ORIGINAL ARTICLE

Qualitative and Quantitative Analysis of Idiopathic Macular Hole by SD-OCT-A Cross Sectional Study

Gyana Prasoona Devi Nookala, Jagannath Challa, Sai Priyanka, Sree Lakshmi Pallamreddy

Abstract

Background: Idiopathic macular hole (IMH) is a condition characterized by anatomic discontinuity of the neurosensory retina in the fovea. Spectral-domain optical coherence tomography (SD-OCT) has emerged as the benchmark for diagnosing and assessing macular holes. The objective of this study was to assess qualitative and quantitative characteristics of IMH on OCT and explore their relationship with the staging of macular holes and the best-corrected visual acuity (BCVA).**Methods:** A cross-sectional observational study was carried out involving 30 patients diagnosed with IMH. Various qualitative and quantitative parameters were recorded using SD-OCT. Associations between these parameters, macular hole staging, and BCVA were analyzed statistically.**Results:** The study revealed a female predominance among IMH patients, full thickness macular hole (FTMH) being the most common stage. Mean BCVA decreased with increasing MH staging, and Significant correlations were identified among BCVA and qualitative characteristics such as loss of integrity of photoreceptor layer and intraretinal cysts. Quantitative parameters including macular hole base diameter (MHBD), macular hole height (MHH), and inner segment/outer segment (IS/OS) defect diameter showed significant differences across MH stages.**Conclusion:** Understanding qualitative and quantitative features observed via SD-OCT in IMH patients is essential for enhancing treatment approaches including preoperative planning, leading to better anatomical and functional prognoses and enhancing visual function.

Key Words

Optical Coherence Tomography, Idiopathic Macular hole, Vitreomacular interface

Introduction

Macular hole (MH) is characterized by an anatomic discontinuity of the neurosensory retina in the fovea, the center of the macula. Common symptoms include a gradual decline in central vision, blurring, metamorphopsia (distorted vision), and central scotomas.[1,2]

MH can arise as a secondary complication of conditions such as diabetic retinopathy, pathological myopia, and other ocular disorders, though trauma accounts for some cases.[3] However, many cases occur without an identifiable secondary cause, termed idiopathic macular hole (IMH). IMH typically affects elderly patients, with about two-thirds being female[4]. Its prevalence ranges from 0.02% to 0.33%.[5,6] The mechanism is mainly attributed to anteroposterior vitreomacular traction from abnormal posterior vitreous detachment.[7,8]

Macular holes generally develop over weeks to months through stages initially described by Gass. In 1995, Gass

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revised the classification, suggesting that most macular holes originate from dehiscent-type defects rather than tearing-type defects. For decades, MHs have been classified based on Gass's criteria.[9,10] The use of high-resolution spectral-domain OCT has allowed for extensive quantitative and qualitative evaluation of macular holes. This technology assesses retinal layer parameters and the vitreoretinal interface, identifying clinical indicators that predict macular hole closure and postoperative visual recovery, thereby aiding in clinical efficacy evaluation.[11-13] The correlation between OCT parameters and best-corrected visual acuity (BCVA) provides insights into visual outcomes. Studies have linked parameters such as macular hole base diameter (MHBD) and defects in the inner segment-outer segment (IS/OS) junction and the external limiting membrane with BCVA.[14,15]

This study aims to evaluate the qualitative and quantitative characteristics of idiopathic macular hole on OCT and examine the correlation between these characteristics, macular hole staging, and BCVA.

Materials and Methods

A cross-sectional observational study was conducted over one year (2019-2020) with 30 patients diagnosed with idiopathic macular hole at SVRRGG Hospital, affiliated with SV Medical College, Tirupathi. Exclusion criteria included significant media opacities, secondary macular holes due to trauma, retinal detachment, diabetic retinopathy, and myopia. The study adhered to the Declaration of Helsinki principles and received approval from the Institutional Ethics Committee of SV Medical College (IEC No.14/2019). All participants provided written informed consent.

