macular hole area (MHA), and macular hole volume (MHV) were performed preoperatively. Presence of inner segment–outer segment (IS/OS) line, external limiting membrane (ELM), and cyst was noted postoperatively. Relationships between these parameters and postoperative BCVA were evaluated.

Results: The study group comprised 25 (83.3%) women. Mean pre and postoperative BCVA values were 0.924±0.320 and 0.487±0.287 logMAR, respectively. BCVA improved significantly after MHS (p<0.001). There was a statistically positive correlation between postoperative BCVA (logMAR) values, and NA (p=0.041), HFF (p=0.048), OD (p=0.045) and symptom duration before MHS (p=0.032). Postoperative BCVA was significantly better in patients with postoperative IS/OS line and ELM presence compared to those without (p=0.002 and p=0.002, respectively). The NA, postoperative IS/OS and ELM variables were found to be effective on postoperative BCVA (logMAR).

Conclusion: In this study, NA was determined as a predictive factor for the first time and together with NA, presence of IS/OS line and ELM were identified as predictive factors for visual prognosis after MHS.

Keywords: ELM, IS/OS Line, macular hole, nasal arm.

ÖZ

Amaç: *Preoperatif Spectral Domain Optik Koherens Tomografi (SD-OKT) parametrelerinin makuler hol cerrahisi (MHC) üzerindeki etkisini ve bu parametrelerin postoperatif en iyi düzeltilmiş görme keskinliği (EİDGK) için tahmini değerini değerlendirmek.*

Gereç ve Yöntemler: *Bu retrospektif çalışmaya makuler holü (MH) olan 30 hastanın 30 gözü dahil edildi. Tüm hastalara 23-gauge pars plana vitrektomi uygulandı. Preoperatif olarak minimum çap (MÇ), taban çapı (TÇ), açılış çapı (AÇ), yükseklik, nazal kol (NK), temporal kol (TK), makuler hol indeksi (MHİ), çap hol indeksi (ÇHİ), traksiyonel hol indeksi (THİ), hol form faktörü (HFF), makuler hol alanı (MHA) ve makuler hol hacmi (MHV) içeren detaylı bir makula analizi yapıldı.*

P*ostoperatif olarak iç-dış segment (IS/OS) bandı, external limitan membran (ELM) ve kist varlığı belirtildi. Bu parametreler ile postoperatif EİDGK arasındaki ilişkiler değerlendirildi.*

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Bulgular: *Çalışma grubu 25 (%83,3) kadından oluşuyordu. Pre-postoperatif ortalama EİDGK değerleri sırasıyla 0,924±0,320 ve 0,487±0,287 logMAR idi. EİDGK, MHC'den sonra anlamlı derecede arttı (p<0,001). Postop EİDGK (logMAR) değerleri ile NK (p=0,041), HFF (p=0,048), AÇ (p=0,045) ve MHC öncesi semptom süresi arasında istatistiksel olarak pozitif korelasyon vardı (p=0,032). Postoperatif IS/OS bandı ve ELM varlığı olan hastalarda, olmayanlara göre postoperatif EİDGK anlamlı derecede daha iyi idi (sırasıyla, p=0,002 ve p=0,002). NK, postoperatif IS/OS bandı ve ELM değişkenlerinin postoperatif EİDGK (logMAR) üzerinde etkili oldukları bulundu.*

Sonuç: *Bu çalışmada NK ilk kez prediktif bir faktör olarak belirlendi ve NK ile birlikte IS/OS bandı ve ELM varlığı MHC sonrası görme prognozu için prediktif faktörler olarak belirlendi.*

Anahtar Sözcükler: *ELM, IS/OS bandı, makuler hol, nazal kol.*

INTRODUCTION

Macular hole (MH) is a macular disease that causes significant impairment of central visual acuity (VA). MHs can be seen in highly myopic eyes or following ocular trauma, but most are idiopathic (IMH). MHs affect older adults, more than 50% of IMH occur in women and more than 50% occur in people 65 to 74 years old. In people with full-thickness macular hole (FTMH) in one eye, the 5-year risk of developing FTMH in the fellow eye is about 10% to 15 (1).

The Gass classification is based on clinical examination and divides MH into 4 stages, stage 1 represents impending hole and stages 2–4 represent FTMHs (1). The International Vitreomacular Traction Study (IVTS) Group developed an Optical Coherence Tomography (OCT)-based anatomical classification system for vitreomacular interface (VMI) diseases (1). In this classification system; FTMH is defined as a foveal lesion with interruption of all retinal layers from the internal limiting membrane (ILM) to the retinal pigment epithelium (RPE). Primary FTMH is caused by vitreous traction. FTMHs are subclassified by the size of the hole; as determined by OCT and the presence or absence of vitreomacular traction (VMT). FTMHs with hole size less than 250 µm are classified as small, 250 to 400 µm as medium and over 400 µm as large. Pars plana vitrectomy (PPV) (with or without ILM peeling), gas-fluid exchange, and face-down positioning are the primary treatment procedures for medium and large FTMHs. Different techniques exist today, to treat all subtypes of macular holes, such as inverted flap and human amniotic membrane technique. However, there is not yet a global consensus on which technique guarantees the best surgical results.

