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Role of OCT in Macular Holes with Clinical Case scenarios

Dr. Manisha Nada[1], Dr. Manoj P Shettigar[2], Dr. Aakash Sharma[3], Dr. Parveen Chandna[4]

Professor[1] Regional Institute Of Ophthalmology, Pt. B.D.Sharma PGIMS, Rohtak, Haryana
Junior Resident[2] Regional Institute Of Ophthalmology, Pt. B.D.Sharma PGIMS, Rohtak, Haryana
Junior Resident[3] Regional Institute Of Ophthalmology, Pt. B.D.Sharma PGIMS, Rohtak, Haryana
Assistant Professor[4] Deptt. Of Radio-Diagnosis, Pt. B.D.Sharma PGIMS, Rohtak, Haryana

Abstract:
Purpose - *To review OCT's available information helps characterize and prognosticate M.H. based on its morphology.*
Design - *Interpretive essay and case scenarios*
Methods - *Literature Review with interpretation and assessment. After taking a brief note of properly informed written consent and complete history. Patients will undergo complete ophthalmic examination including pupillary dilatation, measurement of intraocular pressure by tonometry, pinhole visual acuity, anterior segment examination, retinal examination with the indirect ophthalmoscope, best-corrected Snellen visual acuity, slit-lamp biomicroscopy, and Optical Coherence Tomography.*
Conclusion - *OCT (optical coherence tomography) has dramatically altered vitreoretinal diagnosis by enabling ophthalmologists to visualize and monitor the vitreomacular interface disorders with*
Greater consistency and accuracy than ever before.

Keywords: *Optical coherence tomography, Vitreomacular interface, Macular hole, Full-Thickness Macular Hole, Lamellar Macular Hole, Internal Limiting Membrane.*

Introduction

Macular hole (M.H.) is around the full-thickness opening in the foveal center. Idiopathic macular holes typically occur in the sixth to eighth decades of life, with a 3:1 predominance in women. The incidence of bilaterality is 5% - 10%. Knapp first described a macular hole in 1869. Ogilive coined the term macular hole in 1900.

A macular hole is mostly primary due to abnormal vitreofoveal traction. Secondary macular holes are due to trauma, myopia, macular telangiectasia type 2, Nd: YAG (Neodymium-doped yttrium aluminum garnet), laser injury (including posterior capsulotomy), etc. Vitreomacular traction (V.M.T.) may or may not be a pathogenic factor in forming secondary macular holes. Depending on the macular holes' stage and severity, the visual acuity may be near normal or severely reduced or less than 6/ 60. Amsler grid testing reveals metamorphopsia or a central scotoma.

Material and Methods

Four patients diagnosed with Macular Hole at the outpatient clinics of Rohtak's Tertiary care center from December 2019 to May 2020 were retrospectively reviewed.

The inclusion criteria were: 1) self-reported significant decrease of visual acuity; 2) macular hole involving the foveal center, demonstrated on dilated stereoscopic examination and OCT; 3) no significant ocular pathology other than the macular hole at the time of evaluation.

Exclusion criteria were: 1) traumatic macular hole 2) myopic macular hole

All subjects underwent complete ophthalmic examination, including best-refracted Snellen visual acuity, slit-lamp biomicroscopy, dilated stereoscopic examination, fundus photography. For each patient, clinical characteristics were recorded, including gender, age at diagnosis was noted.

Using Electronic Macular Map 5 mm (EMM5) scanning protocol in RTVue-100 (Optovue, Fremont, CA), with Axial resolution 5um; Scanning rate 26kHz spectral-domain OCT will be used. The internal fixation will be used to ensure proper alignment of the eye with horizontal and vertical scans.

Results

Case1

A 65 years old female with complaints of diminution of vision in the left eye more than right eye since 1year, insidious onset associated with distortion of images and glare and not associated with trauma. BCVA in O.D. was 20/70 and in O.S. was 20/100. Fundus of both eyes had myopic changes with O.D. showed dull foveal reflex, and O.S. showed absent foveal reflex with a well-circumscribed flat reddish lesion of size ¼ disc diameter (D.D.) present in the foveal region. OCT images of the patient are as shown below-

