Evaluation of the changes in the ganglion cell complex and visual prognostic factors after vitreoretinal surgery for idiopathic macular hole

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ABSTRACT

Purpose: To investigate the ganglion cell-inner plexiform layer (GCIPL), ganglion cell complex (GCC) change determined by spectral domain optical coherence tomography (OCT) in cases undergone surgical treatment for idiopathic macular hole (MH), examine the anatomical indices of the hole structure measured by OCT and correlate between best corrected visual acuity (BCVA).

Materials and Methods: Preoperative, postoperative month-1 and month-3 data of 25 eyes of 25 patients, who underwent surgery for idiopathic stage 3 and 4 MH, were retrospectively analyzed. Factors whose effects on BCVA were investigated are age, gender, GCIPL, GCC, hole base diameter, minimum linear dimension, hole height, Macular hole index (MHI), Diameter Hole index, Tractional hole index (THI) and ellipsoid zone (EZ) recovery was determined. The GCIPL and GCC changes of the patients after surgery were compared with the values of the age and sex matched healthy control group in addition to the fellow eyes' measurements.

Results: The patient group consisted of 25 subjects, 32% (n=8) of whom were men and 68% (n=17) of whom were women. The mean age of the patients was 63.8 ± 6.7 (years). The average age of the control group was calculated as 61 ± 8.8 (years) which consisted of 10 males (40%) and 15 females (60%). Preoperative mean of BCVA was 0.91±0.29 logMAR. Post-operative month-1 and month-3 mean of BCVA were 0.74±0.30 logMAR and 0.49±0.26 logMAR respectively ($p<0.05$). The postoperative 3rd month GCIPL and GCC values of the cases showed a significant decrease compared to the preoperative measurements ($p<0.05$). There was a statistically significant linear correlation between postoperative 3rd month BCVA and GCC inferior and temporal values (r=-0.560; r=-0.585 and p=0.004; p= 0.002, respectively). A significant positive linear association was found between the postoperative month-3 BCVA,logMAR, the minimum linear diameter and base diameter (r=0.478; r=0.419 and p=0.016; p= 0.037, respectively). EZ defect was strongly associated with postoperative month-3 BCVA and changes in visual acuity (p=0.0001, r= 0.711 and p=0.0001, r= 0.690, respectively). The value of MHI≥0.419 could predict good visual prognosis.

Conclusions: Preoperative hole geometry could be used to predict surgical prognosis. In the GCIPL and GCC analysis, the inferior and temporal values are associated with the final visual outcome. Visual acuity decreases as the ellipsoid zone loss increases. MHI≥0.419 may be predictive for good visual prognosis.

Keywords: Macular hole, macular hole surgery, optical coherence tomography, ganglion cell complex, ellipsoid zone, macular hole index.

INTRODUCTION

Macular Hole (MH) is described as a full-thickness retinal defect located in the center of the fovea, causing significant visual impairment and metamorphopsia.[1,2] The prevalence of MH was reported to be approximately 3.3 per 1,000 people.[3] It affects mostly women and over 60 years old elderly patients.[1,4,5]

The anatomical closure of the hole is ensured by eliminating the vitreous adhesions on the retinal surface with vitreoretinal surgery. Recent studies have reported

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that anatomical success rates have increased to 87-99% with separation of posterior hyaloid and internal limiting membrane (ILM) peeling.[6,7] However, anatomical outcomes do not always provide visual recovery. In a recent study by Jenisch et al.[8] functional improvement in visual acuity was reported in 143 eyes (64%) of the MH cases even though anatomical closure was achieved in 194 eyes (86%) after surgery. This situation highlights the importance of the patient's risk factors, pre-operative MH parameters and surgical methods.[9,10]

Optical coherence tomography (OCT) has a key role in the diagnosis and management of vitreoretinal interface disorders and retinal diseases.[11] OCT-based parameters of MH have been described previously to estimate anatomical and/or functional success, including the minimum linear diameter of MH, base diameter, hole height, macular hole index (MHI), tractional hole index (THI), diameter hole index (DHI), ellipsoid zone (EZ) and external limiting membrane recovery.[12-18] The results of these studies with different outcomes cannot meet at a common point in the literature.

In this paper, we aim to investigate whether the predetermined indexes MHI, DHI and THI have any role in predicting anatomical and functional success in MH closure and examine the relationship between the final visual acuity and OCT parameters.

MATERIALS AND METHODS

Study Population and Design

This retrospective study was conducted in patients with idiopathic full-thickness MH who had operated in Selcuk University Faculty of Medicine, Department of Ophthalmology, between January 2018 and April 2020. The research protocols were applied in accordance with the principles of the Declaration of Helsinki and was approved by Selcuk University's Institutional Review Board and Ethics Committee (Prot.No:2020/276). All individuals gave written informed consent.

The surgically treated eyes and fellow eyes of 25 patients who met the study criteria were included in the study. Inclusion criteria were existence of an idiopathic full-thickness MH on OCT, MH base diameter of more than 400 µm (stage 3 or 4 according to the Gass Classification),[19] the absence of a MH in the fellow eye, MH closure examined in postoperative OCT scans and a follow-up duration of at least 3 months. Patients were excluded if they had an axial length exceeding 26.5 mm, additional ocular pathology contributing to visual loss (glaucoma, amblyopia, diabetic retinopathy, hypertensive retinopathy, retinal vascular diseases, etc.); macular hole secondary to any other cause such as trauma, postsurgical, diabetic macular oedema; history of previous intraocular or vitreoretinal surgery; or poor quality due to instability fixation in OCT acquisition.

Detailed ophthalmological examination was performed including auto refractometer (Tonoref III, Nidec Co. Ltd, Aichi, Japan) measurement, best corrected visual acuity (BCVA) as measured on the standard Snellen chart, intraocular pressure (IOP) (mmHg) measured by Goldmann applanation tonometry, slit lamp and fundus examination using a +90 D lens after pharmacological dilatation with 1% tropicamide for each subject. After physical examination, OCT variables collected as data. The control group consisted of 25 age and sex matched healthy individuals who applied with complaints of presbyopia. After fully ophthalmological examination, only the right eye measurements of individuals in the control group were used in the study.