A comprehensive history was taken concerning the complaints of blurred vision and any central non seeing areas in the visual fields, and patients underwent detailed ophthalmological examinations. Best-corrected visual acuity (BCVA) was recorded using Snellen's chart and converted to LOGMAR units. The anterior segment and fundus were examined using a slit lamp and a +90D lens. Watzke Allen slit beam test was performed using a Goldmann three-mirror contact lens under slit lamp. Staging of Macular hole was done based on biomicroscopic findings according to Gass description (Table 1).[9,10]

Spectral-domain OCT (SD-OCT, PRIMUS 200, Carl Zeiss) was used to capture 6x6 mm macular images. Qualitative parameters recorded included integrity of the photoreceptor layer (IPRL), IS/OS junction defect, intraretinal cysts (IRC), vitreomacular traction (VMT), vitreopapillary traction (VPT), epiretinal membrane (ERM), and prefoveal opacities (PFO) (Fig 1&2).

Table1: Biomicroscopic Classification of Idiopathic Macular Hole (Gass description)[9,10]

Stages	Biomicroscopic Findings
Stage1A	Central yellow spot, loss of foveolar depression, no vitreo foveolar separation
Stage 1B	Yellow ring with bridging interface, loss of foveolar depression, no vitreo foveolar separation
Stage 2	Eccentric oval, crescent, or horse-shoe retinal defect inside edge of yellow ring. Central round retinal defect with rim of elevated retina, with or without pre foveolar opacity (Small full thickness macular hole <400 µm)
Stage 3	Central round =400 µm diameter retinal defect, no Weiss's ring, rim of elevated retina, with or without prefoveolar opacity (Full-thickness macular hole = 400?microns, no vitreous separation)
Stage 4	Central round defect, rim of elevated retina. Weiss's ring with pre foveolar opacity (Full-thickness macular hole > 400?microns, complete vitreous separation)

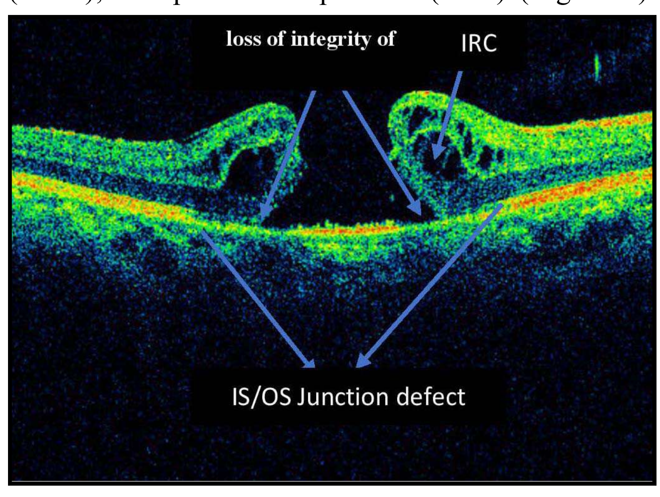

Fig 1 : SD-OCT image of line scan of macula showing FTMH with loss of integrity of photoreceptor layer, IS/OS junction defect and IRC.

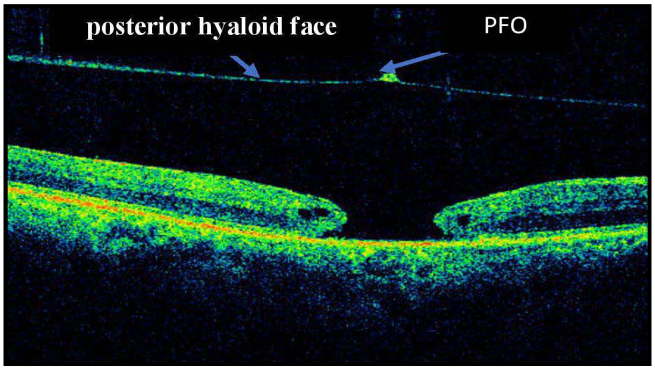

Fig 2 : SD-OCT Image of Line Scan of Macula Showing Stage III MH with PFO and Posterior Hyaloid Face

Quantitative parameters measured were macular hole base diameter (MHBD), macular hole height (MHH), and IS/OS defect diameter. The macular hole index (MHI) was calculated (Fig 3).

