Review Article

Interpretation of Optical Coherence Tomography

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Abstract

Glaucoma is a progressive disease which can lead to blindness. Early detection is crucial to prevent further damage. Though glaucoma is more a clinical diagnosis but investigative tools like optical coherence tomography can help us diagnose suspicious cupping and early glaucoma. The newer modalities help us to prognostigate the disease by seeing for progression. This article will help the reader interpret OCT with better understanding.

Keywords: Glaucoma evaluation, glaucoma imaging, interpretation of optical coherence tomography

Introduction

Glaucoma is a progressive disease which can lead to blindness. Early detection is crucial to prevent further damage. 25-30% of ganglion cell loss happens before it can be detected on field test.[1] Thinning of the neuroretinal rim and RNFL loss predicts glaucoma damage.[2] To document disease progression requires both structural and functional assessment.[3] Imaging techniques are objective and allows quantitative measurement. There are different modalities to image RNFL including OCT, HRT and SLP. This article describes interpretation of the OCT. It also discusses the limitations of OCT and artifacts affecting image quality.

Interpretation of Optical Coherence Tomography

There are four types of spectral-domain optical coherence tomography (OCT) machine available commercially: Zeiss Cirrus, Heidelberg Spectralis, Optovue Avanti TRVue, and Topcon. We describe how to interpret the Cirrus OCT reports; however, the same principle applies to most devices. Due to differences in the measurement protocols in different machines, OCT machine data should be compared interchangeably. Cirrus OCT has superior image quality than time-domain OCT due to faster scanning speed and better image resolution.[4]

Steps in assessment are as follows:

1. Type of scan [Table 1]
2. Assess the quality of the scan: Signal strength, centration of the disc, OCT image, and artifacts[5] [Figures 1-7]
3. Interpret the printout
   a. Age: Important because an inaccurately entered age will result in comparison with the wrong normative data age group. In normal eyes, a 2-μm retinal nerve fiber layer (RNFL) loss/decade and 0.2 μm/year has been reported
   b. RNFL thickness map: It shows the thickness of the RNFL – it is coded from blue (thin) to white (thickest). It normally shows an hourglass pattern. It can give you a gross idea of the RNFL thickness. The superior RNFL and inferior RNFL are the thickest whereas the nasal and temporal are less thick. Small optic discs, long axial length, and older age are associated with thinner RNFL. Every 1-mm increase in the axial length is associated with an approximately 2.2-μm decrease in RNFL thickness
   c. Look for artifacts in this map. Compare with the other eye [Table 2]; interocular difference >9 μm is unusual in normal eyes and glaucoma should be ruled out.[6]

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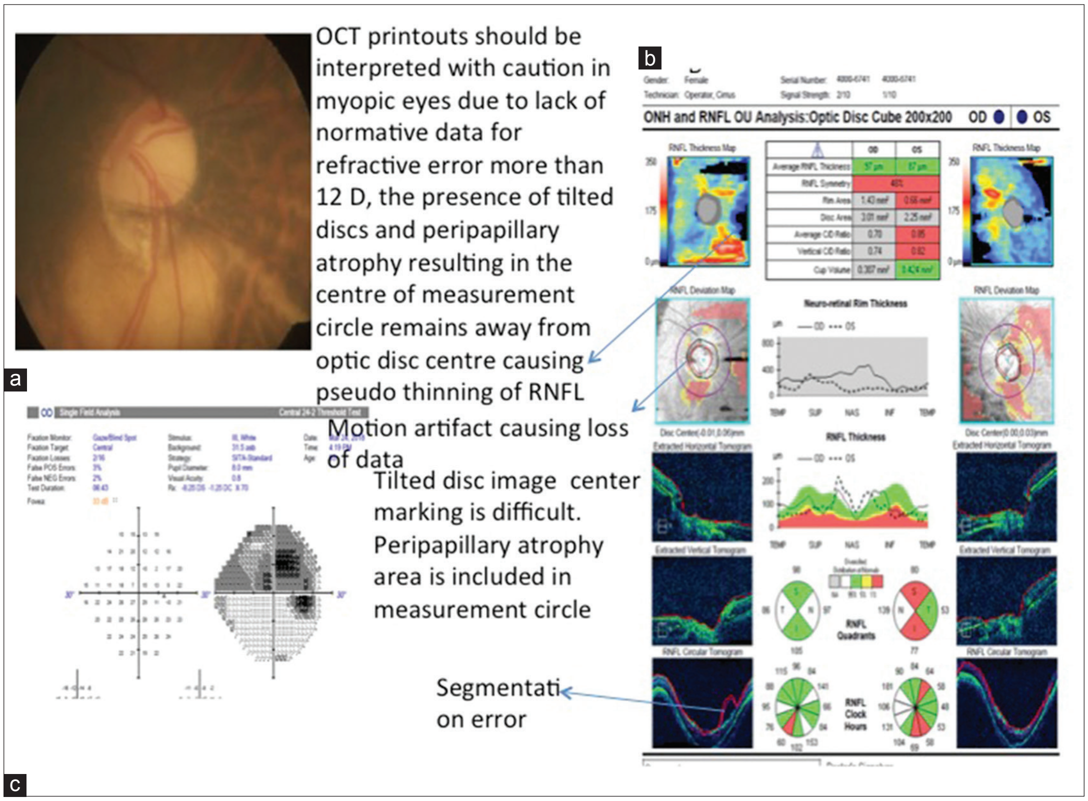

Figure 1: Optical coherence tomography in high myopia. (a) Disc photo showing tilted myopic disc with peripapillary atrophy inferiorly with enlarged CD ratio with inferior rim thinning. (b) Optic nerve head and retinal nerve fiber layer optical coherence tomography of the same patient with poor quality scan. (c) Visual field test showing superior field defect