Surgical Procedure

All surgical procedures were performed by one surgeon (S.G.) using the same method. The surgical technique consisted of standard 23-gauge three-port pars plana vitrectomy, removal of the posterior cortical hyaloid, ILM peeling using 0.2 mL of dye brilliant blue G (BrilliantPeel; Geuder, Heidelberg, Germany), air-fluid exchange, and injection of 20% sulfur hexafluoride (SF_6). Patients were encouraged to strict face-down positioning for 5-7 days. OCT measurements were arranged as preoperative, postoperative 1st month and 3rd month in patients and compared with the control group and the fellow eyes.

Optical coherence tomography technique

We obtained OCT images with the Spectral Domain OCT (Heidelberg Engineering, Heidelberg, Germany) device after pharmacological dilatation with 1% tropicamide for each subject and repeated three times. All parameters were measured by one experienced operator (S.E.) using OCT which operates horizontal axial scans with 512 A-scans per line with scanning area 6 × 6 mm centred at the fovea.

Layer segmentation performed automatically by the OCT Spectralis software in this same B-scan using the criteria of Ishikawa et al.[20] The retinal thickness map analysis to describe numeric averages of the different layers for each of 9 areas as defined by the Early Treatment Diabetic Retinopathy Study (ETDRS) circle. This includes 3 rings of 1-mm (inner), 3-mm (intermediate), and 6-mm (outer) diameter centered at the fovea. The following macular measurements were measured in each of the 9 macular areas defined by the ETDRS circle: (1) total retinal thickness, (2) inner retinal layers (IRLs; comprising the inner limiting membrane and the external limiting membrane), (3) macular retinal nerve fiber layer (RNFL), (4) GCL, (5) IPL, inner nuclear layer, (6) outer plexiform layer, (7) outer nuclear layer, (8) EZ, and (9) RPE. The intermediate ring was examined into 4 zones: superior, nasal, inferior, and temporal.

The GCIPL layer segmentation measured from a combination of the GCL and the inner plexiform layer. Ganglion cell complex (GCC) thickness consists of macular RNFL and GCIPL measurements. GCC and GCIPL thickness were obtained within an annular area centered on the fovea; these were the central and four (superior, nasal, inferior and temporal) values. The thicknesses of the peripapillary RNFL (pRNFL) using the optic disc cube mode and analyzed as the average and six sectoral (superotemporal, superior, superonasal, inferonasal, inferior and inferotemporal) values.

The status of the EZ was assessed with OCT scans during follow-up. OCT-based MH anatomic parameters including minimum linear diameter, base diameter (the hole diameter at the level of RPE) and greatest hole height were measured using the caliper function in the Heidelberg software (Figure 1). MHI was calculated as the ratio of the hole height to the base diameter. DHI was measured as the ratio of the minimum linear diameter to the base diameter. THI was defined as the ratio of hole height to minimum linear diameter.

Statistical analysis

The data were analyzed with the Statistical Package for Social Sciences version 26.0 for Windows (SPSS, Inc., Chicago, IL). All visual acuity values were measured with the Snellen chart and transformed to the logarithm of the minimum angle of resolution (logMAR) equivalent for statistical analysis. Normality for each variable for groups was measured using the Kolmogorov–Smirnov test. Parameters between the two groups were compared with the Mann Whitney U test. Chi-square tests were used to compare categorical variables. For comparisons of data among three groups, a Kruskal-Wallis test was performed, and then a Mann-Whitney U test was used for independent group comparisons. Statistical difference between dependent groups was firstly performed by the Friedman test. Afterwards, Wilcoxon Signed Ranks test was used for the two dependent groups. We applied an adjusted P value with the Bonferroni correction to prevent type 1 error in the comparison of two groups. Spearman correlation coefficient was used for correlation between variables. The receiver operating characteristic (ROC) curve and the area under curve (AUC) analysis were performed to evaluate the predictive ability of different parameters in visual outcomes. The cut-off value was achieved from the ROC curve, and sensitivity and specificity were determined for OCT indices. 'Functional improvement' or "good visual prognosis" was determined if there is a gain of ≥2 Snellen lines (equivalent≥0.3 logMAR units) of BCVA.[21]

RESULTS

The patients group consisted of 25 subjects, 32% (n=8) male and 68% (n=17) female. The healthy control group

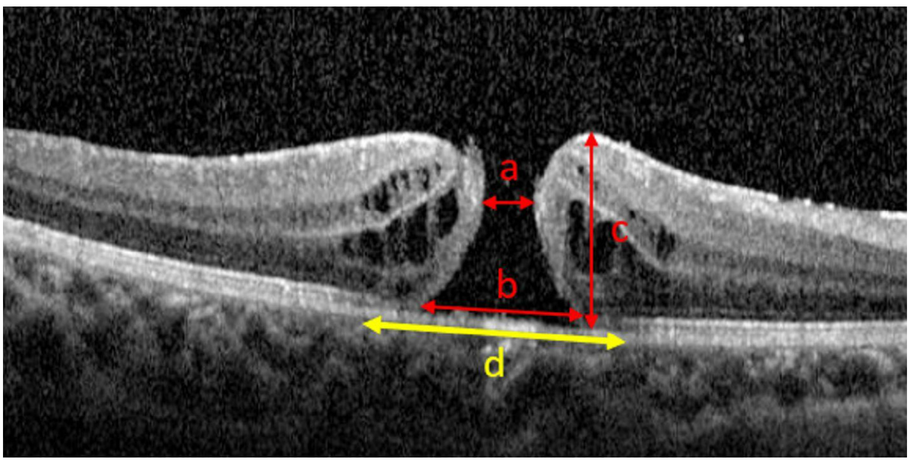

Figure 1: *MH anatomic parameters produced by OCT. a: minimum linear diameter; b: base diameter; c: hole height; d: ellipsoid zone defect. MHI = c/b; THI = c/a; DHI = a/b.*

comprised 25 individuals, 40% (n=10) male and 60% (n=15) female, with a mean age of 61.08 ± 8.84 years. Table 1 summarizes the demographic and OCT data of the 25 study participants and control group. There was no statistical difference in pRNFL, GCIPL and GCC values in eyes with MH depending on age and gender (p>0.05).