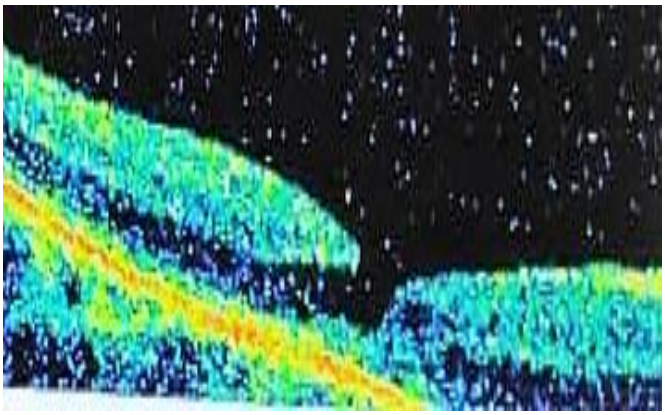


Fig. 5- Case 1 OCT scan of the right eye showing a lamellar hole with irregular base in and the cleft between the inner and outer retina inside the edge

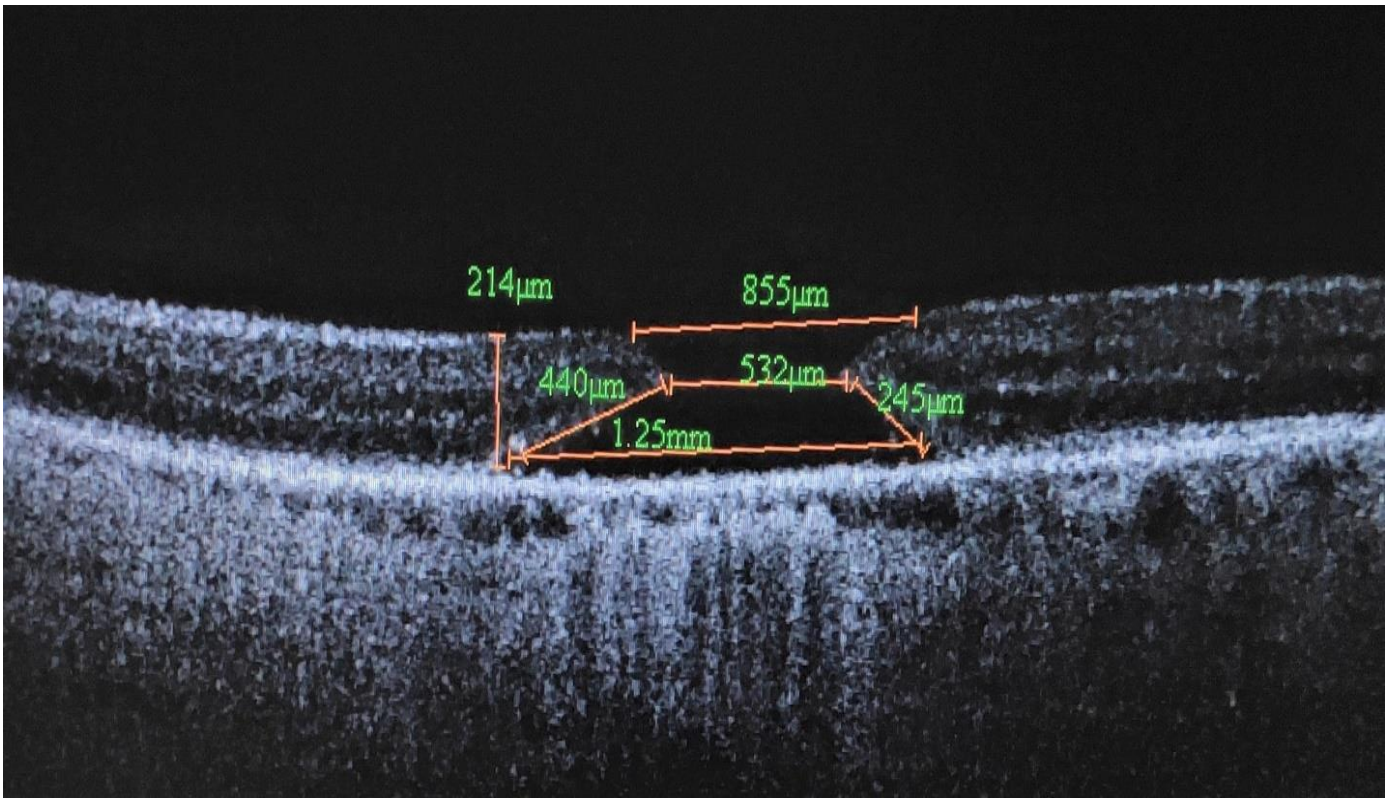


Fig 5 - Case 1- OCT scan of O.S. showing full-thickness macular hole with the posterior hyaloid detached from the macular surface. Cystic spaces thicken the hole's edge, and the photoreceptors are elevated (orange arrow marks the end of the outer segments of the elevated photoreceptors). Hole form factor (HFF, described earlier) =0.55; MHI=0.17; DHI=0.43; THI= 0.40.