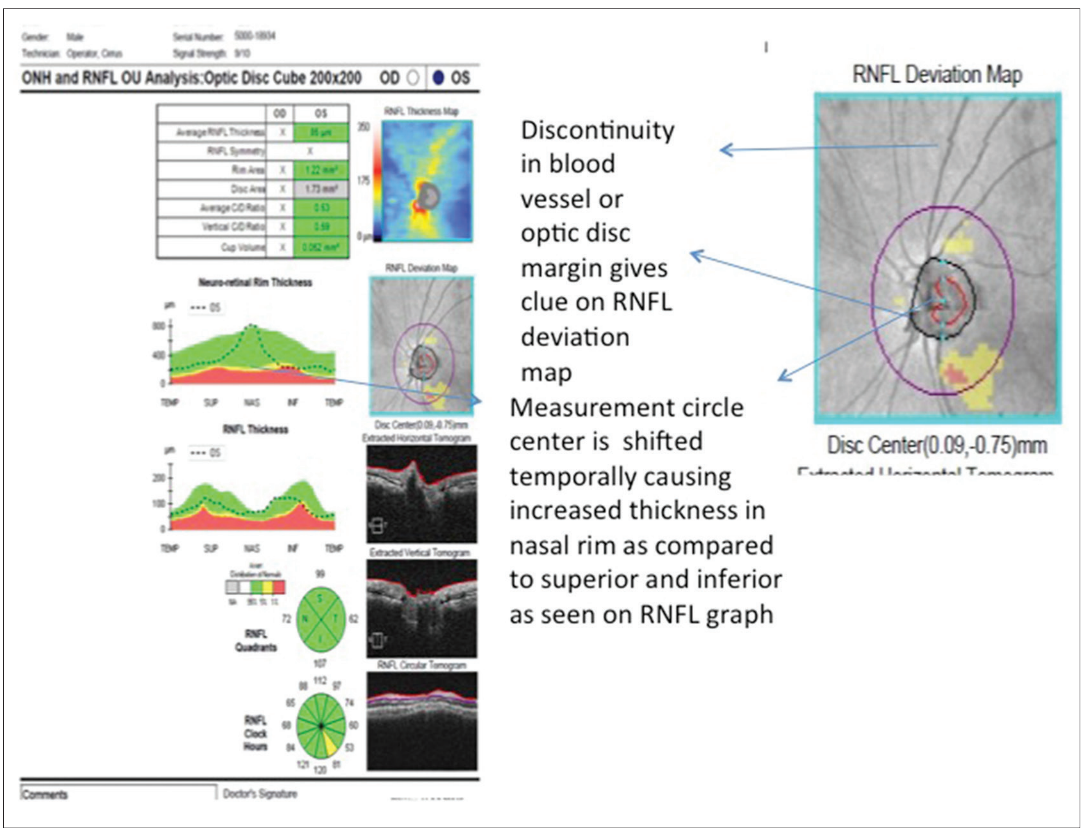

Figure 2: Motion artifact

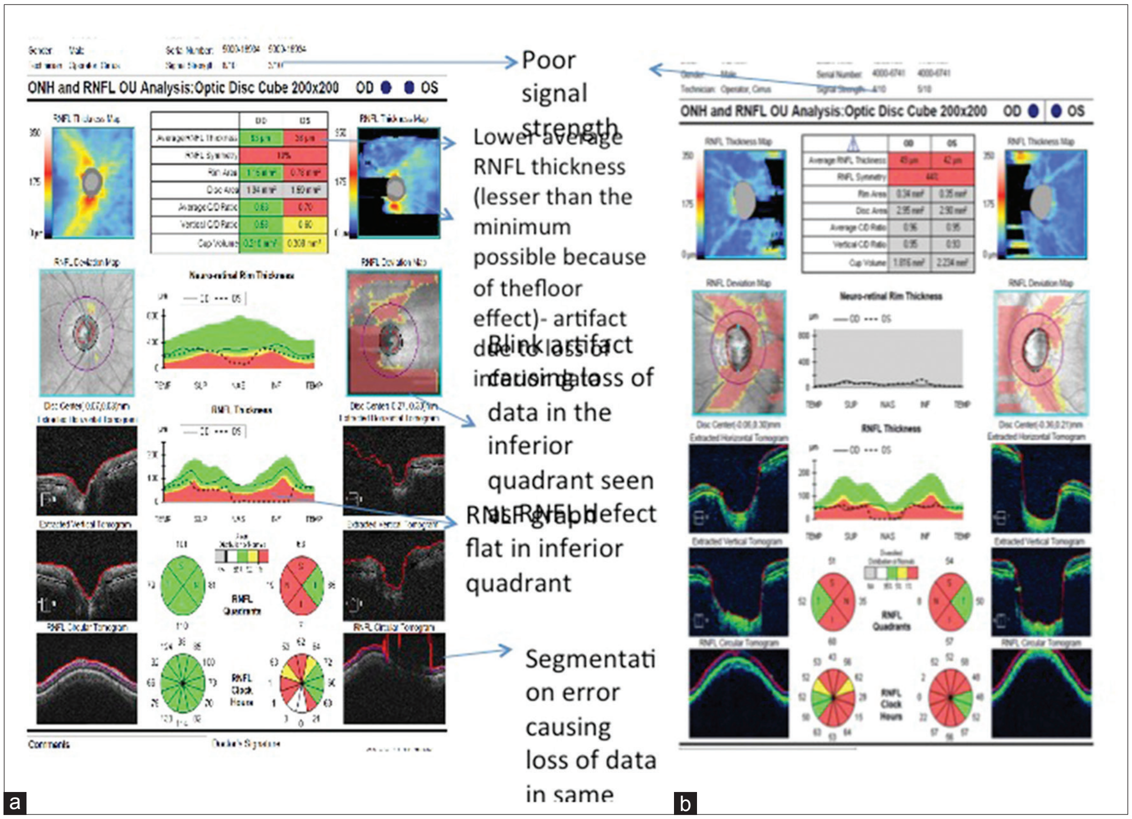

Figure 3: Motion/Blink artifact. (a and b) Optic nerve head and retinal nerve fiber layer optical coherence tomography showing motion/blink artifact