Mean preoperative visual acuity was 0.91±0.29 logMAR; mean visual acuity at postoperative month-1 and month-3 were 0.74±0.3 logMAR and 0.49±0.26 logMAR, respectively. The increase in vision were statistically significant at postoperative month-1 and month-3 (p<0.001, p<0.001, respectively) (Table 2). BCVA improvement was observed in 21 eyes (84%) at postoperative month-3, whereas no change was seen in 4 eyes (16%).

The correlation coefficients of postoperative month-3 OCT data with postoperative month-3 BCVA and changes in visual acuity are demonstrated in Table 3. GCIPL inferior, GCIPL temporal and GCC temporal values were associated with visual acuity increase (p=0.008, r= -0.517; p=0.018, r= -0.470; and p=0.035, r= -0.423, respectively). Recovery of EZ was strongly associated with postoperative month-3 BCVA and changes in visual acuity (p=0.0001, r= 0.711 and p=0.0001, r= 0.690, respectively).

There was no significant relationship between hole height, DHI, THI and preoperative and postoperative month-3 BCVA (p>0.05). Base diameter showed significant relationship with BCVA at postoperative month-3 (p=0.037, r=0.419). There was a statistically significant relationship between the minimum linear diameter and BCVA at preoperative and postoperative month-3 (p=0.046, r=0.403 and p=0.016, r=0.478, respectively). In addition, statistically significant relationship between MHI and BCVA was determined at postoperative month-1 and month-3 (p=0.022, r= -0.456 and p=0.008, r= -0.518, respectively). None of these OCT hole parameters

Table 1: *Demographic and OCT parameters of study participants*

Variables	Preoperative (1)		Control Group (2)		Fellow eye of patients (3)		(1) vs (2)	(1) vs (3)	(2) vs (3)
	Mean±Sd /n(µm)	Median	Mean±Sd /n(µm)	Median	Mean±Sd /n(µm)	Median	*p value*	*p value*	*p value*
Age	63.88 ± 6.78	63	61.08 ± 8.84	58			0.093		
Sex [Female/Male(n/%)]	17/8	68%/32%	15/10	60%/40%			0.556		
BCVA, LogMAR	0.91 ± 0.29	0.82	0	0	0.26 ± 0.36	0.09	**< 0.001**	**< 0.001**	**< 0.001**
IOP (mmHg)	16.60 ± 2.29	16	15.92 ± 1.46	16	15.64 ± 2.64	16	0.316	0.386	0.859
GCIPL-central	97.08 ± 20.87	100	36.12 ± 8.47	36	35.76 ± 16.92	30	**< 0.001**	**< 0.001**	0.298
GCIPL-superior	95.52 ± 9.67	93	93.24 ± 9.14	91	92.52 ± 12.32	95	0.515	0.648	0.823
GCIPL-nasal	95.52 ± 8.99	95	92.76 ± 11.81	94	91.28 ± 9.91	90	0.448	0.193	0.838
GCIPL-inferior	98.04 ± 9.44	99	89.00 ± 11.16	92	90.56 ± 10.99	93	**0.01**	0.026	0.641
GCIPL-temporal	91.80 ± 6.70	92	85.16 ± 11.07	83	85.92 ± 14.76	87	0.023	**0.011**	0.992
GCC-central	186.16 ± 61.60	166	48.20 ± 10.15	50	48.24 ± 19.28	43	**< 0.001**	**< 0.001**	0.454
GCC-superior	134.32 ± 27.74	126	119.04 ± 11.09	118	117.48 ± 16.04	122	0.024	0.058	0.892
GCC-nasal	139.60 ± 38.01	127	114.64 ± 13.76	118	113.12 ± 12.49	115	**0.002**	**< 0.001**	0.923
GCC-inferior	134.80 ± 27.67	125	113.04 ± 15.39	114	115.56 ± 14.21	117	**0.004**	**0.006**	0.62
GCC-temporal	138.72 ± 39.40	125	103.16 ± 10.70	103	104.92 ± 14.91	106	**< 0.001**	**< 0.001**	0.861
pRNFL-average	103.88 ± 10.29	101	95.92 ± 10.14	92	100.88 ± 16.19	102	**0.001**	0.961	**0.003**
pRNFL-superonasal	119.64 ± 27.02	123	112.96 ± 19.71	112	117.68 ± 24.66	119	0.541	0.884	0.103
pRNFL-nasal	79.20 ± 15.93	76	70.76 ± 9.12	69	76.32 ± 17.60	76	0.051	0.9	0.057
pRNFL-inferonasal	133.84 ± 27.77	135	109.04 ± 19.19	105	122.76 ± 25.78	122	**0.002**	0.26	**0.005**
pRNFL-inferotemporal	140.04 ± 19.14	136	134.40 ± 15.18	130	135.52 ± 26.63	130	0.118	0.264	0.992
pRNFL-temporal	74.72 ± 13.55	75	68.80 ± 14.18	64	70.60 ± 15.54	65	0.064	0.214	0.331
pRNFL-superotemporal	130.52 ± 21.99	132	131.88 ± 17.58	129	137.52 ± 22.81	137	0.954	0.218	0.154

Analysis between groups were performed with the Mann-Whitney U test following the Kruskal Wallis test.
P value < 0.016 in bold was considered statistically significant with Bonferroni correction.