Case 2

58 years old female complained of diminution of vision since 1year back when she developed in her right eye, which was insidious onset associated with occasional distortion of images and glare and not associated with trauma. Vision in O.D. 20/200 and OS 20/30. Fundus examination of O.D. showed absent foveal reflex with a well-circumscribed flat reddish lesion of size ¼ D.D. present in the foveal region O.S. had dull foveal reflex.

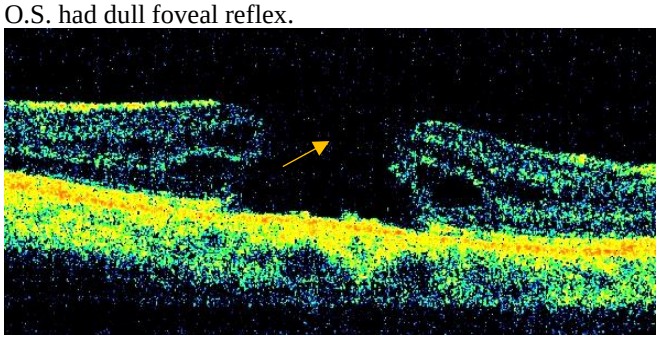


Fig -6 Case 2 OCT scan of O.D. showing a full-thickness macular hole with the posterior hyaloid detached from the macular surface. Cystic spaces thicken the hole's edge, and the photoreceptors are elevated (orange arrows mark the end of the outer segments of the elevated photoreceptors).

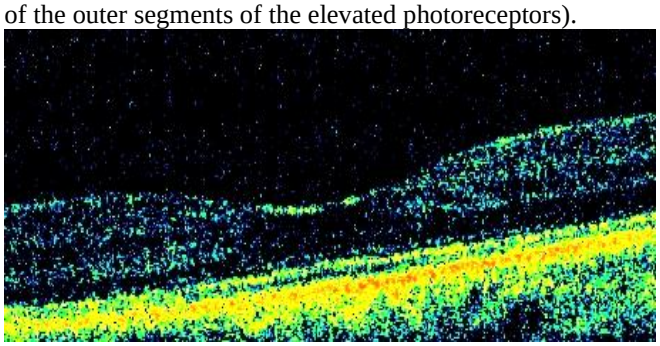


Fig. 7 - Case 2 - OS OCT -WNL

Case 3

A 58 years old female with complaints of diminution of vision for 2 months in both eyes, insidious onset associated with occasional distortion of images and glare and not associated with trauma. BCVA in O.D. was 20/100 and in OS 20/70. Fundus examination of both eyes showed dull foveal reflex.

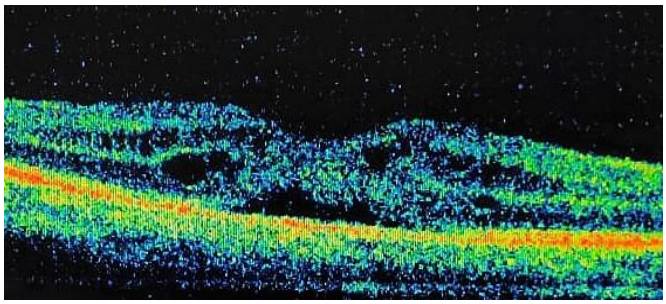


Fig 8. - OCT scan of O.D. of case 3 showing an impending macular hole with vitreomacular traction with multiple intraretinal cystic spaces around the central defect.

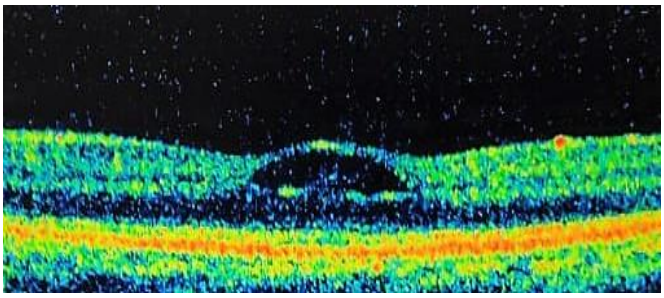


Fig 9. - OCT scan of O.S. showing cyst in the fovea's inner part due to the traction exerted by the detached posterior hyaloid (P.H. not visible in the scan). Impending macular hole with vitreomacular traction. This impending macular hole is an occult macular hole.