Table 2: Distribution of Stage of Macular Hole and Corresponding BCVA in Study Subjects

Macular hole	No of eyes (n=30, 100%)	Mean BCVA (Log mar)
Stage 1A	3 (10%)	0.38±0.17
Stage 1B	6 (20%)	0.59±0.23
Stage 2	5 (16.7%)	0.77±0.23
Stage 3	7 (23.3%)	1.13±0.11
Stage 4	9 (30%)	1.30±0.25
		P value **0.00** **(Kruskal Wallis test)**

BCVA: best corrected visual acuity

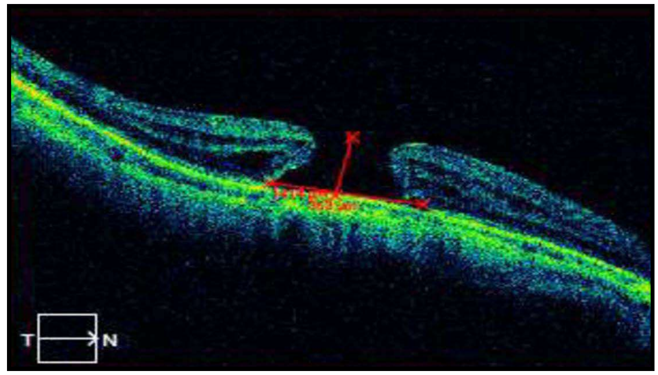

Fig 3 : SD-OCT Image of FTMH Showing Measurements of MHBD and MHH

Statistical analysis was performed using SPSS 25.0. The chi-square test, unpaired student t-test for qualitative variables, and Kruskal-Wallis test for quantitative parameters were used, with a p-value of <0.05 considered significant.

Results

The study examined 30 eyes of 30 patients with idiopathic macular hole (IMH) across all stages. The average age of participants was 58.03±8.5 years, ranging from 44 to 80 years, with a female predominance (M: F= 1:2).The macular hole stage distribution among 30 eyes were outlined in Table 2. Full thickness macular hole (FTMH, stages 2-4) constituted the majority, while stage 1 including 1a and 1b (impending macular hole) was detected in 30% of eyes.

A chi-square test was applied to establish the correlation between age group, gender, and macular hole

Table 3: Comparison of Qualitative Parameters with the Stage of Macular Hole

Qualitative parameters	Stage 1A (n = 3)	Stage 1B (n = 6)	Stage 2 (n = 5)	Stage 3 (n =7)	Stage 4 (n = 9)	Total	P-value#
Loss of IPRL	0	3(50%)	5(100%)	7(100%)	9(100%)	24	<0.001
IS – OS defect	0	3(50%)	5(100%)	7(100%)	9(100%)	24	<0.001
IRC	0	4(66.7%)	4(80%)	7(100%)	9(100%)	24	<0.002
ERM	0	2(33.3%)	1(20%)	2(28.6%)	5(55.6%)	10	0.41
VMT	2(66.7)	2(33.3%)	5(100%)	1(14.3%)	1(11.1%)	11	0.008
VPT	3(100%)	3(50%)	5(100%)	6(85.7%)	0	17	0.001
PFO	0	0	3(60%)	5(7.4%)	0	8	0.002

IPRL: integrity of photoreceptor layer, IS-OS: photoreceptor inner and outer segment junction, IRC: intra retinal cysts, VMT: vitreomacular traction, VPT: vireo papillary traction, ERM: epiretinal membrane, PFO: pre foveal opacities

#*Chi-Square test, p <0.05 considered significant* staging. The test showed no significant correlation between staging and age (p = 0.23) or between staging and gender (p = 0.41). The overall mean BCVA was 0.94±0.39 LOG MAR units. Using the Kruskal-Wallis test, it was found that BCVA decreased significantly with advancing stages of macular hole (p = 0.00) (Table 2).