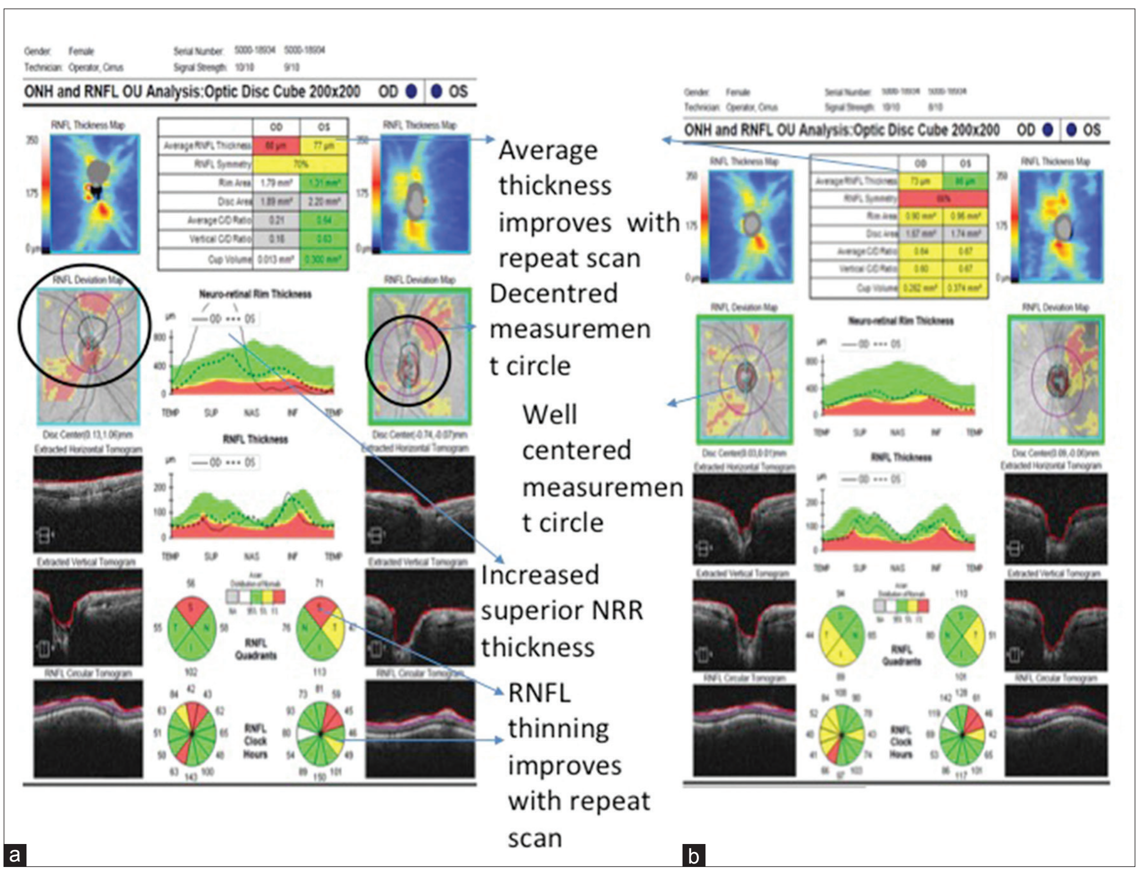

Figure 4: (a) Decentration artifact. (b) After centration correction

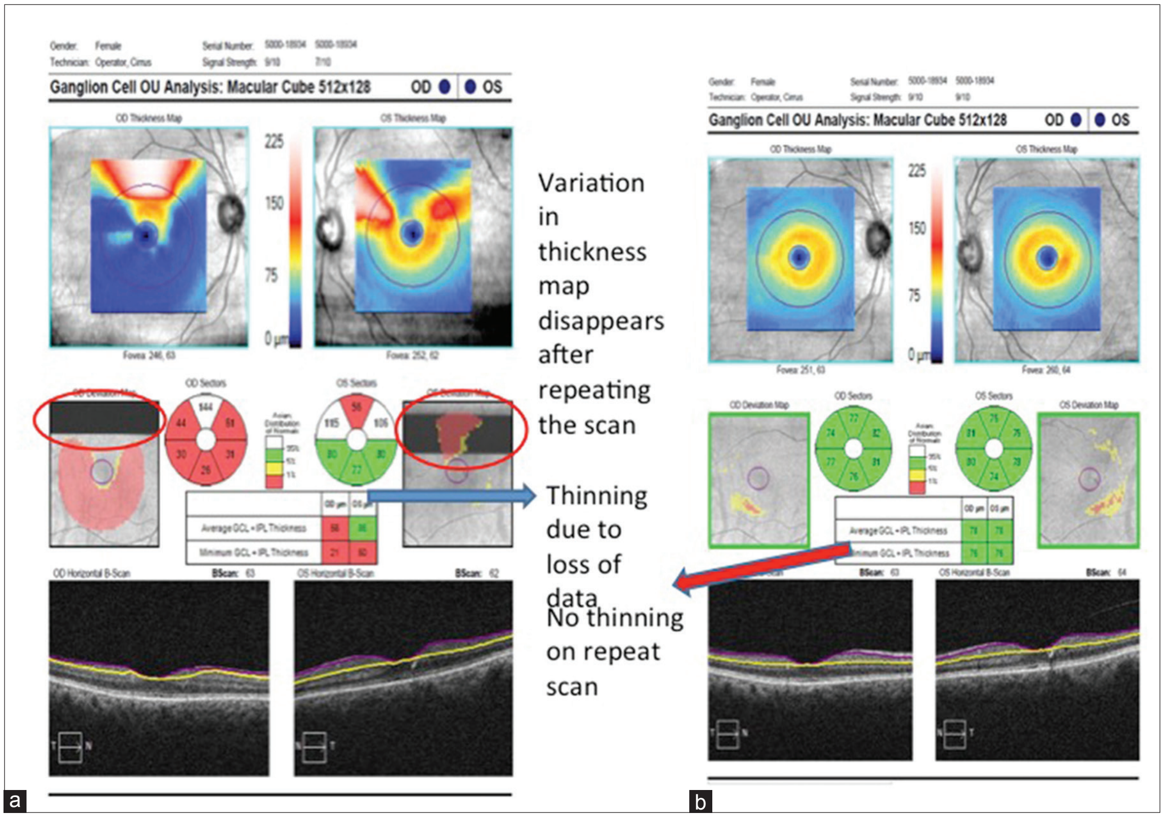

Figure 5: (a) Blink artifact. (b) After artifact correction

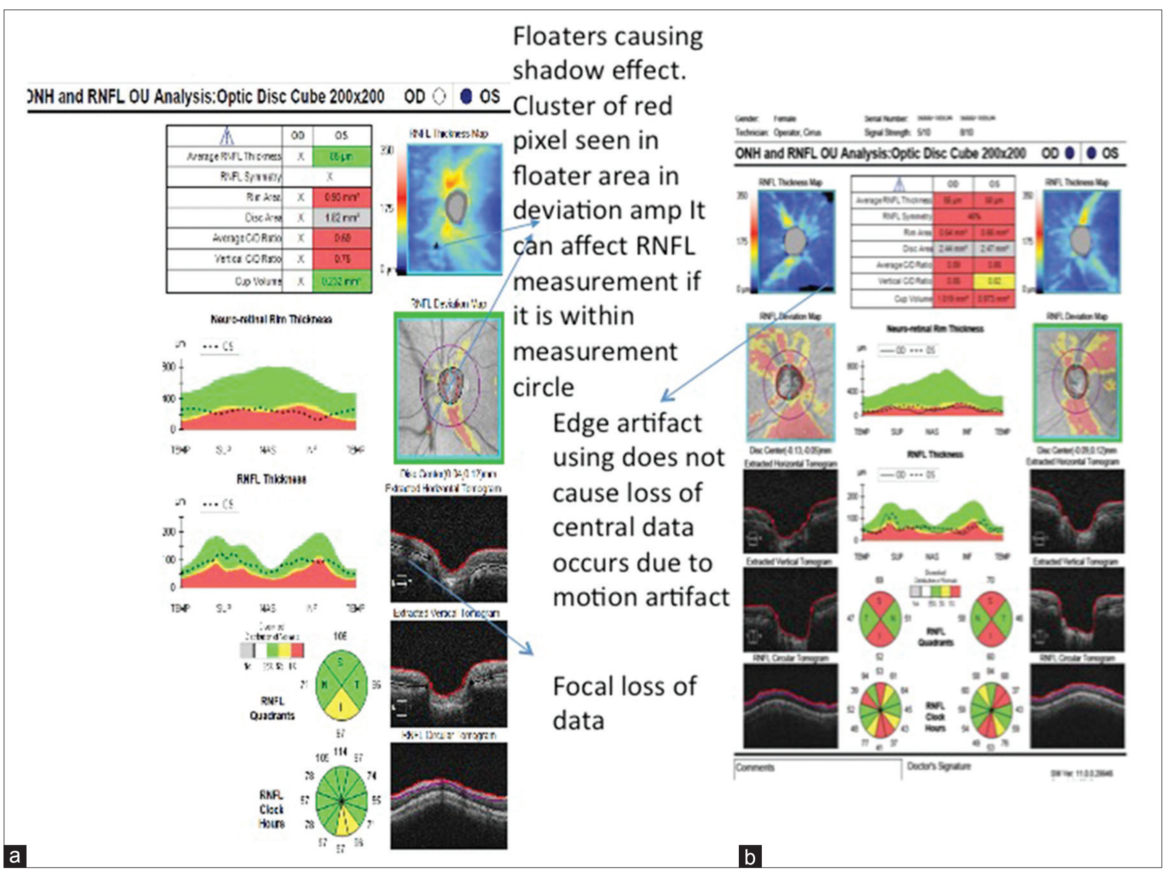

Figure 6: (a) Artifact due to floater. (b) Edge artifact

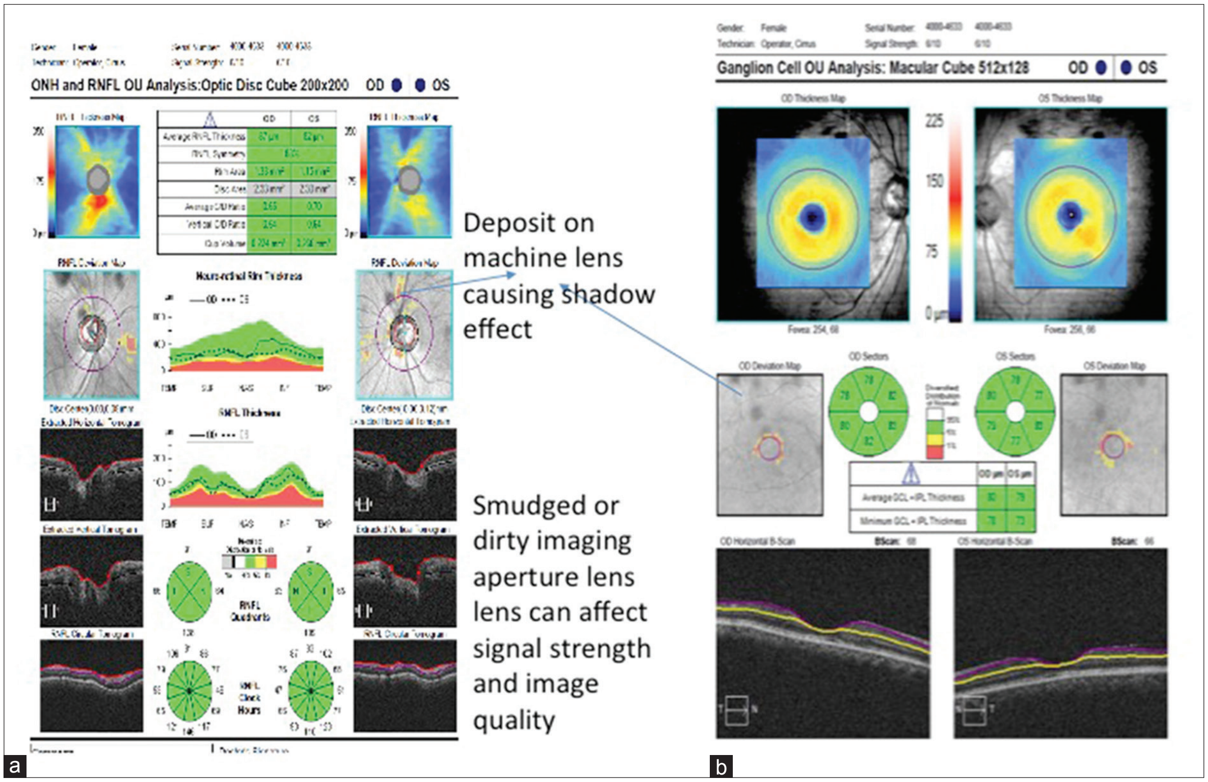

Figure 7: Machine-related artifacts. a and b showing shadow effect due to deposit in machine lens

Table 1: Types of scans and its limitations

	Optic nerve head	RNFL analysis	Macular ganglion cell analysis
Scan protocol	Optic disc cube 200×200 (4 mm×4 mm)	3.4 mm measurement circle centered on optic disc using radial line scan	Macular cube 512×128 (6 mm×6 mm)
Parameters	Disc area rim area Vertical and horizontal cup disc ratio Cup volume, average RNFL value RNFL symmetry	Mean RNFL measurement TSNT graph symmetry, sectoral chart Clock chart	Ganglion cell complex including RNFL, ganglion cells inner plexiform layer
Best parameter for glaucoma detection	Rim area Vertical rim thickness Vertical CD ratio[5]	Inferior RNFL Average RNFL[5,6]	Minimum GCIPL (macula, ganglion cell, inner plexiform layer)[7]
Limitations	Can miss glaucoma in smaller discs	Tilted myopic disc with PPA	Confounded by macular disease
Glaucoma detection	Not well established	Good	Comparable to RNFL Better when done in combination of RNFL Does not consider RGC outside macular areas[7,8]

RNFL: Retinal nerve fiber layer, GCIPL: Ganglion cell-inner plexiform layer, RGC: Retinal ganglion cells, TSNT: Temporal,superior,nasal,temporal graph

RNFL deviation map: This compares the clusters of pixels in the test image with the normative database and color codes the areas accordingly. It is important to carefully assess this map because small localized defects may sometimes be seen only on this printout. Look specifically for the measurement circle and motion artifacts

4. [Figures 8-17].