Case 4

66 years old female complained of diminution of vision since to finger counting at 2m, since 2 months in O.D., following cataract surgery, associated with occasional distortion of images and glare and not associated with trauma. Fundus examination of the right eye showed dull foveal reflex. It was further characterized on slit-lamp biomicroscopy as FTMH with the inner diameter being greater than 1/3rd of disc diameter (i.e.,>500 µm) surrounded by a cuff of intraretinal edema and subretinal fluid.

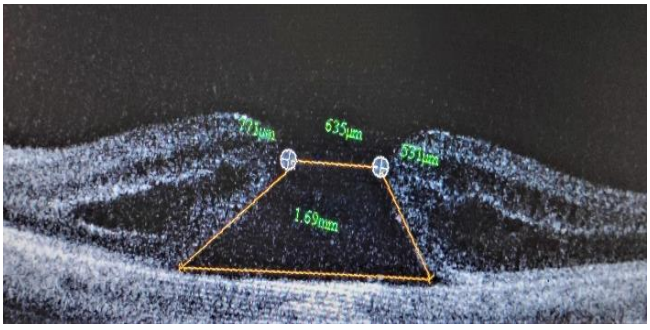


Fig. 10 - OCT scan of O.D. of case 4 showing FTMH with the posterior hyaloid detached from the macular surface. Cystic spaces thicken the edge of the hole, and the photoreceptors are elevated. Hole form factor (described earlier) = 0.77

Discussion

Pathogenesis of Macular Hole

Clinical studies have implicated vitreous traction as the cause of M.H. formation. It is now widely accepted that traction at the level of the vitreofoveal interface is the underlying mechanism. SD-OCT has now refined the description of the initial stages of impending M.H. by showing discrete changes in the foveal tissue such as discrete elevation of the interdigitation zone, minute foveolar detachment, subtle vertical line across the foveal center, or paracentral foveal

splits, and the occurrence of intrafoveal microstructural changes even before the occurrence of a foveal cyst.[1]

Prevalent theories in the pathogenesis of MH:
1. Perifoveal vitreous detachment theory: Development of posterior vitreous detachment (P.V.D.) the by the pull of the vitreous on fovea leads to mechanical breakdown of the integrity of fovea. Anteroposterior vitreous tractional force exerted on the fovea causes breaks in both the internal limiting membrane (I.L.M.) and the external limiting membrane (E.L.M.), leading to the mechanical breakdown of integrity of fovea. A discrete linear signal is seen on OCT is the signal from the posterior vitreous face.
High-resolution scanning of the posterior segment using a probe frequency of 10 MHz plays an important role in diagnosing and managing P.V.D.
2. Hydration theory: Tear involving inner fovea following P.V.D. Allows seepage of fluid into the outer fovea, thereby creating a cavity leading to a macular hole formation. As a result, the hole edge thickens, and events due to the retina's hydration develop after the outer retina is directly exposed to the vitreous fluid. This results in the formation of a cavity leading into the formation of a macular hole.
3. Muller cell cone hypothesis**:** Degeneration of the Muller cell cone–vitreous cortex interface is the earliest change in macular hole formation. This causes muller cell invasion and proliferation within the foveolar vitreous cortex, leading to the prefoveolar vitreous cortex's contraction. This contraction results in full-thickness retinal dehiscence at the umbo and centrifugal retraction of the receptor cell layer, forming age-related macular holes**.**[2]

Impending (Occult) Macular Hole

Asymptomatic patients with impending macular holes have partial perifoveal vitreous detachment, but foveal cysts are not seen. SD-OCT (spectral-domain OCT) shows the slight focal foveal elevation and minor changes in the ellipsoid zone due to centrifugally displaced photoreceptor, interdigitation zone. Still, the outer retinal layers may remain intact.[6]

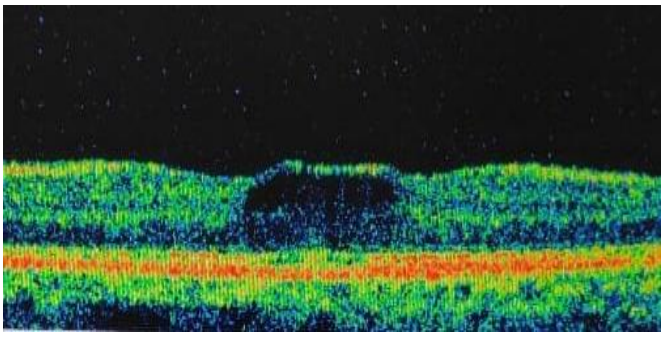


Fig.1- OCT image showing perifoveolar detachment of posterior hyaloid with a foveal cyst in the inner foveola in impending MH