Qualitative analysis revealed that loss of photoreceptor layer integrity and intraretinal cysts (IRC) were prevalent and increased with MH stage, both showing high statistical significance (P<0.00 for IPRL, P<0.05 for IRC). Epiretinal membrane (ERM) prevalence increased with stage but was not statistically significant (p = 0.41). Vitreomacular traction (VMT) was more common in early stages and significantly different across stages (P<0.05), as was vitreopapillary traction (VPT) (P<0.001) (Table 3). The correlation between qualitative characteristics and BCVA was analyzed using the unpaired student t-test. Loss of IPRL and IRC showed a significant negative association with BCVA (P<0.001). No significant correlation was found for ERM (p = 0.62) and PFO (p = 0.9), although BCVA was lower in these cases (Table 4).Quantitative parameters, including macular hole base diameter (MHBD), macular hole height (MHH), and IS/OS defect diameter, increased with the stage of the macular hole, while the mean macular hole index (MHI) decreased, all showing high statistical significance (p<0.001). The Kruskal-Wallis test was used to compare the means of MHBD, MHH, IS/OS defect diameter, and MHI values with staging (Table 5).

Table 4: Relationship Between BCVA and Changes in Qualitative Characteristics of Macular Hole

	Qualitative characteristics of MH			
	IPRL (n=30)		IRC n=30	
	Intact (6)	Lost (24)	No (5)	Yes (25)
Mean BCVA±SD	0.42±0.21	1.71±0.30	0.34±0.13	1.05±0.30
P value#	< 0.001		< 0.001	

 # unpaired t test *IPRL: integrity of photoreceptor layer, IRC: intra retinal cysts*

Discussion

SD-OCT is a valuable tool to observe the characteristic sequence of events in the development of idiopathic MH over time. Vitreoretinal interface is the primary site where changes occur initially which can lead to the formation of macular hole. Visualization of vireo retinal interface was challenging before the advent of OCT. Anterior-posterior forces due to vireo foveal traction that result in intraretinal splitting and subsequent MH have been documented longitudinally by OCT.

This study described OCT findings, both qualitative and quantitative, in patients with idiopathic macular hole (IMH) and their association with MH staging and best-corrected visual acuity (BCVA). Our findings revealed a female predominance, consistent with previous studies (Ruiz *et al*.,[13] Seyhan *et al.*,[16] Tanner *et al*.[17]). Among the 30 eyes analysed, full-thickness macular hole (FTMH) stages 2 to 4 were the predominant category, aligning with findings reported by Seyhan *et al*.[16]

Table 5: Quantitative Macular Hole Characteristics and BCVA in Various Stages of Macular Hole

Quantitative parameters	Stage1A (n=3)	Stage1B (n=6)	Stage2 (n=5)	Stage3 (n=7)	Stage4 (n=9)	P value
MHBD			1019.60±156.36	1302.43±125.03	1434.22±128.51	0.00 1
MHH			378.8±20.86	424.29±28.05	418.00±22.00	
MHI			0.360±0.05	0.32±0.04	0.28±0.03	
IS-OS defect diameter		169.05 ±77.77	1369.20 ±27.24	1928.29 ±26.74	2060.44 ±36.78	
Mean BCVA±SD (Logmarunits)	0.38±0.17	0.59±0.23	0.77±0.23	1.13±0.11	1.30±0.25	0.00 2

MHBD: Macular hole base diameter, MHH: Macular hole height, MHI: Macular hole index, IS-OS: inner and outer photoreceptor junction, BCVA: best corrected visual acuity
1Chi-Square test was used ,2 Kruskal Walli's test p<0.05 considered significant

We observed a decrease in mean BCVA with increasing MH staging. The overall mean BCVA in our study was 0.94±0.39 Log MAR units, comparable to findings in other studies.[12,14]

In our study, 24 out of 30 eyes with macular holes (MH) exhibited a loss of integrity of the photoreceptor layer (IPRL), except for stage 1 MHs. This loss, presented as an IS/OS defect in OCT scans, showed a statistically significant correlation with MH staging. Similar findings were reported by Seyhan *et al.*[16], highlighting the IS/OS defect as a common qualitative characteristic of MHs. Research by Jaerung *et al*.[18] and Chang *et al*.[14] further demonstrated that larger photoreceptor defects correlated with poorer postoperative BCVA. Our study aligns with these findings, showing significantly lower mean BCVA in subjects with photoreceptor integrity loss (P<0.001). Disruption of the IS/OS boundary likely contributes to vision loss in idiopathic MHs, as histopathological studies on autopsy eyes with MHs have shown similar intraretinal changes, including photoreceptor layer disruption and cystic retinal edema, now visualized in vivo with OCT.