Normative Database

The normative database is based on 284 healthy adults with an age range of 18–84 years, refractive error of − 12 to + 8D; ethnicity includes Caucasians 43%, Asians 24%, African

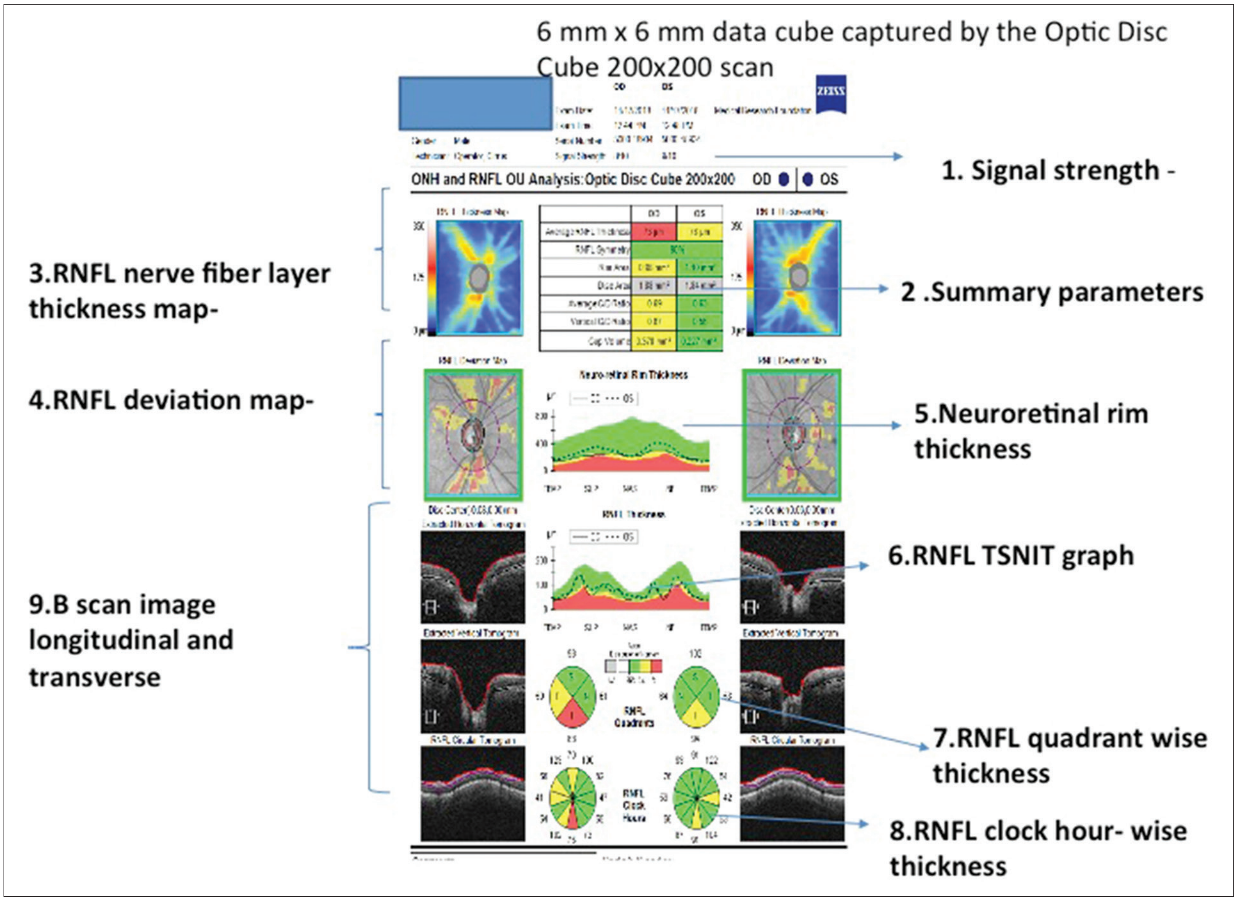

Figure 8: Optic nerve head and retinal nerve fiber layer optical coherence tomography analysis report

Table 2: Decoding the color code

Color code	RNFL analysis (Normative database matched to age)	ONH analysis (Normative database matched to age and disc area)
Green	Between 5%- 95% Within normal limit	Between 5%- 95% Within normal limit
Yellow	Between 1%- 5% borderline thinning suspect	Between 1%- 5% borderline thinning suspect
Red	< 1% Outside normal limit (Thinnest)	<1 Outside normal limit (Thinnest for neuroretinal rim and largest for CD ratio)
White	>95%(Thickest) Also used when normative database not available ex: age more than 18 years	>95% (Thickest for neuro retinal rim and smallest for CD/ratio)
Grey	Not applicable	Used when normative database not applicable •Average or vertical CD ratio is below 0.25 •When disc area is less than 1.3 mm^2 or greater than 2.5 mm^2 rim area •Normative data off

America 18%, Hispanic 12%, mixed ethnicity 6%, and Indian 1%. There were six groups based on age 18–29, 30–39, 40–49, 50–59, 60–69, and 70 years[7-11] [Figure 18]. The average RNFL thickness in Indian eye reported in the literature is 104.8 ± 38.81 µm. Superior RNFL is 138.2 ± 21.74 µ, inferior RNFL 129.1 ± 25.6 µ, nasal 85.71 ± 21, and temporal 66.38 ± 17.37.[12] Caucasians had thinner mean RNFL values 98.1 ± 10.9 µm than Asians 105.8 ± 9.2 µm.

Macula Optical Coherence Tomography

The macula has 50% of ganglion cells, which has been reported to help detect early glaucoma. It uses macular cube of 512 × 128 pixels with six linear scans in a spoke configuration. The inner boundary is formed by vitreous-retinal interface and outer boundary by retinal pigment epithelium. Yellow, green, and red represent thicker retina and blue represents thinner retina. It has thickness map, deviation map, sectoral value and average ganglion cell layer (GCL) + inner plexiform layer (IPL), and minimum GCL + IPL [Figures 19-22].

Figures 23 and 24 illustrate clinical examples that depict the structure–function correlation of the optic nerve head and the retina in the diagnosis of glaucoma.

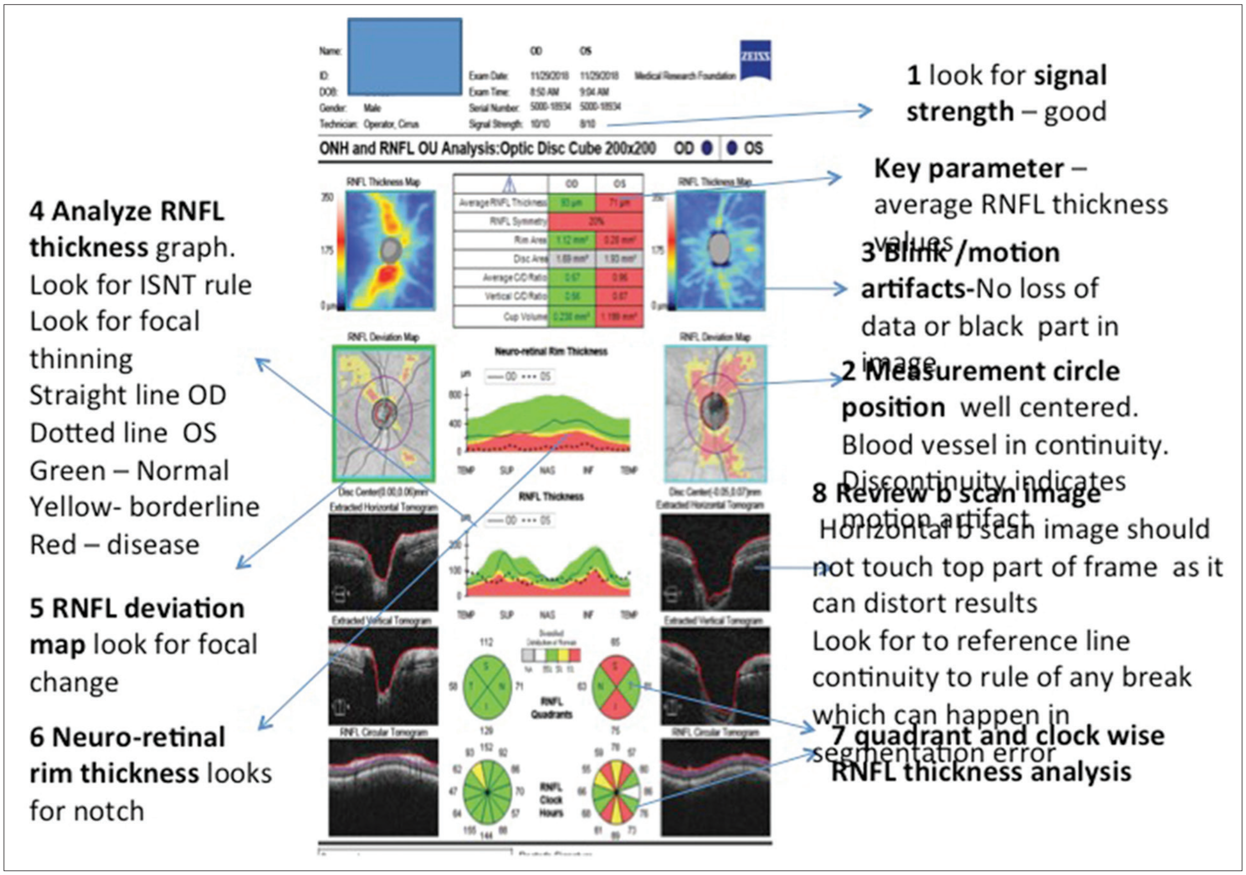

Figure 9: How to interpret optical coherence tomography

1. **Signal strength** -It range from 0-10. Anything above 6 is acceptable
2. **Key parameters :** compared to normative database for RNFL analysis and normative database and disc area for disc parameter. Disc area values are always shown in grey as no normative database is available. When disc area is less than 1.3mm^2 or greater than 2.5 mm^2 rim area, CD ratio and CD volume will be shown in grey colour . Two eyes have a similar profile when symmetry parameter is close to 100%,.Average RNFL thickness values should be looked for which decreased with severity of glaucoma increases.