OCT Classification of Macular Hole

The classification given below is based on both the M.H. diameter and the status of the vitreous attachment at the hole edge

	Biomicroscopy (Gass-1995) [3]	**OCT** [3,4,5,6]	**International VMT Classification**[7]
Stage 0 MH		Perifoveolar detachment of P.H. with normal fovea contour	V.M.A.
Stage 1A Impending MH	Central yellow spot, loss of foveolar depression, no Vitreofoveolar separation	Perifoveolar detachment of P.H. Foveal cyst in the inner foveola and foveolar detachment of the COST line	V.M.T.
Stage 1B Impending/ Occult MH	Yellow ring with Bridging interface, loss of foveolar depression, no vitreofoveolar separation	Perifoveolar detachment of P.H. Foveal cyst extending in the outer retina, causing a break in the photoreceptor layer.	V.M.T.
Stage 2 Macular Hole	Eccentric oval, crescent, or horseshoe retinal defect inside edge of the yellow ring	Hole of various sizes. Partial opening of the cyst roof, operculum staying still attached to the edge of the hole. A partial detachment of the P.H., which is still attached at the operculum. The operculum contains retinal elements	Small (≤250µm) or medium (>250µm and ≤400µm) FTMH with V.M.T.
	Central round retinal defect retina, with or without foveolar opacity		

Stage 3 Macular Hole	Central round ≥400 µm diameter retinal defect, no Weiss ring, the rim of the elevated retina, with or without foveolar opacity	Hole of various sizes. P.H. detached from the macular surface but still attached to the optic disc, most often containing an operculum	Medium or Large(>400µm) FTMH with V.M.T.
Stage 4 Macular Hole	Central round defect, the rim of the elevated retina. Weiss ring with foveolar opacity	Hole of various sizes, with complete P.V.D. on biomicroscopy. P.H. is not visible on OCT.	Small, medium, or large FTMH without V.M.T.

PH-Posterior Hyaloid, COST-Cone Outer Segment Tip, V.M.A. –Vitreomacular adhesion, FTMH- Full-thickness macular hole

Steel et al. [8] proposed an OCT-based classification system with the acronym WISPERR, which includes 6 domains for focal V.M.T. with and without the macular hole. Each category is then scored hierarchically, qualitatively, and quantitatively.

Letter	Feature classified	Description of feature	Units of measurement or graded categories
W	Width of V.M.A.	Width of the longest measurable V.M.A. extent	Measurement in microns
I	Interface between retina and vitreous cavity	Surface membrane	(0) None (1) Hyper-reflective inner retinal signal on the V.M.A. itself compared with adjacent retina (2) Any ERM
S	Shape	Foveal shape based on foveal profile and position	0) Normal (1) Abnormal profile, e.g., notch formation, concave with loss of depression relative to another side, asymmetry of depression, or a flat profile (2) Convex profile of the central fovea
P	Pigment epithelium	Presence of RPE abnormalities	(0) Not present (1) Present (could include drusen and RPE atrophy)
E	Elevation of retinal surface from RPE	Height of maximum central retinal thickness	Measurement in microns
R1	Inner retina	Inner retinal changes within central 3-mm ETDRS circle	(0) Normal (1) Inner retinal cysts or cleavage
R2	Outer retina	Outer retinal changes within central 3-mm ETDRS circle	(0) None (1) Focal outer retinal abnormality (including 'cotton ball' sign, IS/OS/ELM disruption/ fragmentation) (2) SRF (3) Outer retinal dehiscence (4) FTMH and 'maximum minimum' horizontal linear dimension

ERM-Epiretinal membrane, ETDRS- Early Treatment Diabetic Retinopathy Study, I.S.- Inner segment; O.S.- Outer segment, RPE- Retinal pigment epithelium; S.R.F.- Subretinal fluid

According to Soon et al.[9], there is a little difference between 350 μm and 450 μm M.H., and in the sense of planning surgery, 400 μm is not very practical. 650 μm is a much better marker to divide medium and large macular holes, based on their results with 90% success in standard full-thickness macular hole (FTMH) vitrectomy involving

internal limiting membrane (I.L.M.) peel and gas tamponade on medium MH between 250 and 650 μm. The standard surgery for large M.H. (>650 μm) is less successful, and such techniques as I.L.M. flaps and retinal expansion technique for macular hole apposition (RETMA) should be considered for this matter [9].

Traumatic Macular Hole

Traumatic macular holes (T.M.H.) occur following closed-globe trauma, open-globe, laser injury, surgical trauma, lightning injury, and injury by shock with electrical current.