Performing vitrectomy for FTMH has some potential complications; cataract formation, RPE changes, retinal detachment (RD), cystoid macular edema (CME), visual field defects, choroidal neovascularization, and endophthalmitis (1).

To date, investigators have evaluated various preoperative variables in order to predict postoperative visual outcome, including preoperative VA, symptom duration, MH parameters such as the horizontal and vertical dimensions, their ratios, and MH diameter measured by OCT, but a consensus has yet to be reached (2). Some studies have also evaluated MH configuration, but the relationship between preoperative MH configuration and postoperative VA remains unclear.[3−10] Therefore, the aim of this study was to determine MH diameters, nasal arm (NA)-, temporal arm (TA), indexes, and area- and volume-based predictive factors related to preoperative MH configuration and evaluate these parameters as visual prognostic factors.

MATERIALS and METHODS

This retrospective study was performed in adherence with the tenets of the Declaration of Helsinki and approved by the local ethics committee (2020/7-29/08.06.2020).

Informed consent was obtained from all the study participants. We reviewed the records of all patients who underwent vitrectomy for FTMH between 2013 and 2020 and were followed up for at least 6 months after surgery. The inclusion criterion was diagnosis of idiopathic FTMH by fundoscopic examination and SD-OCT. Patients with other eye diseases which may affect vision, including high myopia, glaucoma, optic neuropathy, proliferative vitreoretinopathy, RD, and other retinal diseases were excluded. Patients in whom MH failed to close, underwent secondary PPV.

According to Gass classification, MH was stage 2 in 2 eyes and stage 4 in 28 eyes. Data obtained included age, sex, intraocular pressure (IOP), and best-corrected visual acuity (BCVA) before and after MHS. Snellen VA values were converted to logarithm of the minimum angle of resolution (logMAR). Various MH parameters (Figure-1) including base diameter (BD), minimum diameter (MD), opening diameter (OD), height, D_2, nasal arm (NA), and temporal arm (TA) length were measured using the Optovue RTVue XR Avanti SD-OCT (Software 2018.1.0.37, CA, USA) caliper from high-definition 18-line radial scans of the macula with line length of 10 mm and depth of 2.6 mm, each line consisting of 1024 scans with 5-µm axial resolution and 15-µm lateral resolution. OD, MD, and BD were measured at the level of the inner opening of MH, at the level of the minimum extent of the MH (narrowest hole width in the mid-retina, as a line drawn roughly parallel to the RPE), and at the level of RPE, respectively. Height was defined as the maximum distance from RPE to the innermost aspect of the hole and D_2 was defined as the distance from RPE to MD. Nasal and temporal arm lengths were defined as the distance from RPE to the level of minimum extent of the hole nasally and temporally, respectively.

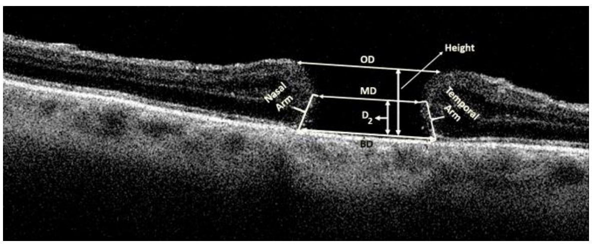

Figure-1. Macular hole measurement parameters.

Hole form factor (HFF) was calculated as the ratio of the sum of nasal arm length and temporal arm length to BD, as defined by Ullrich et al.(2). Macular hole index (MHI) was calculated as the ratio of maximum height and BD, as defined by Kusuhara et al.(11). Diameter hole index (DHI) was calculated as the ratio between MD and BD, and tractional hole index (THI) as the ratio between maximum height and MD, as defined by Ruiz-Moreno et al.(12). Area and volume of MHs were also evaluated separately for the lower (from BD to MD) and upper (from MD to OD) parts of the MH. Macular hole area (MHA) was calculated using the software of the SD-OCT device and MH volume (MHV) was calculated using a truncated cone volume formula. Pre-operative and post-operative presence of intraretinal cysts at the edge of the macula and continuity of the RPE, inner segment–outer segment (IS/OS) boundary, and external limiting membrane (ELM) lines were also evaluated.

Internal software used an averaging system to calculate the central macular thickness (MT) as the distance between the RPE and the ILM by preset algorithms.