Table 2: *Changes in OCT parameters of the study group*

Variables	Preoperative (a)		Postoperative month-1 (b)		Postoperative month-3 (c)		(a) vs (b)	(b) vs (c)	(a) vs (c)
	Mean (µm)	Sd	Mean (µm)	Sd	Mean (µm)	Sd	*p value*	*p value*	*p value*
BCVA (Snellen)	0.15	0.09	0.22	0.15	0.37	0.17	**0.004**	**< 0.001**	**< 0.001**
BCVA (LogMAR)	0.91	0.29	0.74	0.3	0.49	0.26	0.006	**< 0.001**	**< 0.001**
IOP (mmHg)	16.6	2.29	20.5	3.46	17.12	2.35	**< 0.001**	**< 0.001**	0.15
GCIPL-central	97.08	20.87	64.16	12.87	59.76	13.72	**< 0.001**	0.216	**< 0.001**
GCIPL-superior	95.52	9.67	85.48	9.69	78.68	10.71	**< 0.001**	0.019	**< 0.001**
GCIPL-nasal	95.52	8.99	92.2	10.1	87.8	7.84	0.315	0.028	**0.007**
GCIPL-inferior	79.84	12.65	79.84	12.65	77.44	14.38	**< 0.001**	0.467	**< 0.001**
GCIPL-temporal	91.8	6.7	76.04	12.61	66.84	9.47	**< 0.001**	**0.002**	**< 0.001**
GCC-central	186.16	61.6	89.44	17.41	82.08	17.96	**< 0.001**	0.103	**< 0.001**
GCC-superior	134.32	27.74	113.48	15.46	105.56	14.07	**< 0.001**	**0.014**	**< 0.001**
GCC-nasal	139.6	38.01	122.08	14.93	116.08	10.11	0.1	0.056	**0.001**
GCC-inferior	134.8	27.67	116.28	21.37	103.24	17.22	0.027	**0.006**	**< 0.001**
GCC-temporal	138.72	39.4	100.04	17.32	88.4	10.78	**< 0.001**	**0.002**	**< 0.001**
pRNFL-average	103.88	10.29	111.84	14.77	107.24	13.7	**< 0.001**	0.103	0.138
pRNFL-superonasal	119.64	27.02	125.12	32.04	119.16	24.52	0.117	0.51	0.821
pRNFL-nasal	79.2	15.93	81.88	14.6	79.2	18.82	0.223	0.266	0.687
pRNFL-inferonasal	133.84	27.77	135.84	27.5	135.6	28.45	0.382	0.742	0.369
pRNFL-inferotemporal	140.04	19.14	156.12	19.74	166.56	129.55	**0.001**	**0.002**	0.275
pRNFL-temporal	74.72	13.55	59.68	24.11	82.08	19.63	**< 0.001**	0.033	**0.009**
pRNFL-superotemporal	130.52	21.99	135.64	22.71	133.12	21.99	0.097	0.584	0.177
OCT-Ellipsoid zone defect (µm)	1643.88	456.32	1219.48	418	681.6	404.3	**< 0.001**	**< 0.001**	**< 0.001**

Variables were first examined with the Friedman test. Statistical difference between dependent groups was analyzed with Wilcoxon Signed Rank Test. P value < 0.016 in bold was considered statistically significant with Bonferroni correction.

Table 3: *Correlation between postoperative month-3 variables and BCVA (LogMAR)*

Postoperative month-3, BCVA, LogMAR			Postoperative change in visual acuity, LogMAR		
Postoperative month-3 variables	*r*	p value	Postoperative month-3 variables	*r*	p value
GCIPL-central	-0.137	0.514	GCIPL-central	-0.142	0.499
GCIPL-superior	-0.044	0.836	GCIPL-superior	-0.083	0.692
GCIPL-nasal	0.25	0.228	GCIPL-nasal	0.263	0.203
GCIPL-inferior	**-.673****	**0.0001**	GCIPL-inferior	**-.517****	**0.008**
GCIPL-temporal	**-.558****	**0.004**	GCIPL-temporal	**-.470***	**0.018**
GCC-central	0.008	0.969	GCC-central	-0.008	0.97
GCC-superior	-0.132	0.528	GCC-superior	-0.052	0.804
GCC-nasal	0.297	0.149	GCC-nasal	0.217	0.297
GCC-inferior	**-.560****	**0.004**	GCC-inferior	-0.373	0.066
GCC-temporal	**-.585****	**0.002**	GCC-temporal	**-.423***	**0.035**
pRNFL-average	-0.323	0.115	pRNFL-average	-0.225	0.28
pRNFL-superonasal	**-.490***	**0.013**	pRNFL-superonasal	-0.284	0.169
pRNFL-nasal	-0.359	0.078	pRNFL-nasal	-0.272	0.189
pRNFL-inferonasal	-0.261	0.208	pRNFL-inferonasal	-0.149	0.477
pRNFL-inferotemporal	0.021	0.922	pRNFL-inferotemporal	-0.035	0.867
pRNFL-temporal	-0.09	0.668	pRNFL-temporal	-0.061	0.772
pRNFL-superotemporal	-0.391	0.053	pRNFL-superotemporal	-0.336	0.101
Ellipsoid zone defect	**.711****	**0.0001**	Ellipsoid zone defect	**.690****	**0.0001**

*The value is statistically significant (p <0.05). Spearman rank difference correlation coefficient (r) was used in analysis.

correlated with changes in visual acuity. Figure 2 shows scattergram of the relationship between postoperative month-3 BCVA and OCT hole parameters.

ROC curves analysis was performed for the minimum linear diameter, base diameter, hole height, MHI, DHI and THI as predictors of a visual prognosis (Table 4). The cut-off values were significant for the base diameter and MHI as 0.875 and 0.419, respectively. MHI was found to be the strongest and statistically significant index among patients with visual improvement using the AUC results and cut-off values (Table 5). The value of MHI≥0.419 could predict good visual prognosis (p=0.017). Besides, THI≥0.779 could indicate for good visual outcome at postoperative month-1 BCVA (p=0.023). DHI did not predict visual prognosis significantly.