OCT-based Classification of full-thickness T.M.H. (Huang et al.).[10]

Type I - Macular holes with cystic edema of the neurosensory retina on both the hole's margins on both the horizontal and vertical scans. Morphologically these T.M.H.s were similar to idiopathic macular holes.

Type II - Macular holes with cystic edema of the neurosensory retina on only one margin of the hole on either the horizontal or vertical scan.

Type III - Macular holes with a full-thickness defect of the neurosensory retina without cystic edema or the margins' detachment.

Type IV - Macular hole with the neurosensory retina's localized detachment at the margin without cystic edema.

Type V - Macular hole with thinning of the neurosensory retina.

Lamellar Macular Hole (L.M.H.)

Lamellar macular hole defects in the inner fovea occur due to the avulsion of the roof of a foveal cyst, which can be either tractional or due to cystoid macular edema. On biomicroscopy, L.M.H. differs from FTMH because they are rarely round but rather bi- or trilobulated. Their center is reddish like that
of FTMH, but their edge is thin, whereas the FTMH edge is thick and elevated. SD-OCT, the irregular thickness of the foveal center,
due to the contraction of an ERM was also referred to as an L.M.H. OCT shows irregular thinning of the foveal floor, the separation between the layers of outer nuclear and outer plexiform layer at the L.M.H. edge and the absence of a contractile ERM. Intraretinal cystoid changes are sometimes present within the inner plexiform layer. The outer retinal layers, including the ellipsoid zone, are usually not affected. Gaudric et al. [12] have shown that L.M.H. with tractional distortion of the inner and the outer retinal layers respond very well to macular surgery.

About 30% of L.M.H. cases have an epiretinal proliferation but differs from conventional ERMs called lamellar hole-associated epiretinal proliferation (LHEP). OCT shows an amorphous medium reflectivity material with no evidence of traction, especially on en face OCT images, where no retinal folds are seen. LHEP has a dense yellow appearance with a fluffy consistency on biomicroscopy. LHEP originates from middle retinal layers of lamellar hole defect because it contains retinal glial cells, specifically Muller cells. Histopathology of LHEP, unlike conventional ERMs, does not contain myofibroblasts. LHEP intraoperatively sometimes appears as a yellowish and soft tissue, which is often difficult to grasp and separate from the underlying internal limiting membrane (I.L.M.). [12,13]

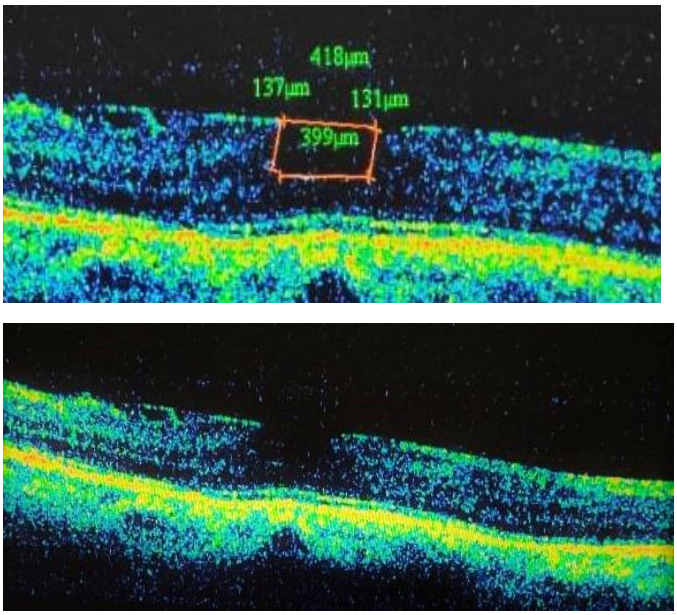


Fig. 2- OCT scan showing the irregular base of the lamellar hole and the cleft between the inner and outer retina inside the edge of the Lamellar Hole.