Macular Hole Surgery

All patients underwent 3-port 23-gauge PPV performed by the same surgeon. The main steps of the procedure included: 1) core vitrectomy and triamcinolone acetonide-assisted (10 mg/mL) posterior vitreous detachment; 2) ILM staining with brilliant blue G (BBG) 0.05% (Ocublue Plus; Aurolab India mixed with 10% dextrose in 1:2 proportions); 3) BBG aspiration using a backflush flute needle after 1-2 minutes; 4) ILM peeling in a 3-4 disc diameter area around the edges of the MH; and 5) filling the vitreous cavity with 15% sulfur hexafluoride (SF6). Fluid-air exchange was done multiple times at the end of the surgery to ensure that the macula was completely "dry." Patients with lens opacity underwent concurrent cataract surgery. The inverted ILM flap technique was not used in any of the patients. Patients remained in the face-down position after surgery for 5 days to allow stabilization of the hole area and partial absorption of the SF6 gas.

Postoperative follow-up visits were scheduled for day 1, day 5, month 1, and month 3 with additional visits if needed by the patients. At each follow-up visit, BCVA, IOP, and OCT images were recorded. Anatomical closure was evaluated according to SD-OCT findings and was defined as flattening of the MH with resolution of the subretinal cuff of fluid and neurosensory retina completely covering the fovea. Functional success was determined as 1 line improvement of BCVA.

Statistics

All data were evaluated using IBM SPSS Statistics Standard Concurrent User version 26 (IBM Corp., Armonk, New York, USA) statistics package software. Descriptive statistics were given as number of units (n), percentage (%), and mean ± standard deviation ($\bar{x} \pm SD$). The normality of the data of numerical variables was evaluated by Shapiro-Wilk normality test. The homogeneity of variances was evaluated by Levene test. Independent two-sample t-test was used to compare postop BCVA and ΔBCVA values according to gender, postop cyst and postop ELM, and one-way analysis of variance was used for the comparison of lens status. Tukey HSD test was used as a post hoc test in one-way analysis of variance. The correlations between postop BCVA and ΔBCVA values with normally distributed numerical variables were evaluated with Pearson correlation analysis, and the correlations between non-normally distributed variables were evaluated by Spearman correlation analysis. Variables with p<0.10 values were included in the linear regression model in univariate comparisons with postop BCVA (logMAR) and ΔBCVA (logMAR). Categorical variables were included in the analysis with dummy coding. Backward elimination method was used to determine the variables that were found important in the final model. In the linear regression model, the value of $p<0.10$ was considered statistically significant. In other univariate analyzes, the value of $p<0.05$ was considered statistically significant.

RESULTS

Demographic and clinical characteristics of the patients were as described in Table-1. Median follow-up time after MHS was 9 (6-30) months. MH was stage 2 in 2 eyes and stage 4 in 28 eyes. Mean height of MH was 409.93 ±79.56 (µm), MD was 398.16±161.06 (µm) and BD was 857.00±461.76 (µm)

Table-1. Demographic and clinical characteristics of the macular hole (MH) patients.

Variables	*n*	(%)
Sex		
Male	5	16.7
Female	25	83.3
Age (years), mean± SD	68.5±7.5	
Preop IOP (mmHg), mean± SD	14.36±2.88	
Postop IOP (mmHg), mean±SD	14.56±3.74	
Preoperative BCVA (logMAR), mean± SD	0.924±0.320	
Postoperative BCVA (logMAR), mean± SD	0.487±0.287	
ΔBCVA (logMAR), mean± SD	0.437±0.367	
Height (µm), mean± SD	409.93 ±79.56	
MD (µm), mean± SD	398.16±161.06	
BD (µm), mean± SD	857.00±461.76	
Anatomic closure		
No	2	6.7
Yes	28	93.3
Functional success		
No	4	13.3
Yes	26	86.7
Line improvement (BCVA)		
None	4	13.3
1 line	4	13.3
2 lines	5	16.7
3 or more lines	17	56.7
Lens Status		
0 (phakic)	11	36.7
1 (pseudophakic after MH surgery)	12	40.0
2 (pseudophakic before MH surgery)	7	23.3
Complication*		
No closure	2	6.7
Epiretinal membrane	3	10.0
Retinal detachment (RD)	2	6.7
Glaucoma	2	6.7
Recurrent hole (RH)	2	6.7
Spontaneous closure after RH	1	3.3
Cataract	12	40.0
IOL dislocation	1	3.3
Comorbidity*		
Diabetes mellitus (DM)	6	20.0
MH in fellow eye	7	23.3
Glaucoma	1	3.3
Hypertension (HT)	2	6.7
Atherosclerotic heart disease	1	3.3
Hyperthyroidism	1	3.3
Hyperlipidemia	1	3.3

ΔBCVA= Postoperative – Preoperative BCVA; *Every category was evaluated independently.