a

	OD	OS
Average RNFL Thickness	103 µm	103 µm
RNFL Symmetry	98%	
Rim Area	1.17 mm²	1.32 mm²
Disc Area	1.95 mm²	2.25 mm²
Average C/D Ratio	0.64	0.63
Vertical C/D Ratio	0.61	0.58
Cup Volume	0.327 mm³	0.364 mm³

b

	OD	OS
Average RNFL Thickness	50 µm	74 µm
RNFL Symmetry	34%	
Rim Area	0.63 mm²	0.98 mm²
Disc Area	2.26 mm²	2.16 mm²
Average C/D Ratio	0.84	0.72
Vertical C/D Ratio	0.84	0.67
Cup Volume	0.749 mm³	0.421 mm³

c

	OD	OS
Average RNFL Thickness	59 µm	94 µm
RNFL Symmetry	7[illegible]	5%
Rim Area	0.64 mm²	1.25 mm²
Disc Area	2.91 mm²	1.27 mm²
Average C/D Ratio	0.89	0.15
Vertical C/D Ratio	0.90	0.13
Cup Volume	1.470 mm³	0.004 mm³

Figure 10: Steps of optical coherence tomography interpretation – signal strength and key parameter. (a) Key parameters in healthy eye. (b) Key parameter in glaucoma. (c) When disc area is < 1.3 mm^2 or > 2.5 mm^2 rim area, CD ratio and CD volume are shown in gray color

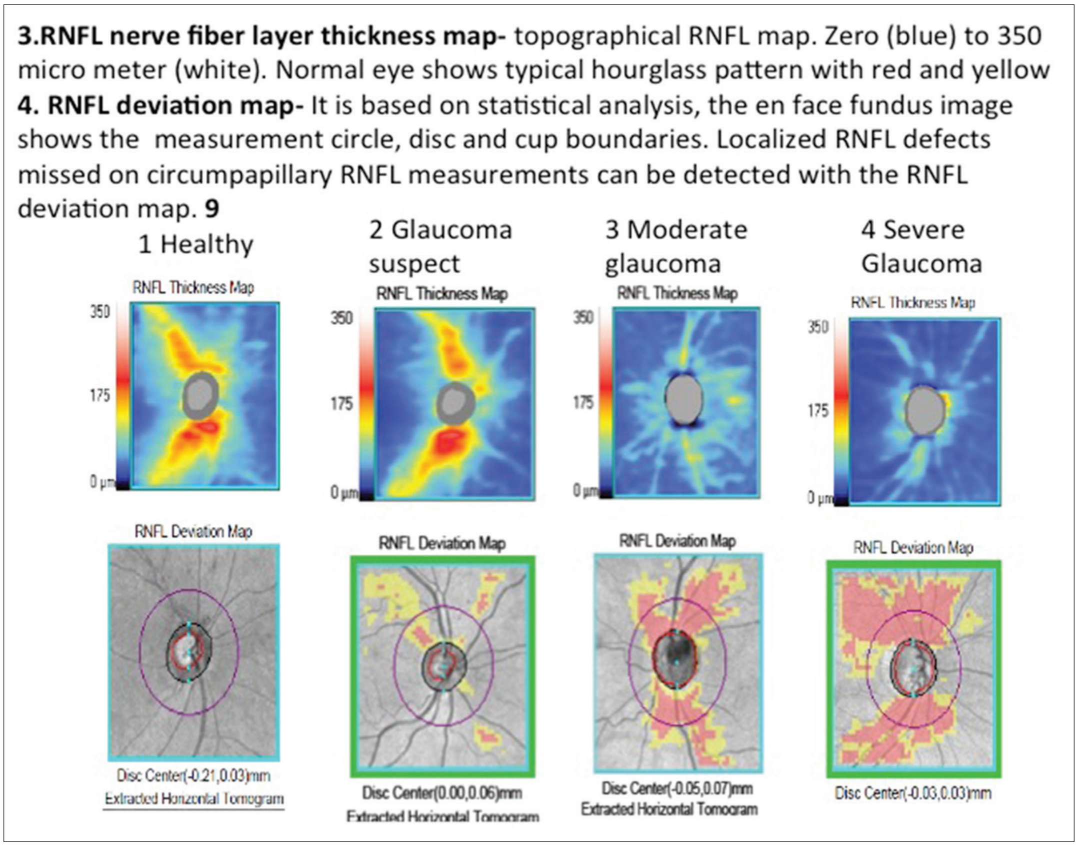

Figure 11: Steps of optical coherence tomography interpretation – retinal nerve fiber layer nerve fiber layer thickness map and retinal nerve fiber layer deviation map – Severity of glaucoma shows corresponding decrease in retinal nerve fiber layer thickness. (1) Healthy; (2) glaucoma suspect; (3) moderate glaucoma; and (4) severe glaucoma

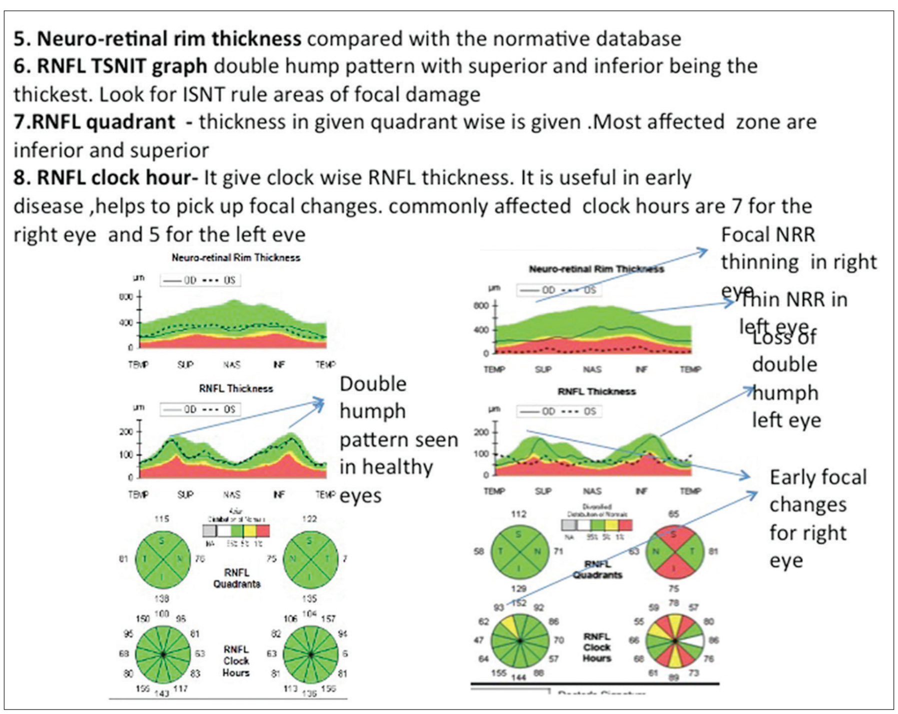

Figure 12: Steps of optical coherence tomography interpretation – Neuroretinal rim thickness, retinal nerve fiber layer TSNIT graph, retinal nerve fiber layer quadrant and retinal nerve fiber layer clock hour‑wise thickness. (a) Neuroretinal rim and retinal nerve fiber layer thickness in healthy eye. (b) Neuroretinal rim and retinal nerve fiber layer thickness in glaucoma