Among patients with MHI≥0.419, women predominate significantly (Fisher's Exact Test = 0.010). No significant difference according to gender was observed for DHI and THI (p>0.05). Moreover, the mean age of the patient group with MHI<0.419 was statistically significantly higher than the patient group with MHI≥0.419 (p=0.005). There was no difference according to the age for DHI and THI (p>0.05).

The preoperative and postoperative month-3 BCVA of the patients aged<64.5 was found significantly higher (MWU test, p=0.029 and p=0.017, respectively) as predictors of a good visual prognosis. In addition, the increase in vision compared to baseline was found to be significantly higher in the group aged<64.5 years (MWU test, p=0.047).

DISCUSSION

Anatomical closure of the MH following surgery does not always associated with a good visual prognosis.[22] Previously, it has been shown that postoperative BCVA could be associated with duration, configuration and novel indices of MH.[12-18,22-26] The current study aimed to evaluate preoperative OCT parameters that affect the functional success of MH cases after surgery. In our study, the mean of final visual acuity was increased significantly compared

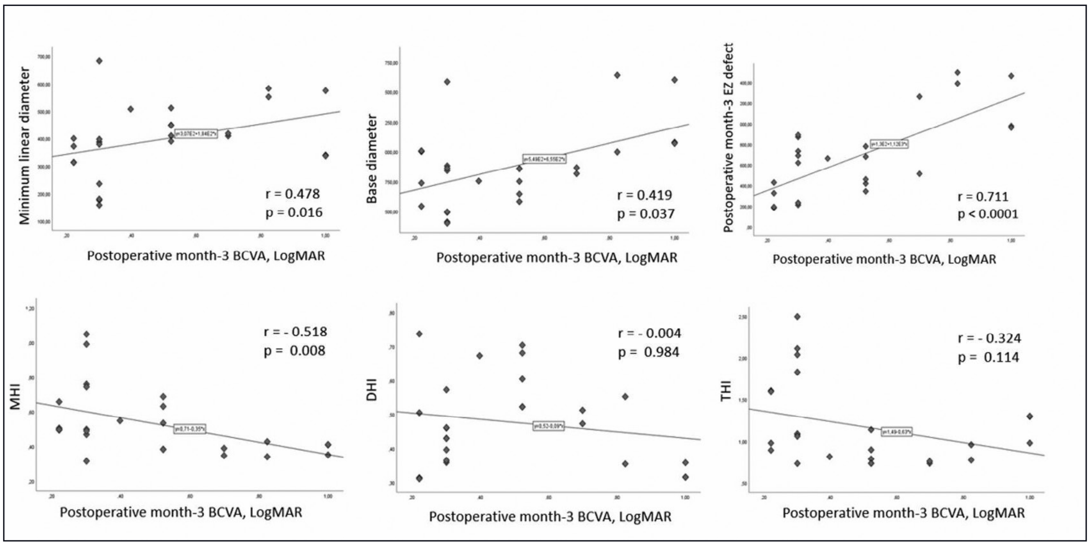

Figure 2: *Scattergram showing the relationship between postoperative best corrected visual acuity (BCVA) at 3 months and optical coherence tomography hole parameters. EZ, Ellipsoid zone; MHI, Macular Hole Index; THI, Tractional Hole Index; DHI, Diameter Hole Index.*

Table 4: *Receiver operating curve analysis obtained for OCT hole parameters as predictors of a good visual prognosis*

OCT hole parameters	AUC (%95 CI)	Cut-off value	p value	Sensitivity (%)	Specificity (%)
Base diameter	0.167 (0.003 - 0.331)	0.875	**0.038**	28	25
Minimum linear diameter	0.310 (0.039 - 0.580)	0.41	0.236	38	50
Hole height	0.393 (0.015 - 0.771)	0.429	0.505	33	50
Macular Hole Index	0.821 (0.656 - 0.987)	0.419	**0.045**	71	75
Diameter Hole Index	0.607 (0.329 - 0.885)	0.358	0.505	50	50
Tractional Hole Index	0.631 (0.369 -0.893)	0.779	0.415	81	50

The p value in bold is statistically significant (p <0.05)

Table 5: *Comparison of the patient's BCVA using the receiver operating characteristic curve analysis for various macular hole indices*

Variables	MHI			DHI			THI		
	Cut-off value		*p value*	Cut-off value		*p value*	Cut-off value		*p value*
	MHI < 0.419	MHI ≥ 0.419		DHI < 0.358	DHI ≥ 0.358		THI < 0.779	THI ≥ 0.779	
	Mean Rank	Mean Rank		Mean Rank	Mean Rank		Mean Rank	Mean Rank	
Pre-op BCVA, Snellen	7.61	16.03	**0.005**	12.8	13.05	0.945	9.17	14.21	0.134
Pre-op BCVA, LogMAR	18.39	9.97	**0.005**	13.2	12.95	0.945	16.83	11.79	0.134
Post-op month-1 BCVA, Snellen	7.89	15.88	**0.006**	13.6	12.85	0.869	7.33	14.79	**0.023**
Post-op month-1 BCVA, LogMAR	18.11	10.13	**0.006**	12.4	13.15	0.869	18.67	11.21	**0.023**
Post-op month-3 BCVA, Snellen	6.78	16.5	**0.001**	11.1	13.48	0.509	9.17	14.21	0.134
Post-op month-3 BCVA, LogMAR	19.22	9.5	**0.001**	14.9	12.53	0.509	16.83	11.79	0.134
Changes in visual acuity, LogMAR	17.67	10.38	**0.017**	16.2	12.2	0.273	16	12.05	0.248

Analysis was performed with the Mann-Whitney U test.
The p value in bold is statistically significant (p <0.05)

to the preoperative BCVA and had significant correlations. In addition, functional improvement was found to be 84%. Similarly, it could be seen that the functional improvement is not at high rates even if anatomical success reaches 100%.[27] Therefore, we tried to find correlations between postoperative BCVA and different preoperative OCT parameters in predicting the postoperative functional outcome.