Preop: Preoperative, Postop: Postoperative, BCVA: Best corrected visual acuity, IS/OS: Inner segment-outer segment, ELM: External limiting membrane, MD: Minimum diameter, MHV: Macular hole volume, HFF: Hole form factor, D_2: Distance from RPE to MD, BD: Base diameter, OD: Opening diameter, MHI: Macular hole index, DHI: Diameter hole index, THI: Tractional hole index, MHA: Macular hole area, MT: Macular thickness, MH: Macular hole

Table-2. Comparison of postoperative BCVA and ΔBCVA (logMAR) values with categorical variables and correlation of numerical variables with postoperative BCVA and ΔBCVA values (logMAR).

	Postop BCVA (logMAR)			**ΔBCVA (logMAR)**		
Categorical Variables	*mean±SD*	*t/F*	*p*	*mean±SD*	*t/F*	*p*
Gender						
Male	0.640±0.251	1.315	0.199	0.100±0.122	**4.446**	**<0.001**
Female	0.456±0.289			0.504±0.363		
Lens status						
0 (phakic)	0.554±0.220	0.458	0.638	0.236±0.150[a]	**3.468**	**0.046**
1(pseudophakic after MH surgery)	0.451±0.397			0.608±0.397[b]		
2(pseudophakic before MH surgery)	0.442±0.127			0.458±0.437[ab]		
Postop cyst						
No	0.422±0.216	1.470	0.163	0.495±0.351	1.149	0.260
Yes	0.600±0.366			0.336±0.388		
Postop IS/OS line						
Absent	0.771±0.309	**3.519**	**0.002**	0.157±0.350	**2.505**	**0.018**
Present	0.401±0.222			0.522±0.333		
Postop ELM						
Absent	0.675±0.283	**3.407**	**0.002**	0.216±0.282	**3.044**	**0.005**
Present	0.362±0.219			0.583±0.347		

Numeric Variables	*r/rho*	*p*	*r/rho*	*p*
Age (*years*)	0.263	0.161	-0.090	0.637
Preop IOP (mmHg)	0.202	0.285	-0.133	0.485
Postop IOP (mmHg)	-0.184	0.330	-0.293	0.116
Height (µm)	-0.003	0.989	-0.230	0.221
Nasal arm (µm)	**0.387**	**0.041**	-0.111	0.560
MD (µm)	0.144	0.448	0.050	0.794
Upper MHV (mm^3)	0.209	0.267	-0.200	0.288
Lower MHV (mm^3)	-0.219	0.244	-0.136	0.474
HFF (µm)	**0.360**	**0.048**	-0.096	0.615
D2 (µm)	0.264*	0.159	-0.182*	0.336
BD (µm)	0.145*	0.446	-0.048*	0.803
OD (µm)	**0.369***	**0.045**	-0.231*	0.219
Temporal arm (µm)	0.248*	0.186	-0.231*	0.220
MHI (µm)	-0.031*	0.869	-0.059*	0.758
DHI (µm)	0.016*	0.935	0.080*	0.675
THI (µm)	-0.141*	0.459	-0.036*	0.849
Lower MHA (mm^2)	0.203*	0.283	-0.114*	0.550
Upper MHA (mm^2)	0.156*	0.411	-0.117*	0.538
Time of MT measurement (months)	-0.226	0.257	**0.534***	**0.004**
Postop MT (µm)	-0.218*	0.274	0.063*	0.754
Follow-up time (months)	-0.153*	0.420	**0.386***	**0.035**
Symptom duration before MH surgery (months)	**0.415***	**0.032**	-0.254*	0.201

Preop: Preoperative, Postop: Postoperative, BCVA: Best corrected visual acuity, IS/OS: Inner segment-outer segment, ELM: External limiting membrane, MD: Minimum diameter, MHV: Macular hole volume, HFF: Hole form factor, D_2: Distance from RPE to MD, BD: Base diameter, OD: Opening diameter, MHI: Macular hole index, DHI: Diameter hole index, THI: Tractional hole index, MHA: Macular hole area, MT: Macular thickness, MH: Macular hole; [a] and [b] show differences between lens groups, *r*: Pearson correlation coefficient; *rho* and *: Spearman correlation coefficient

Table-3. Linear regression analyses results for factors affecting postoperative BCVA (logMAR) and ΔBCVA (logMAR).