In our study, intraretinal hypo-reflective spaces (IRC) were frequently detected around the edges of macular holes (MHs), with 80% of eyes exhibiting IRC. This proportion increased significantly with MH staging. These findings align with studies by Jaerung *et al* ,[18] Seyhan *et al* [16] all reporting high IRC prevalence in advanced MHs. IRC presence may indicate fluid leakage in the elevated outer retina, leading to retinal detachment from the retinal pigment epithelium (RPE).

We observed pre-foveal opacity (PFO) mainly in stage II and III macular holes (MHs), indicating significant retinal tissue tearing during MH formation. Most PFOs on OCT correspond to the combination of thickening of the posterior hyaloid face and varying amounts of retinal tissue rather than the full thickness retinal operculum (Fig 3). Epiretinal membrane (ERM) was noted in various MH stages, consistent with previous studies.[16] Though its presence may contribute to MH formation, prevalence was not statistically significant. ERM is a fibro cellular tissue on the internal limiting membrane and may develop around the hole and macular area.

Vitreomacular traction (VMT) was more common in early-stage MHs, potentially contributing to MH formation and progression by causing retinal stretching and intraretinal cystoid cavities. VMT is characterized by retinal changes on OCT with perifoveal PVD, such as altered foveal contour, intraretinal cysts, or elevated fovea from the RPE. VMT often initiates IRC formation. In the early stages of MH formation VMT and foveal cystoid spaces cause anteroposterior traction on the fovea.

Our findings align with Seyhan *et al.*,[16] showing similar VPT prevalence across MH stages, with no VPT cases in stage IV MHs. VPT involves anteroposterior traction by fibro cellular vitreous membranes at the optic disc, significantly affecting vitreoretinal interface forces and potentially inducing cystoid spaces. VPT's presence in early MH stages suggests its role in MH pathogenesis.

We assessed several quantitative parameters, including macular hole base diameter (MHBD), macular hole height (MHH), and macular hole index (MHI). These parameters offer valuable insights regarding the severity of MHs and their impact on visual outcomes. The measurement of the inner segment/outer segment (IS/OS) defect diameter provided quantitative insights into MH severity, with larger defect diameters associated with poorer visual outcomes. This highlights the importance of IS/OS defect diameter in predicting visual prognosis and guiding treatment for macular holes.

Consistent with earlier studies,[12, 13, 16, 19] we found that macular hole base diameter (MHBD) increased with macular hole (MH) stage, correlating with decreased best-corrected visual acuity (BCVA) and indicating a negative impact on visual outcomes. Although macular hole height (MHH) also increased with MH stages, this did not significantly affect BCVA in our study. The mean macular hole index (MHI), representing the ratio of MHH to MHBD, was less than 0.5, aligning with previous research,[12,13,20] that linked lower MHI values to worse postoperative visual outcomes. Ünsal *et al*..[20] observed a significant correlation between parameters such as base diameter (BD), macular hole volume (MHV), MHI, and postoperative BCVA scores. As MH stage increased, both MHI and BCVA decreased, showing a significant association between MHI and visual prognosis. Elkhouly *et al*.[21] in their Optical Coherence Tomography Study of Macular Hole, found a significant positive correlation between MHI and BCVA. Venkatesh *et al*.[22] reported that MHI, which considers anteroposterior traction forces in MH formation, had higher AUROC values for predicting type 1 macular hole closure. Patel *et al* [23] also found that higher MHI values were predictive of good anatomical closure post-surgery.

Therefore, MHBD and MHI are key quantitative parameters for assessing visual prognosis in eyes with MHs.

There are some *limitations* with the current study that should be acknowledged. The study design was cross-sectional and observational, meaning that longitudinal follow-up of patients was not conducted, Newer quantitative variable such as Diameter Hole Index and Tractional Hole Index were not studied in the analysis.

Conclusion

The current study provides valuable insights into the qualitative and quantitative features observed via spectral-domain optical coherence tomography in patients with macular holes. It highlights that the severity of idiopathic macular holes is associated with increased disruption of photoreceptor layers, and significant changes in macular hole morphology that lead to worsening visual acuity. These findings emphasize the importance of detailed monitoring and evaluation in management of patients with macular holes.

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