GCIPL and GCC thickness measurements are used in clinical practice for monitoring macular ganglion cell loss in glaucoma.[28] In the current study, significant decrease was observed in the operated eyes at postoperative month-3 in all sectors of the GCIPL compared to baseline and the superior, inferior and temporal sectors of the GCIPL compared to controls. Similarly, Demirel et al.[24] reported significant decrease in all sectors of GCIPL at the 3rd month after surgery in their retrospective study on idiopathic MH. In another study, it was thought that ILM peeling procedures were associated with a significant attenuation in the temporal value of GCIPL at the 6th month.[29] Baba et al.[30] found significant decrease in the temporal and inferior sectors of GCC in 28 idiopathic MH cases at the 3rd and 6th months after surgery. GCC temporal, GCIPL inferior and temporal values measured at the postoperative month-3 showed a high level of positive correlation with the postoperative month-3 BCVA and visual improvement according to the Snellen chart in our study. It has been thought that the GCC and GCIPL reduction, especially in the temporal area, may be induced by neuronal and ganglion cell loss with ILM peeling during the surgical technique.[30,31] Since there was no difference in the mean IOP measured at postoperative month-3 and no patient had chronic glaucoma, GCC and GCIPL reduction was not considered to be IOP relevant. It may bring up the ILM peeling procedure to be performed with different techniques to reach better functional outcomes other than temporal approach of peeling process.

MHI is calculated as the ratio between hole height and base diameter and could easily be applied to clinical use.[15] Higher MHI value represents a smaller horizontal and a greater perpendicular hole dimension. It demonstrates positive correlation with postoperative visual outcomes.[16] In the current study, MHI had a significant correlation with the preoperative, postoperative month-1 and month-3 BCVA. It was thought that anteroposterior vitreomacular traction causing greater hole height could have a better surgical outcome when intervened and positive effect on visual prognosis with an increase in MHI. The prognostic value of the MHI was further assessed by ROC analysis among patients with good functional outcomes, resulting the cut-off value as 0.419. Our results showed that the postoperative month-1 or month-3 visual acuity or visual improvement in the group with MHI values ≥0.419 was significantly greater than in the group with MHI values <0.419. In another study, it has been reported that the visual prognosis of cases with an MHI higher than 0.5 is better than those with an MHI less than 0.5.[15] Dai et al.[32] stated that patients with MHI ≥0.475 and THI ≥0.973 were higher visual acuity at the 3rd month postoperatively and were associated with good visual prognosis. It was thought that the tractional forces of the vitreous were contributed to increase in MHI and THI, allowing it to have better surgical benefit.

Ruiz-Moreno et al.[17] reported that the basal diameter, minimal hole diameter, THI and MHI were significantly correlated with postoperative month-3 BCVA. In this regard, we found correlations of base diameter, minimum linear diameter and MHI. The minimum linear diameter of the hole showed significant correlation with preoperative and postoperative month-3 BCVA. Higher values of it were associated with worse preoperative vision as well as postoperative visual outcome. Base diameter of the hole indicated significant negative correlation with final visual acuity. Similarly, a significant negative correlation of BCVA with base diameter was reported in another study.[22] There were poor correlations between hole height, DHI and THI and final visual acuity in our study. Based on ROC analysis, postoperative month-1 BCVA had significantly higher in the group with THI ≥0.779; however, it did not differ in final visual acuity. Ruiz-Moreno et al.[17] reported 2 Snellen lines of vision gain in eyes with a THI ≥1.41. On the other hand, an association was determined with the minimum linear diameter between final visual acuity; but no significant relationship was found with MHI, DHI or THI in another study.[25]

The incidence of idiopathic MH is higher in women according to epidemiological and clinical studies.[22,33] Interestingly, the mean of MHI was found to be significantly higher in females compared to male patients in the current study. However, no statistical difference was determined between men and women in terms of final visual acuity.

In the current study, the base diameter, minimum linear diameter and hole height did not show any difference by gender. In the study of Wang et al.[34] it was reported that the age of MH was earlier, and the minimum linear diameter was smaller in women. Nevertheless, it was stated that these parameters, which were different in women, had no effect on surgical outcomes.[34] van Deemter et al.[35] reported that women over 50 years of age had a faster accumulation of pentosidine in the vitreous, which prevented total vitreous detachment. Delayed posterior vitreous detachment is thought to lead to the persistence of tractional forces on the macula.[36] In this case, it can be thought that women may have better prognosis and benefit more from surgery.

Houly et al.[18] reported a significant relationship between EZ loss of integrity and BCVA after MH surgery. In the present study, EZ defect measured at the postoperative month-3 showed a high level of negative correlation with the postoperative month-3 BCVA and visual improvement according to the Snellen chart. As the loss of EZ increases, there is a significant decrease in final visual acuity. In the detailed further examination of 4 eyes in the study group who did not show visual improvement or remained the same, it was observed that the EZ defect was prominent. It was thought that the strongest OCT parameter of hole affecting functional visual outcome was the EZ status.

The fellow eyes of MH cases have a risk for vitreoretinal interface disorders. In the literature, rates of MH development in the fellow eye are reported to vary between 13-22%.[37,38] In a comprehensive retrospective study, 1082 MH cases were followed for 20 years, and MH development in the fellow eye was detected in 122 patients (11.3%).[39] In another study, it was reported that vitreomacular traction was present in one-third of the patients in the fellow eye who developed MH in the first examination.[40] There was no significant difference in the measurements of the fellow eye in the GCIPL and GCC sectors compared to the control group in our study. In the study of Lee et al.[41] no difference was found in pRNFL measurements in the comparison of the eye with the hole and the fellow eye of MH cases. On the other hand, our study revealed that average pRNFL and inferonasal sector of pRNFL values were found to be significantly higher in eye with the hole and the fellow eye of MH cases compared to the control group. However, in the postoperative 3rd month pRNFL measurements, a significant change was observed only in the temporal sector compared to the preoperative values. While a decrease was detected in all sectors of GCC, only the temporal value of pRNFL increased at the 3rd months after surgery. It was determined that GCC and pRNFL change do not correlate with each other. Therefore, we considered GCC analysis to be more valuable than pRNFL measurements to evaluate prognosis.