	Regression Coefficients					Collinearity Statistics	
	β	*se*	*zβ*	*t*	*p*	*Tolerance*	*VIF*
Model 1: Postop BCVA (logMAR)							
Intercept	0.533	0.129		4.132	<0.001		
Nasal Arm	0.001	0.000	0.344	2.423	0.023	0.997	1.003
Postop IS/OS line							
Present	-0.226	0.129	-0.338	-1.757	0.091	0.543	1.840
Postop ELM							
Present	-0.192	0.111	-0.332	-1.724	0.097	0.542	1.845
Model Summary: *F*(3,29)=7.882, *p*=0.001, R^2=0.476, *Adj* R^2=0.416							
Variables entered: Postop ELM, HFF, Nasal arm, symptom duration before MH surgery, postop IS/OS, OD							
Model 2: ΔBCVA (logMAR)							
Intercept	-0.140	0.132		-1.059	0.300		
Lens status							
Pseudophakic after MHS	0.356	0.119	0.483	2.995	0.006	0.767	1.303
Pseudophakic before	0.288	0.136	0.338	2.115	0.045	0.784	1.276
MHS	0.312	0.128	0.366	2.435	0.022	0.882	1.134
Postop IS/OS line	0.029	0.015	0.311	2.015	0.055	0.837	1.195
Time of MT measurement							
Model Summary: *F*(4,29)=6.272, *p*=0.001, R^2=0501, Adj R^2=0.421							
Variables entered: Time of MT measurement, follow-up time, gender, lens status, Postop IS/OS line**,** Postop ELM							

β: Unstandardized coefficients, *se*: Standard error, ***zβ***: Standardized coefficients, *VIF*: Variance inflation factor

Those 2 patients without anatomical closure had MH in their other eyes, but they did not have diabetes mellitus (DM), epiretinal membrane (ERM), or postoperative cyst. Of the 4 patients without functional success, 3 had DM.

Factors thought to be effective on postop BCVA (logMAR) and ΔBCVA (logMAR) were evaluated with univariate analyzes. Patients with postoperative IS/OS line and ELM had significantly lower postoperative logMAR than the patients without IS/OS line and ELM (p=0.002, p=0.002 respectively). There were statistically positive correlations between postop BCVA (logMAR), and NA (p=0.041), HFF (p=0.048), OD (p=0.045) and symptom duration before MHS (p=0.032) (Table-2).

BCVA improved more in women (p<0.001) and more in patients who had cataract surgery after MHS (p=0.046). There were also statistically positive correlations between ΔBCVA (logMAR) values and time of MT evaluation (p=0.004) and follow-up time after MHS (p=0.035) (Table-2).

Postop ELM and IS/OS, HFF, NA, symptom duration before MHS, and OD variables which were evaluated as univariate with postop BCVA (logMAR) and found statistically significant, were included in the linear regression analysis in Table-3. Backward screening method was used to determine the final important variables; and the NA, postop IS/OS and postop ELM variables which have p<0.10, were found to be effective on postop BCVA (logMAR). According to these results, as the NA value increases, the BCVA (logMAR) value increases. Presence of postop IS/OS line and ELM cause reduction in postop BCVA (logMAR) values.

Time of MT measurement, follow-up time, gender, and lens status, postop IS/OS and ELM variables which were evaluated as univariate with ΔBCVA (logMAR) and found statistically significant, were included in the linear regression analysis in Table-3. Backward screening method was used to determine the final important variables. The ΔBCVA (logMAR) values of those with lens status pseudophakic after and pseudophakic before MHS were statistically higher than those of phakic values. Postoperative improvement in IS/OS line continuity and a longer duration of MT evaluation, cause an increase in ΔBCVA (logMAR).

DISCUSSION

Consistent with the previous studies, MH was more common in women in the present study and outnumbered men 5 to 1. The risk of IMH development in fellow eyes has been estimated at around 17% at 10 years. In our study, 23.3% of patients also had MH in the other eye. Stage 1 and many stage 2 IMHs are mostly asymptomatic and VA is inversely correlated with the size of the IMH (1-13).

Previous studies have estimated the prevalence of any type of epimacular traction, including ERM, vitreoschisis, and classic VMT, as 24–32% among eyes with DME (14-15). In our study, 20% of patients had concomitant DM as the most common systemic comorbidity. There were no signs of diabetic retinopathy either on OCT or fundus fluorescein angiography in our patients.

MHS is considered as the most successful vitreoretinal surgery with anatomical success rates of 93–98% (16). Nevertheless there are patients with large and chronic MH in whom the surgery is not successful (17-18). Consistent with the literature, our anatomical success rate was 93%.

SD-OCT technology has allowed us to evaluate foveal morphological features and investigate the relationship between MH measurement parameters and postoperative visual outcome after successful MHS. In order to explore determinant factors; different research groups proposed various morphological characteristics, including several indexes (MHI, HFF, THI, DHI), linear dimensions (MD, BD, OD), and area/volume-based indexes such as area ratio factor (ARF) and volume ratio factor (VRF) (2, 19). These parameters only express quantitative information. SD-OCT also enabled characterization of the postoperative macular configuration, and studies investigating this issue have emphasized the importance of restoration of the photoreceptors at the IS/OS junction and ELM (3, 4, 20-23). The demographic and clinical characteristics of our patient group were consistent with previous studies. The coexistence of age-related macular degeneration and DM has been mentioned in previous studies, but there was no clear research (14,15, 24). One of the notable findings of this study was the high frequency of DM in MH patients.