Pseudohole

Macular pseudoholes are formed due to the dehiscence of a gliotic preretinal membrane. This induces centripetal contraction and verticalization of the edge of the foveal pit. Pseudoholes are associated with idiopathic ERM, V.M.T., Proliferative diabetic retinopathy, rhegmatogenous retinal detachment, posterior uveitis, Venous occlusive disease, trauma. Vision may remain relatively good, and there are no microscotomas. OCT shows the thickening of the macula contracted by an ERM and the fovea's U or V shape. There is no loss of retinal tissue at the umbo of the fovea.
Macular pseudoholes have been mistaken for L.M.H. because of stretching of the Henle fibres on the fovea's edge. However, en face OCT and surgical outcome show that these aspects are a peculiar form of the macular pseudo hole with lamellar cleavage of their edge and remain pseudoholes. Histopathology has confirmed the presence of myofibroblasts in ERMs. At the same time, they were absent in L.M.H. Surgical intervention is generally often recom-

mended in the presence of a fractional component including, epiretinal tissue as seen in pseudoholes with or without intraretinal separation. [12,13]

Stage 0 M.H. (Pre macular hole)

Stage 0 occurs when a P.V.D. with persistent foveal attachment develops. It has a normal biomicroscopic appearance clinically. OCT findings consist of a subtle loss of the foveal depression with normal retinal thickness and a preretinal, minimally reflective, thin band inserting obliquely on at least one side of the fovea. Stage 0 holes usually do not progress to advanced stages. This stage represents a vitreomacular adhesion. Visual acuity is usually unaffected in this stage.[14]

Spontaneous Closure

The rate of spontaneous closure of primary FTMHs has been reported to range from 3% to 6%. Four different hypotheses suggest a mechanism of spontaneous closure: (1) complete vitreous detachment over the fovea releasing the tractional forces, (2) formation of an epiretinal membrane resulting in hole shrinkage, (3) glial cell proliferation at the base of the hole, and (4) growth of retinal tissue bridging the hole.

Watzke-Allen Test: -

Performed by projecting a narrow slit beam over the hole's centre both vertically and horizontally with a 90D or 78D lens. Patients with macular holes will report that the beam is broken or thinned.

Laser aiming beam test: -

Performed by projecting a 50 u spot of a laser aiming beam （, e.g. He-Ne) at the centre of the hole. A patient with a macular hole will report that the spot has disappeared.

Preoperative OCT predictive factors for M.H. surgery outcome

Larger foveal floors may tend to form a larger macular hole. Hole diameter may be related to foveal shape.[15] Centrifugally retracted photoreceptors may be repositioned immediately after surgery. The extent of photoreceptor retraction preoperatively may be an important predictor of microstructural and visual recovery after surgery.[16]

M.H. geometry and features parameters can predict surgical outcomes. Base diameter (B.D.), minimum linear diameter (M.L.D.), and hole form factor (H.F.F.) predicts M.H. closure rate after surgery. M.L.D., B.D., macular hole index (M.H.I.), traction hole index (T.H.I.), and H.F.F. predict M.H. postoperative visual acuity.

1) Diameter hole index (D.H.I.) is defined as the ratio of M.L.D. to B.D. It is an indicator of the extent of tangential traction.

2) Macular hole index (M.H.I.) is the ratio of H to BD

MHI value of ≥0.5 could be used to predict better postoperative outcomes

3) Traction hole index (T.H.I.) is defined as the ratio of maximal height to M.L.D. Patients with higher T.H.I. values (>1.41) and low D.H.I. values (<0.50) had the best post-op V.A. recovery.

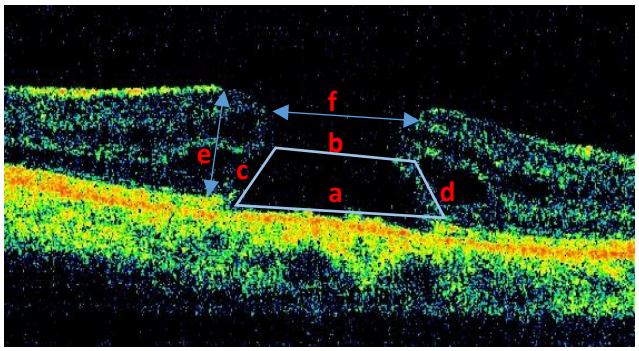
4)Hole form factor is defined as the ratio of left arm length and right arm length to the macular hole's base diameter. Higher H.F.F. preoperatively was associated with better postoperative functional outcomes. The base or minimum diameters were independent of the duration of the symptoms.