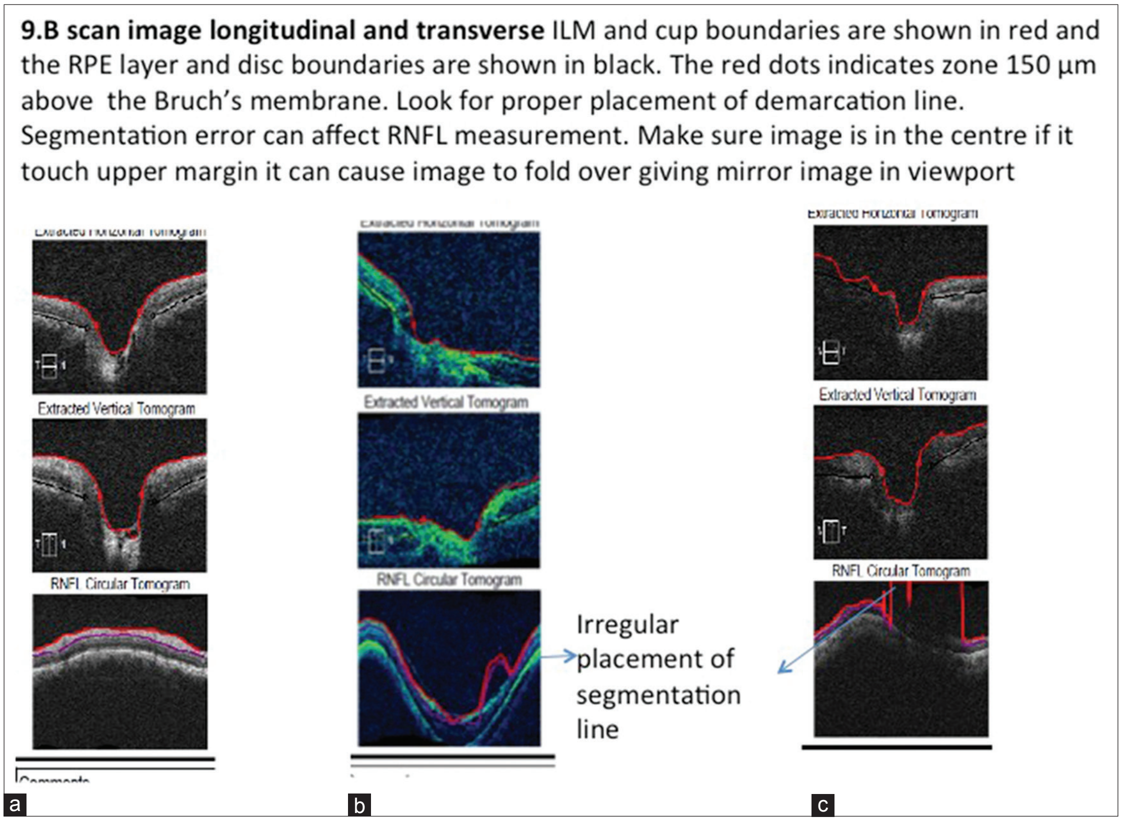

Figure 13: Steps of optical coherence tomography interpretation-B scan image longitudinal and transverse. (a) Properly placed segmentation line; (b and c) segmentation error

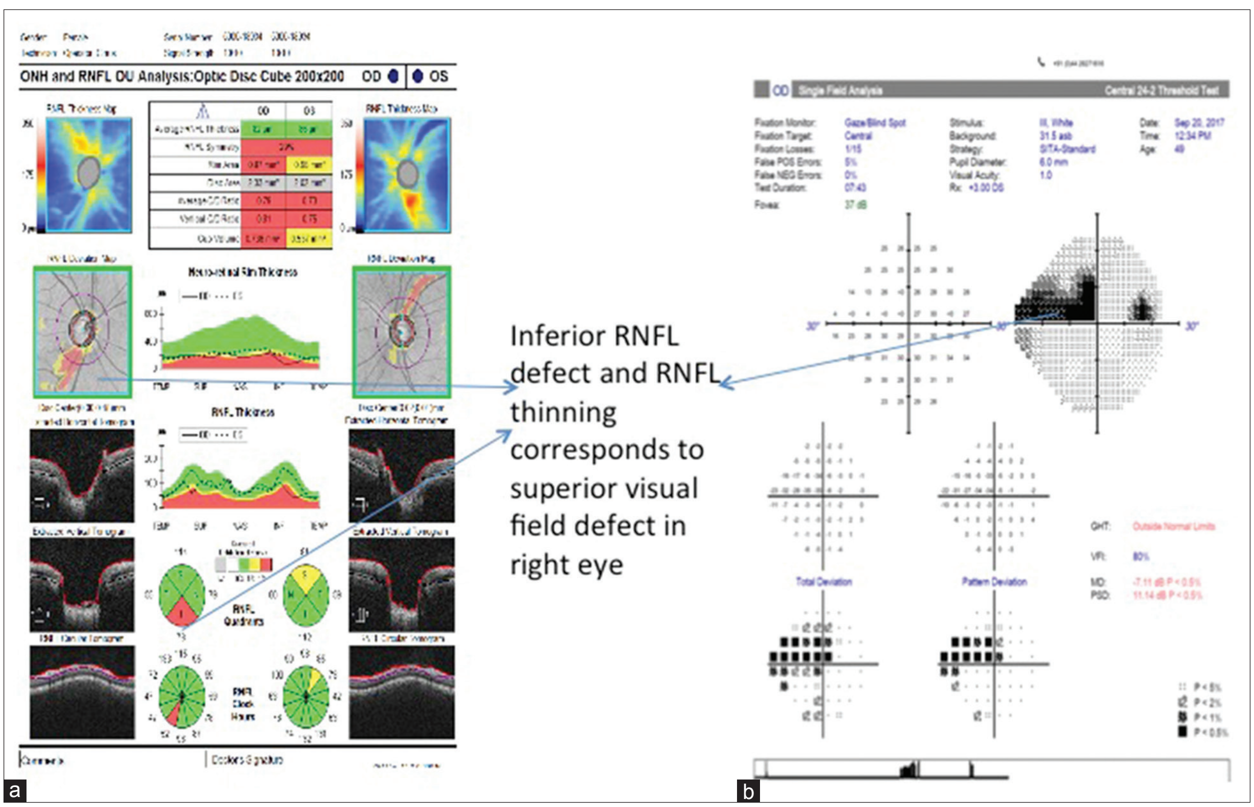

Figure 14: Structure and function correlation. (a) Optical coherence tomography optic disc and retinal nerve fiber layer shows inferior retinal nerve fiber layer defect and retinal nerve fiber layer thinning in right eye; (b) visual field test shows superior visual field defect in right eye

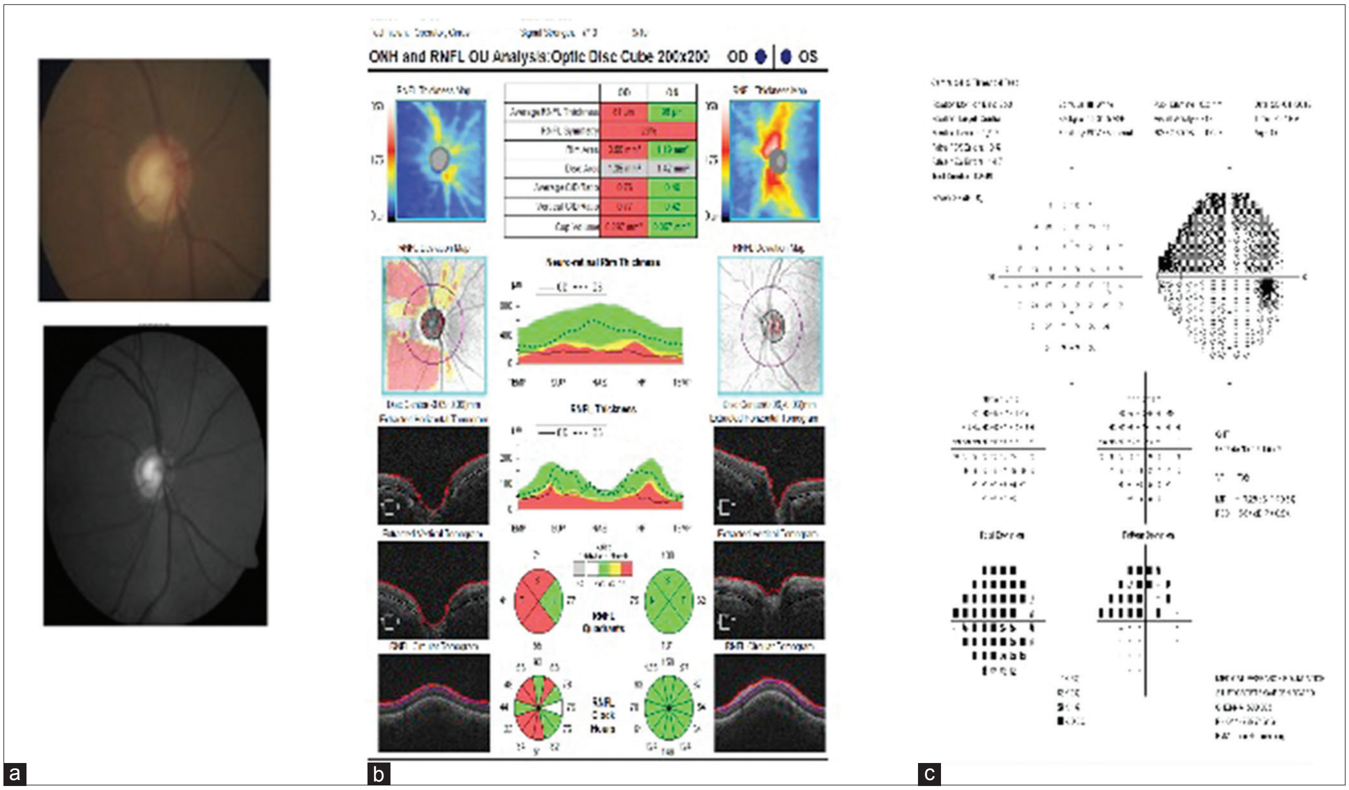

Figure 15: Structure and function correlation. (a) Disc photo and red free disc photo showing concentric cup enlargement. (b) Diffuse retinal nerve fiber layer loss with retinal nerve fiber layer thinning in all quadrants except nasal quadrant in right eye. (c) Visual field test showing corresponding superior arcuate scotoma