Of all the MH measurement parameters analyzed in our study; only Nasal Arm (NA) and postoperative presence of IS/OS line, ELM and time of MT evaluation were significantly associated with postoperative BCVA. In our study NA was determined as a predictive factor for the first time. The location of NA is within the papillomacular bundle (PMB) and PMB is the collection of retinal ganglion cells that carry the information from the macula to the optic nerve and on to the brain. If PMB is damaged, impairment of VA and color perception with central or cecocentral visual field defects occur (25). The relationship between time from symptom onset to MHS and postoperative anatomical closure and VA has been reported previously (2). However, it is noteworthy that postoperative VA was not related to BD, MD, height, MHI, DHI, THI, HFF, or ARF as reported in other studies (2, 19). Postoperative BCVA was significantly better among women, but this might be attributable to the 5:1 female to male ratio in our study. Anatomical closure was observed in all female patients. Although anatomical closure was not achieved in only 2 patients, those patients were both male.

Three of the 4 patients without functional success had DM. This is evidence that vascular pathologies affect postoperative visual outcome and delay tissue organization, as stated by Wilczynski et al. (5). Postoperative continuity of the IS/OS line was another parameter that affected functional success. These results suggest that both anatomic and hemodynamic changes may be involved in the healing process of MH after surgery. Therefore DM might cause delayed or non-existent functional recovery after MHS, as it causes disorders in the vascular structure.

Inverted flap technique is preferred in traumatic MH, MH with RD, MH in high myopia or positioning distress, besides seemed does not improve postoperative BCVA, as reported in previous studies (26-27). Since all of our patients had idiopathic FTMH, and none of the patients had positioning distress, we used PPV with ILM peeling technique instead of the inverted flap technique.

There have been studies using SD-OCT to evaluate the relationship between postoperative BCVA and postoperative IS/OS junction and ELM

(6, 22). This may be attributed to glial cells and restoration of the outer segments from the intact photoreceptor body. In the present study, visual outcomes were significantly better in eyes with a continuous IS/OS line than in those with a disrupted IS/OS line. Several studies measured the size of the disruption in the IS/OS junction and reported that larger disruptions were associated with poorer visual prognosis (3, 21, 23). In our study, we also found a positive relationship between postoperative follow-up time and postoperative BCVA as Shimozono et al. (1).

Although IS/OS measurements are seen in the literature, objective criteria and measurement techniques have not been developed (3, 8). Wakabayashi et al. regarded the ELM as a marker of photoreceptor cell survival and demonstrated that its integrity was critical for visual recovery (9). Although we did not measure preoperative IS/OS defect length or postoperative IS/OS area (because of the lack of descriptive method that was accepted technically with consensus), our findings, that restoration of the IS/OS junction and ELM were associated with better postoperative BCVA, are consistent with these previous studies. Foveal cysts might develop during follow-up and in the presence of an intact outer nuclear layer, they might progressively fill in upon complete recovery of the IS/OS junction. In our study, we evaluated the presence of foveal cyst after MHS and whether its presence affected post-operative BCVA or not, but we could not find a relationship between post-operative cyst presence and BCVA.

There have been studies which observed the association between restoration of the ELM and the IS/OS junction in surgically closed MHs (4, 7, 10, 28). Our results and those of these studies show that the IS/OS junction and the ELM are complements of one another in terms of prognostic evaluation and that the restoration of both segments is related with better visual outcomes. About the restoration of layers, ELM is the external cellular component of the Muller cells which is the most important supportive element of the retinal structure and may facilitate the regeneration and restoration of the photoreceptors outer segment bearing the mitochondrial centers producing the cellular energy. Kaz´mierczak et al. concluded that anatomical and functional outcomes were satisfactory after MHS and improved with time (29). Therefore we may think that there is a correlation between ELM restoration and VA improvement.

Michalewska et al. determined that photoreceptor layer defects continued to decrease in size with time, whereas defects in the nerve fiber layer and RPE did not change over time. They noted that reduction in photoreceptor layer defect size over the first postoperative year were significantly correlated with improvement in VA (6). Consistent with that study, we also observed in the present study that macular configuration normalized over time and macular edema decreased, resulting in increased VA.

Ullrich et al. reported that preoperative measurement of MH size with OCT could serve as a prognostic factor for postoperative visual outcome and anatomical success rate after MHS. In their study, symptom duration did not correlate with measured MH diameters, but BD and MD in particular seemed to have predictive value in MHS (2). In contrast to the Ullrich et al. study, we could not find any relationship between BD or MD and better functional outcome. In our study we found statistically positive correlations between postop BCVA (logMAR), and NA, HFF, OD and symptom duration before MHS.