5) Fluid cuff (FC) is BD minus MLD.[17,18]

Intraoperative OCT (iOCT)

It is useful in identifying intraoperative changes in macular anatomy and provides additional information to predict macular surgery's visual outcomes. iOCT (SD-OCT) identifies occult residual membrane identifies a cleavage plane for the subsequent

I.L.M. peeling, allowing an accurate I.L.M. peel causing minimum disruption of retinal architecture thus provides valuable feedback for peel completeness during I.L.M. peeling with minimal tissue disruption.[19]



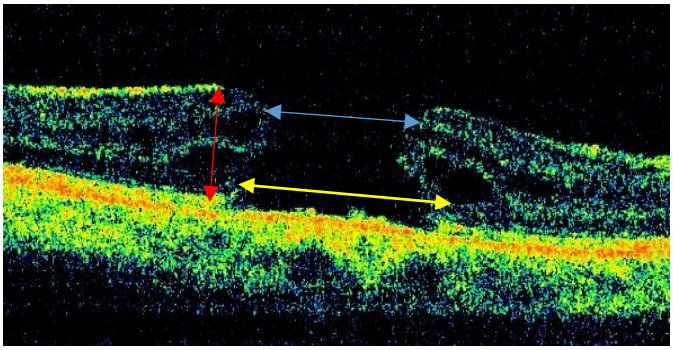


Fig. 3- OCT of a full-thickness macular hole showing base diameter (yellow arrows), height (red arrows), and minimum linear diameter (blue arrows)

HFF (Hole form factor) = c+d/a MHI (Macular Hole Index) - e/a DHI (Diameter Hole Index) - b/a THI (Tractional Hole Index) - e/b	a- base diameter b- minimum linear diameter c- left arm length d- right arm length e- macular hole height f- macular hole inner opening

Fig. 4- showing various key indices on OCT for macular hole evaluation

Post-op role of OCT: anatomic versus functional success

Macular hole closure can be observed clinically 9–10 days after gas injection.

a. Photoreceptor inner/outer segment (IS/OS) junction photoreceptor integrity is the best prognostic factor for V.A.

Grade 0: IS/OS junction absent under the fovea.

Grade 1: IS/OS junction present under the fovea (abnormal).

Grade 2: IS/OS junction present under the fovea (normal).

Anatomic success with the restoration of foveal contour does not always translate to improved postoperative visual acuity.

Irregularities at the level of the inner hyperreflective layer after macular hole surgery may prevent visual acuity

Improvement. Improvement in BCVA has been noted with IS/OS junction normalization in the postoperative period.[19]

b. Foveolar gaps (lucencies).[20]

c. Macular hole closure can be classified as

Two types of hole closure have been defined: -

• Flat/open and flat/closed anatomic closure

• Elevated/open

The closed macular holes have been variously classified based on OCT

type 1 closure indicates that the macular hole is closed without foveal defect of the neurosensory retina.

Type 2 closure indicates that a foveal defect of the neurosensory retina persists postoperatively. However, the whole rim of the macular hole is attached to the underlying RPE with flattening of the cuff.

Visual improvement is achieved in 55% to 85%of eyes with a final visual acuity of 6/12 or better in up to 65%. Stage 2 holes randomized to surgery had a significantly lower incidence of hole enlargement. Bilateral visual function improves after surgery, especially in patients with subnormal (<20/40) visual acuity in the fellow eye. [21]

Imai et al.[22] classified repaired macular hole OCT images into three patterns:

• U-type (normal foveal contour) - the retinal pigment epithelium and choriocapillaris
layers covered by a smooth surface

• V-type (steep foveal contour) - retinal pigment epithelium and choriocapillaris layers covered with moderately backscattering layers with a notch

• W-type (foveal defect of the neurosensory retina) - terminating sensory retinal layers, leading to exposure of retinal pigment epithelium and choriocapillaris layers.

OCT in the fellow eye

OCT can be used for serial follow-up of the fellow eye to pick up early changes. Patients with a full-thickness macular hole in one eye and foveal abnormalities in the fellow eye, consistent with a stage 1 macular hole, have a high risk of progression in the fellow eye. A close follow-up of these patients can help early intervention resulting in better visual outcomes.

Conclusion

OCT is vital for clinical and surgical decision-making, in particular for macular pathologies. It complements clinical examination in diagnosing vitreoretinal interface pathologies, including M.H. OCT, allows the clinician to detect initial stages of macular hole, follow its progression, and intervene early in progression to FTMH. OCT provides useful insight into the intraoperative and postoperative evaluation of M.H. With OCT in our armamentarium. We can see an exponential expansion of our ophthalmic knowledge with unprecedented improvement inpatient care.

Conflict of interest

No conflict of interest

Limitations of the study

The study is retrospective, so it cannot accurately describe the evolution of macular holes' clinical parameters. Patients may not be able to seek medical attention due to limited access to health care. Therefore, a selection bias might have existed among patients who were included in the study.

Centration of macular scans of fovea involving pathology in patients with poor vision was difficult. Macular holes which were irregular, parameters (area, eccentricity) had to be approximated. Despite these limitations, we believe this study provides some insight into the variable morphology of macular holes.

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