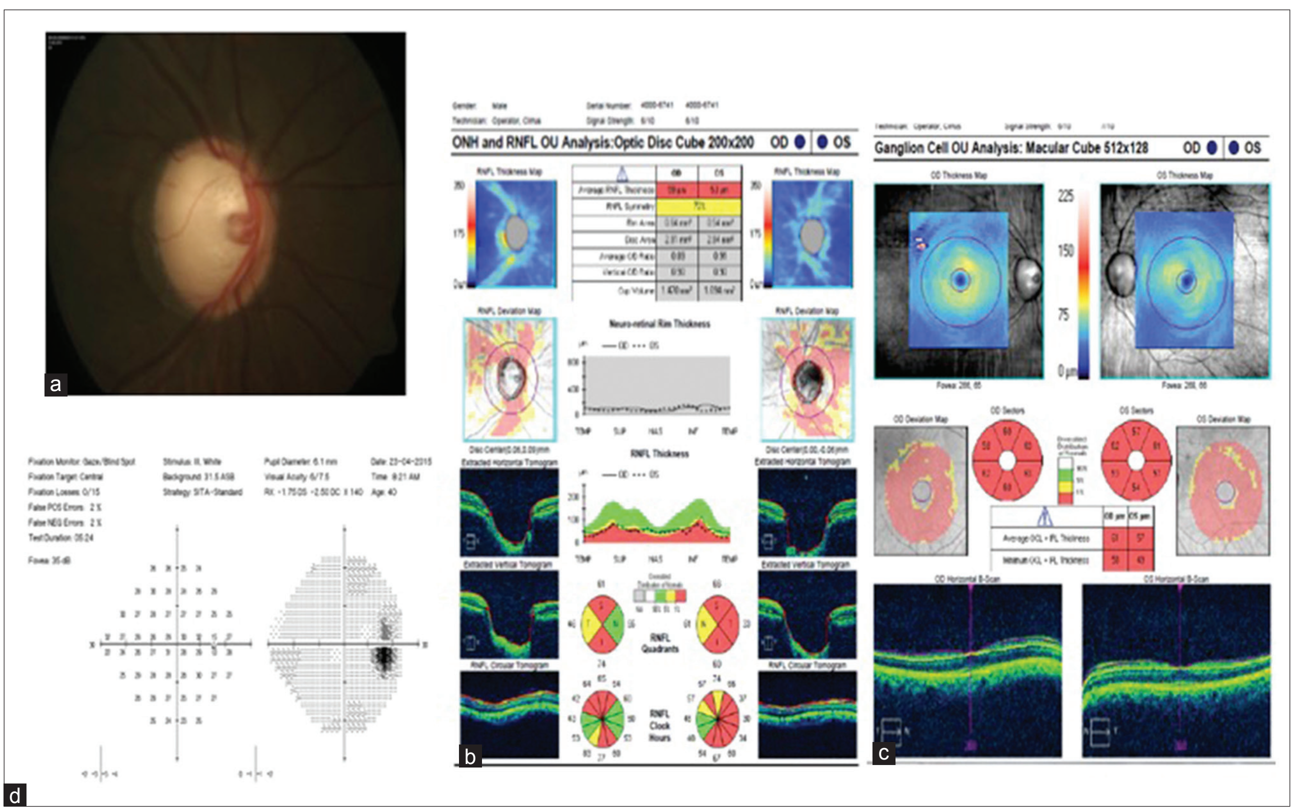

Figure 16: Preperimetric glaucoma. (a) Disc photograph of the right eye showing large disc with large cup with superior and inferior rim thinning. (b and c) optical coherence tomography retinal nerve fiber layer and macula confirms thinning. (d) Visual filed test noted to be within normal limit