Puliafito and Ullrich found that the anatomical success rate was significantly better among patients with HFF greater than 0.9 and that MD measured with OCT seemed to be a better predictor than HFF (2). In contrast to the work of Ullrich and Puliafito, we could not compare anatomical success with HFF because in our study anatomical closure was absent only in two patients, which may be due to the difference in sample sizes in the studies. However we found a statistically positive correlation between postop BCVA (logMAR) and HFF.

Geng et al. aimed to predict visual outcome in patients undergoing MHS using the 3-dimensional morphological OCT parameters ARF and VRF. They found that ARF had better sensitivity and specificity compared to MHI and HFF, suggesting it may be a more effective parameter for the prediction of visual outcome after MHS (19). In our study, we did not detect a statistical relationship between MHA and visual prognosis, but this may be because we used different measurement methods and SD-OCT devices. They calculated ARF using the Zeiss SD-OCT software (19), whereas we used an Optovue RTvue device and calculated the upper and lower area (delineated by the MD) with the formula in the software, and we observed no relationship between postoperative BCVA and upper or lower area. The OCT device we used does not have a VRF calculation program, so we calculated upper and lower MHV (again separated by the MD) using the truncated cone volume calculation formula. However, we did not detect a relationship between MHV and postoperative VA as reported by Geng et al.

Kusuhara and Moreno reported that MHI was a prognostic factor for visual outcome in their studies (11-12). In contrast to their studies, we did not detect a relationship between MHI and visual outcome, nor did we find a relationship between BD, MD, and THI as Moreno did. However, the lack of a relationship between DHI and MH height was compatible with the Moreno study. The number of participants was very similar in all of these 3 studies.

Vaziri et al. found that the rates of reoperation was 9.5% within 12 months (30). This rate was 6.7% within 12 months in our study.

CONCLUSION

In conclusion, the results of our study indicate that preoperative NA, postoperative IS/OS line and ELM continuity are predictive factors for visual prognosis after MHS.

It appears to be a consensus that the IS/OS junction is a useful indicator of visual function after MHS and that the IS/OS junction and ELM are complementary in prognostic evaluation, with restoration of both segments associated with better visual outcome. Although many studies have evaluated MH parameters and the relationship between these parameters and postoperative VA, it is not yet clear which of these parameters affect VA.

In our study we determined NA as a predictive factor for the first time. The reason of NA being a predictive factor, may be its location which is within the PMB. Impairment of the PMB causes reduced VA and impaired color perception with central or cecocentral visual field defects. That's why we suppose that this study might be a new sight of view by regarding the importance of NA for the first time in the literature.

The discrepancies among studies may be due to the differences in number of participants, surgical methods, preoperative duration of symptoms, follow-up time, or the use of different SD-OCT devices and software. Therefore, our results should be supported by larger case series.

Conflict of interest: The authors report no relevant conflict of interest or disclo-sures relevant to this viewpoint.

References

1. Duker JS, Kaiser PK, Binder S, et al. The international vitreomacular traction study group classification of vitreomacular adhesion, traction, and macular hole. Ophthalmology 2013; 120: 2611-9.
2. Ullrich S, Haritoglou C, Gass C, et al. Macular hole size as a prognostic factor in macular hole surgery. Br J Ophthalmol 2002; 86: 390-3.
3. Oh J, Smiddy W, Flynn H, et al. Photoreceptor inner/outer segment defect imaging by spectral domain OCT and visual prognosis after macular hole surgery. Invest Ophthalmol Vis Sci 2010; 51: 1651-8.
4. Ooka E, Mitamura Y, Baba T, et al. Foveal Microstructure on Spectral-Domain Optical Coherence Tomographic Images and Visual Function After Macular Hole Surgery. Am J Ophthalmol 2011; 152 (2) :283-90.
5. Wilczyński T, Heinke A, Niedzielska-Krycia A, et al. Optical coherence tomography angiography features in patients with idiopathic full-thickness macular hole, before and after surgical treatment. Clinical Interventions in Aging 2019; 14: 505-14.
6. Michalewska Z, Michalewski J, Nawrocki J. Continuous changes in macular morphology after macular hole closure visualized with spectral optical coherence tomography. Graefes Arch Clin Exp Ophthalmol 2010; 248: 1249-55.
7. Shimozono M, Oishi A, Hata M, et al. Restoration of the photoreceptor outer segment and visual outcomes after macular hole closure: spectral-domain optical coherence tomography analysis. Graefes Arch Clin Exp Ophthalmol 2011; 249: 1469-76.
8. Itoh Y, Inoue M, Rii T, et al. Correlation between length of foveal cone outer segment tips line defect and visual acuity after macular hole closure. Ophthalmology 2012; 119: 1438-46.
9. Wakabayashi T, Fujiwara M, Sakaguchi H, et al. Foveal microstructure and visual acuity in surgically closed macular holes: spectral-domain optical coherence tomographic analysis. Ophthalmology 2010; 117: 1815-24.