The main limitations of the study are the small number of subjects and the short postoperative follow-up period. The short follow-up period may have caused inadequacies in terms of visual improvement. Eyes with worse anatomical outcome cannot be entirely investigated because of the patient selection process. We could not include duration of MH in the study analysis because it was not clear in the patient's history when the decrease in vision occurred. Another limitation of the current study was the absence of microperimetry or electroretinogram tests which can examine functional vision results in more detail. Prospective studies with a long follow-up period will be useful in understanding the morphological changes after vitreoretinal surgery and association with visual prognosis.

Idiopathic MH is a serious macular pathology that can cause irreversible vision loss. The effect of the preoperative hole geometry should be taken into consideration to predict functional outcomes. MHI is a valuable index and could be used as a prognostic factor for visual prognosis in eyes with idiopathic MH. The integrity of the EZ may help to explain cases of unsatisfactory final visual acuity even though successful anatomic hole closure. Results of the present study may provide important prognostic and surveillance information to surgeons and patients.

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REFERENCES

1. Meuer SM, Myers CE, Klein BE, et al. The epidemiology of vitreoretinal interface abnormalities as detected by spectral-domain optical coherence tomography: the beaver dam eye study. Ophthalmology 2015;122:787-95. https://doi.org/10.1016/j.ophtha.2014.10.014
2. Landolfi M, Zarbin MA, Bhagat N. Macular holes. Ophthalmol Clin North Am 2002;15:565-72. https://doi.org/10.1016/s0896-1549(02)00047-0
3. Ezra E. Idiopathic full thickness macular hole: natural history and pathogenesis. Br J Ophthalmol 2001;85:102-8. https://doi.org/10.1136/bjo.85.1.102
4. Kelly NE, Wendel RT. Vitreous surgery for idiopathic macular holes. Results of a pilot study. Arch Ophthalmol 1991;109:654-9. https://doi.org/10.1001/archopht.1991.01080050068031
5. Hwang S, Kang SW, Kim SJ, et al. Risk factors for the development of idiopathic macular hole: a nationwide population-based cohort study. Sci Rep 2022;12:21778. https://doi.org/10.1038/s41598-022-25791-1
6. Yu Y, Liang X, Wang Z, et al. Internal limiting membrane peeling and air tamponade for stage iii and stage iv idiopathic macular hole. Retina 2020;40:66-74. https://doi.org/10.1097/IAE.0000000000002340
7. Fallico M, Jackson TL, Chronopoulos A, et al. Factors predicting normal visual acuity following anatomically successful macular hole surgery. Acta Ophthalmol 2021;99:e324-9. https://doi.org/10.1111/aos.14575
8. Jenisch TM, Zeman F, Koller M, Märker DA, Helbig H, Herrmann WA. Macular hole surgery: an analysis of risk factors for the anatomical and functional outcomes with a special emphasis on the experience of the surgeon. Clin Ophthalmol 2017;11:1127-34. https://doi.org/10.2147/OPTH.S125561
9. Zhao PP, Wang S, Liu N, Shu ZM, Zhao JS. A Review of Surgical Outcomes and Advances for Macular Holes. J Ophthalmol 2018;2018:7389412. https://doi.org/10.1155/2018/7389412
10. Bikbova G, Oshitari T, Baba T, Yamamoto S, Mori K. Pathogenesis and Management of Macular Hole: Review of Current Advances. J Ophthalmol 2019;2019:3467381. https://doi.org/10.1155/2019/3467381
11. 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. https://doi.org/10.1007/s00417-010-1370-5
12. Wakely L, Rahman R, Stephenson J. A comparison of several methods of macular hole measurement using optical coherence tomography, and their value in predicting anatomical and visual outcomes. Br J Ophthalmol 2012;96:1003-7. https://doi.org/10.1136/bjophthalmol-2011-301287
13. Narnaware SH, Bawankule PK, Bansal A, et al. Pre-operative optical coherence tomography predictors: Do they hold any relevance in the era of inverted internal limiting membrane flap in large macular holes? Indian J Ophthalmol 2022;70:1689-94. https://doi.org/10.4103/ijo.IJO_2895_21
14. Ozturk Y, Ağın A, Kockar N, et al. The Importance of Anatomic Configuration and Cystic Changes in Macular Hole: Predicting Surgical Success with a Different Approach. Curr Eye Res 2022;47:1436-43. https://doi.org/10.1080/02713683.2022.2096908
15. 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;138:709-16. https://doi.org/10.1016/j.ajo.2004.04.063
16. Matsumiya W, Kusuhara S, Shimoyama T, Honda S, Tsukahara Y, Negi A. Predictive value of preoperative optical coherence tomography for visual outcome following macular hole surgery: effects of imaging alignment. Jpn J Ophthalmol 2013;57:308-15. https://doi.org/10.1007/s10384-013-0232-1
17. Ruiz-Moreno JM, Staicu C, Piñero DP, Montero J, Lugo F, Amat P. Optical coherence tomography predictive factors for macular hole surgery outcome. Br J Ophthalmol 2008;92:640-4. https://doi.org/10.1136/bjo.2007.136176
18. Houly JR, Veloso CE, Passos E, Nehemy MB. Quantitative analysis of external limiting membrane, ellipsoid zone and interdigitation zone defects in patients with macular holes. Graefes Arch Clin Exp Ophthalmol 2017;255:1297-306. https://doi.org/10.1007/s00417-017-3636-7
19. Johnson RN, Gass JD. Idiopathic macular holes. Observations, stages of formation, and implications for surgical intervention. Ophthalmology 1988;95:917-24. https://doi.org/10.1016/s0161-6420(88)33075-7
20. Ishikawa H, Stein DM, Wollstein G, Beaton S, Fujimoto JG, Schuman JS. Macular segmentation with optical coherence tomography. Invest Ophthalmol Vis Sci 2005;46:2012-7. https://doi.org/10.1167/iovs.04-0335
21. Steel DH, Lotery AJ. Idiopathic vitreomacular traction and macular hole: a comprehensive review of pathophysiology, diagnosis, and treatment. Eye (Lond) 2013;27(Suppl 1):S1-21. https://doi.org/10.1038/eye.2013.212
22. Haritoglou C, Neubauer AS, Reiniger IW, Priglinger SG, Gass CA, Kampik A. Long-term functional outcome of macular

hole surgery correlated to optical coherence tomography measurements. Clin Exp Ophthalmol 2007;35:208-13. https://doi.org/10.1111/j.1442-9071.2006.01445.x