10. Bottoni F, De Angelis S, Luccarelli S, et al. The dynamic healing process of idiopathic macular holes after surgical repair: a spectral-domain optical coherence tomography study. Invest Ophthalmol Vis Sci. 2011; 52: 4439-46.
11. Kusuhara S, Teraoka Escaño MF, Fujii S, et al. Prediction of postoperative visual outcome based on hole configuration by optical coherence tomography in eyes with idiopathic macular holes. Am J Ophthalmol 2004; 138 (5): 709-16.
12. Ruiz-Moreno JM, Staicu C, Piñero DP, et al. Optical coherence tomography predictive factors for macular hole surgery outcome. Br J Ophthalmol 2008; 92 (5): 640-4.
13. Kumagai K, Ogino N, Hangai M, et al. Percentage of fellow eyes that develop full-thickness macular hole in patients with unilateral macular hole. Arch Ophthalmol 2012; 130: 393-4.
14. Jackson TL, Nicod E, Angelis A, et al. Vitreous attachment in age-related macular degeneration, diabetic macular edema, and retinal vein occlusion: a systematic review and metaanalysis. Retina 2013; 33: 1099-108.
15. Ophir A, Trevino A, Fatum S. Extrafoveal vitreous traction associated with diffuse diabetic macular oedema. Eye 2010; 24: 347-53.
16. Chablani J, Khodani M, Hussein A, et al. Role of macular hole angle in macular hole closure. Br J Ophthalmol 2015; 99: 1634-8.
17. Shukla SY, Afshar AR, Kiernan DF, et al. Outcomes of chronic macular hole surgical repair. Indian J Ophthalmol 2014; 62: 795-8.
18. Rahimy E, McCannel CA. Impact of internal limiting membrane peeling on macular hole reopening: A systematic review and meta-analysis. Retina 2016; 36: 679-87.
19. Geng XY, Wu HQ, Jiang JH, et al. Area and volume ratios for prediction of visual outcome in idiopathic macular hole. Int J Ophthalmol 2017; 10 (8): 1255-60.
20. Chalam KV, Murthy RK, Gupta SK, et al. Foveal structure defined by spectral domain optical coherence tomography correlates with visual function after macular hole surgery. Eur J Ophthalmol 2010; 20: 572-7.
21. Chang LK, Koizumi H, Spaide RF. Disruption of the photoreceptor inner segment-outer segment junction in eyes with macular holes. Retina 2008; 28: 969-75.
22. Baba T, Yamamoto S, Arai M, et al. Correlation of visual recovery and presence of photoreceptor inner/outer segment junction in optical coherence images after successful macular hole repair. Retina 2008; 28: 453-8.
23. Inoue M, Watanabe Y, Arakawa AC. Spectral-domain optical coherence tomography images of inner/outer segment junctions and macular hole surgery outcomes. Graefes Arch Clin Exp Ophthalmol 2009; 247: 325-30.
24. Okamoto T, Shinoda H, Kurihara T, et al. Intraoperative and fluorescein angiographic findings of a secondary macular hole associated with age-related macular degeneration treated by pars plana vitrectomy. BMC Ophthalmology 2014; 14: 114-7.
25. Baek S, Lee WJ, Park KH, et al. Health screening program revealed risk factors associated with development and progression of papillomacular bundle defect. EPMA Journal 2021; 12: 41-55.
26. Ling L, Liu Y, Zhou B, et al. Inverted internal limiting membrane flap technique versus internal limiting membrane peeling for vitrectomy in highly myopic eyeswith macular hole-induced retinal detachment:an updated meta-analysis. Hindawi Journal of Ophthalmology 2020;1-9.
27. Yuan J, Zhang LL, Lu YJ, et al. Vitrectomy with internal limiting membrane peeling versus inverted internal limiting membrane flap technique for macular hole-induced retinal detachment. A systemic review of literature and meta-analysis. BMC Ophthalmology 2017; 17: 219.
28. Theodossiadis PG, Grigoropoulos VG, Theodossiadis GP. The significance of the external limiting membrane in the recovery of photoreceptor layer after successful macular hole closure: a study by spectral domain optical coherence tomography. Ophthalmologica 2011; 225: 176-84.
29. Kaz´mierczak K, Stafiej J , Stachura J, et al. Long-Term Anatomic and Functional Outcomes after Macular Hole Surgery. Hindawi Journal of Ophthalmology 2018; 1: 1-9.
30. Vaziri K, Schwartz SG, Kishor KS, et al. Rates of Reoperation and Retinal Detachment Following Macular Hole Surgery. Ophthalmology 2016; 123 (1): 26-31.