23. Venkatesh R, Mohan A, Sinha S, Aseem A, Yadav NK. Newer indices for predicting macular hole closure in idiopathic macular holes: A retrospective, comparative study. Indian J Ophthalmol 2019;67:1857-62. https://doi.org/10.4103/ijo.IJO_364_19
24. Demirel S, Abdullayev A, Yanık Ö, Batıoğlu F, Özmert E. Evaluation of Ganglion Cell-Inner Plexiform Layer Thickness after Vitreoretinal Surgery with Internal Limiting Membrane Peeling in Cases with Idiopathic Macular Hole. Turk J Ophthalmol 2017;47:138-43. https://doi.org/10.4274/tjo.34545
25. Alkabes M, Padilla L, Salinas C, et al. Assessment of OCT measurements as prognostic factors in myopic macular hole surgery without foveoschisis. Graefes Arch Clin Exp Ophthalmol 2013;251:2521-7. https://doi.org/10.1007/s00417-013-2347-y
26. Ip MS, Baker BJ, Duker JS, et al. Anatomical outcomes of surgery for idiopathic macular hole as determined by optical coherence tomography. Arch Ophthalmol 2002;120:29-35. https://doi.org/10.1001/archopht.120.1.29
27. Ittarat M, Somkijrungroj T, Chansangpetch S, Pongsachareonnont P. Literature Review of Surgical Treatment in Idiopathic Full-Thickness Macular Hole. Clin Ophthalmol 2020;14:2171-83. https://doi.org/10.2147/OPTH.S262877
28. Tan O, Chopra V, Lu AT, et al. Detection of macular ganglion cell loss in glaucoma by Fourier-domain optical coherence tomography. Ophthalmology 2009;116:2305-14.e1-2. https://doi.org/10.1016/j.ophtha.2009.05.025
29. Sabater AL, Velázquez-Villoria Á, Zapata MA, et al. Evaluation of macular retinal ganglion cell-inner plexiform layer thickness after vitrectomy with internal limiting membrane peeling for idiopathic macular holes. Biomed Res Int 2014;2014:458631. https://doi.org/10.1155/2014/458631
30. Baba T, Yamamoto S, Kimoto R, Oshitari T, Sato E. Reduction of thickness of ganglion cell complex after internal limiting membrane peeling during vitrectomy for idiopathic macular hole. Eye (Lond) 2012;26:1173-80. https://doi.org/10.1038/eye.2012.170
31. La Heij EC, Dieudonné SC, Mooy CM, et al. Immunohistochemical analysis of the internal limiting membrane peeled with infracyanine green. Am J Ophthalmol 2005;140:1123-5. https://doi.org/10.1016/j.ajo.2005.05.054
32. Dai YM, Shen J, Li JK, Jin XH, Li YM. Optical coherence tomography predictive factors for idiopathic macular hole surgery outcome. Zhonghua Yan Ke Za Zhi 2013;49:807-11.
33. Chung H, Byeon SH. New insights into the pathoanatomy of macular holes based on features of optical coherence tomography. Surv Ophthalmol 2017;62:506-21. https://doi.org/10.1016/j.survophthal.2017.03.003
34. Wang J, Yu Y, Liang X, Wang Z, Qi B, Liu W. Pre- and post-operative differences between genders in idiopathic macular holes. BMC Ophthalmol 2020;20:365. https://doi.org/10.1186/s12886-020-01633-4
35. van Deemter M, Ponsioen TL, Bank RA, et al. Pentosidine accumulates in the aging vitreous body: a gender effect. Exp Eye Res 2009;88:1043-50. https://doi.org/10.1016/j.exer.2009.01.004
36. van Deemter M, Bank RA, Vehof J, Hooymans JMM, Los LI. Factors associated with pentosidine accumulation in the human vitreous. Retina 2017;37:770-7. https://doi.org/10.1097/IAE.0000000000001219
37. Choi JH, Kim KT, Kang SW, Bae K, Lee SE, Kim AY. Development of idiopathic macular hole in fellow eyes: Spectral domain optical coherence tomography features. Retina 2020;40:765-72. https://doi.org/10.1097/IAE.0000000000002439
38. Ezra E, Wells JA, Gray RH, et al. Incidence of idiopathic full-thickness macular holes in fellow eyes. A 5-year prospective natural history study. Ophthalmology 1998;105:353-9. https://doi.org/10.1016/s0161-6420(98)93562-x
39. Kumagai K, Ogino N, Hangai M, Larson E. Percentage of fellow eyes that develop full-thickness macular hole in patients with unilateral macular hole. Arch Ophthalmol 2012;130:393-4. https://doi.org/10.1001/archopthalmol.2011.1427
40. Astroz Evtouchenko P, Philippakis E, Tadayoni R, et al. Idiopathic macular hole in the fellow eye: prognostic significance of vitreomacular traction at the first examination. Invest Ophthalmol Vis Sci 2016;57(12):4069.
41. Lee WH, Jo YJ, Kim JY. Thickness of the macula, retinal nerve fiber layer, and ganglion cell-inner plexiform layer in the macular hole: The repeatability study of spectral-domain optical coherence tomography. Korean J Ophthalmol 2018;32:506-16. https://doi.org/10.3341/kjo.2018.0030