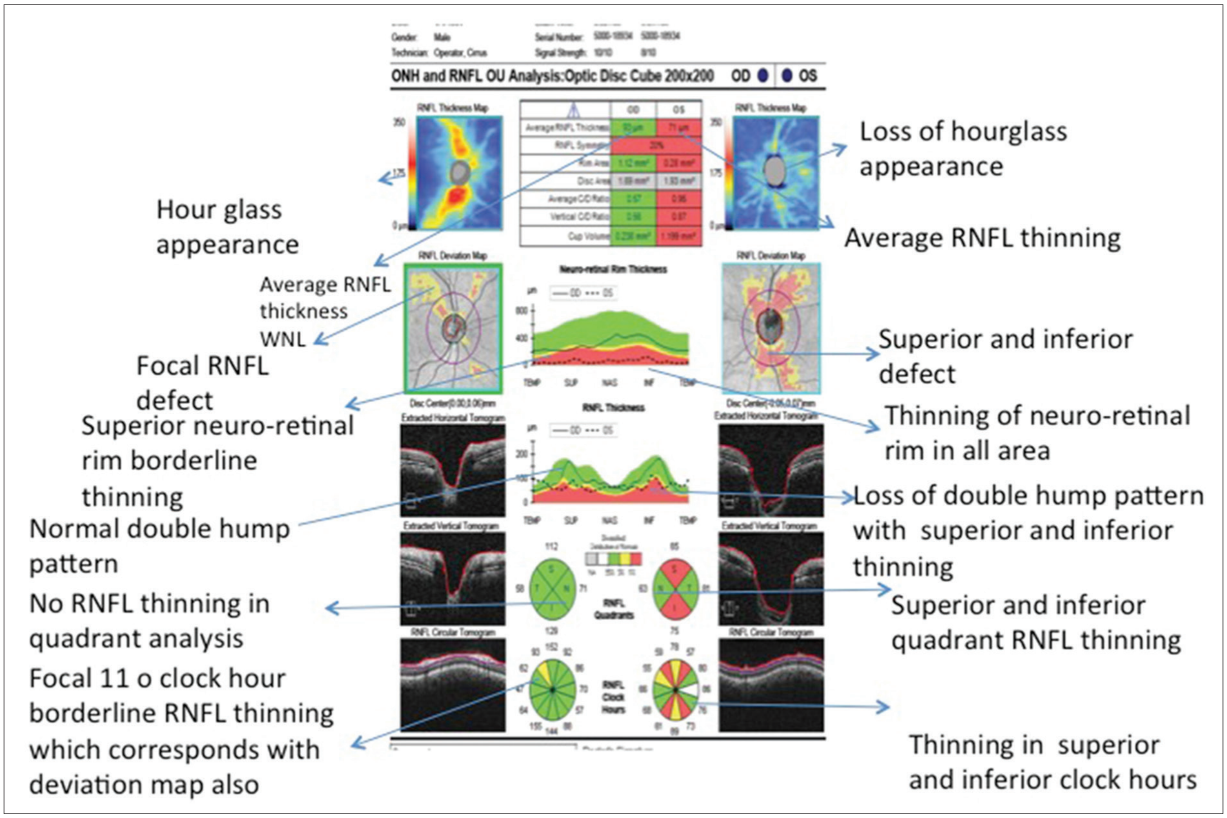

Figure 17: Example of optical coherence tomography interpretation

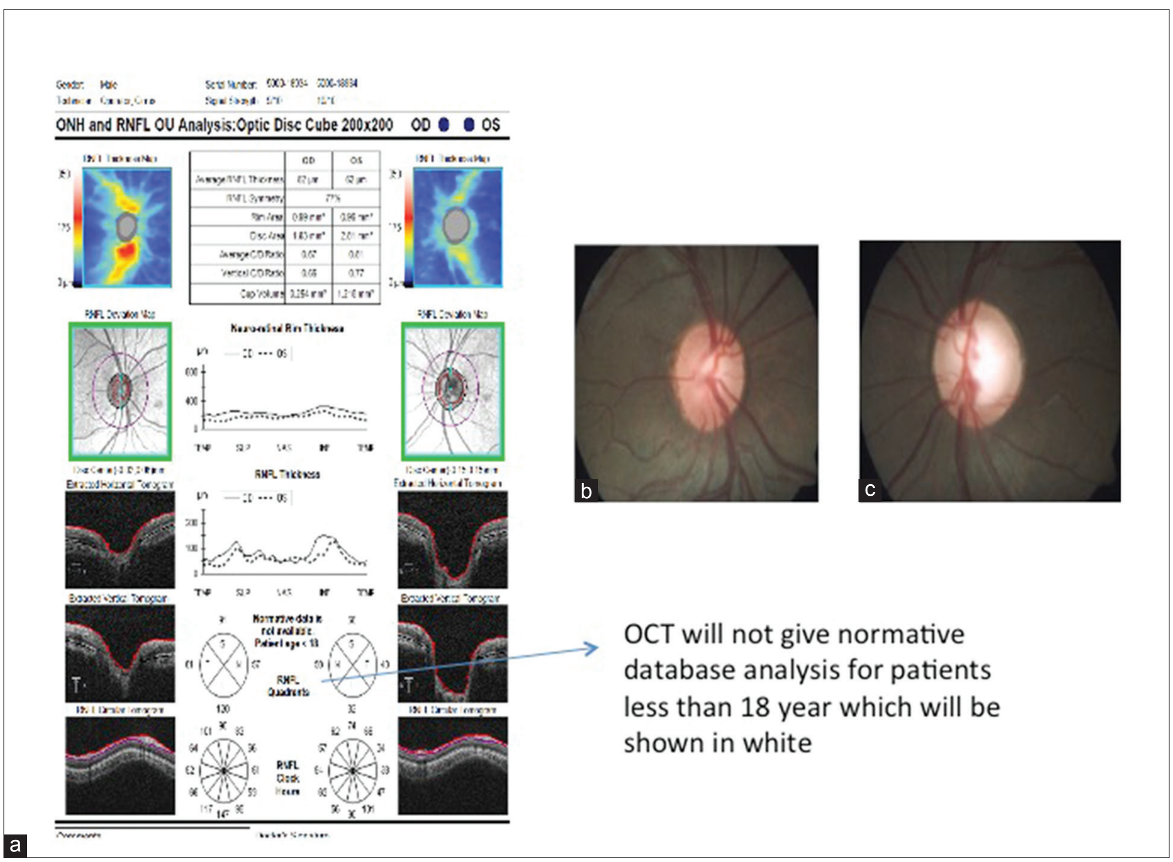

Figure 18: Limitation of OCT interpretation. (a) No normative analysis details less than 18 years (b) Small disc with increased cup disc ratio in a paediatric patient (c) Large disc with increased cupping in a paediatric patient

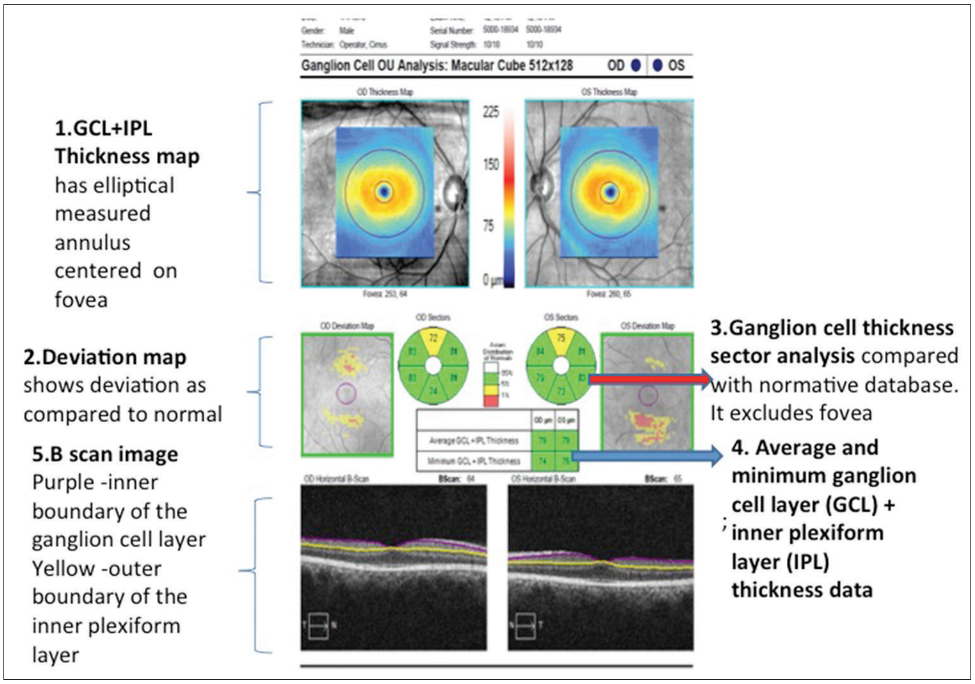

Figure 19: Ganglion cell analysis report – based on macular cube analysis 512 × 128 or 200 × 200 scans

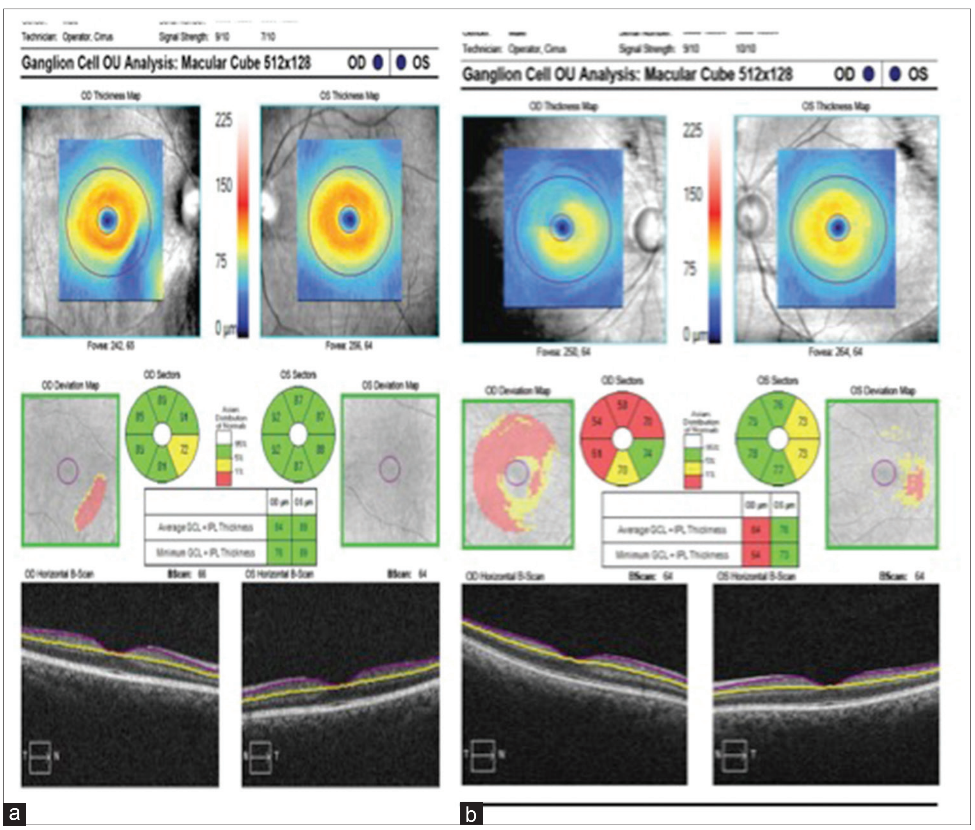

Figure 20: Ganglion cell analysis report. (a) Healthy and (b) glaucoma

Recent Advances

Lower vessel densities have been reported in glaucoma as compared to healthy adults and have shown good discriminatory abilities.[13,14] Enhanced depth imaging allows lamina cribrosa imaging which is a proposed site for retinal ganglion cell injury.[15] Lamina cribrosa deformation in response to IOP changes may play a role in pathophysiology of glaucoma and the OCT may help analyze this.[16]

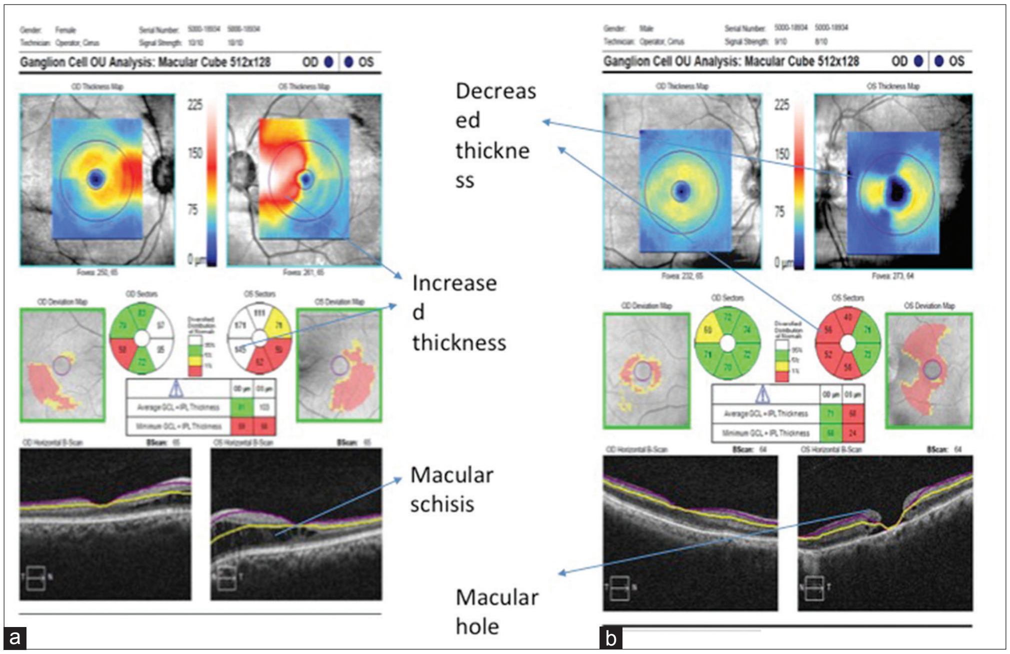

Figure 21: Ganglion cell analysis in macular disorder. (a) Macular schisis and (b) Macular hole

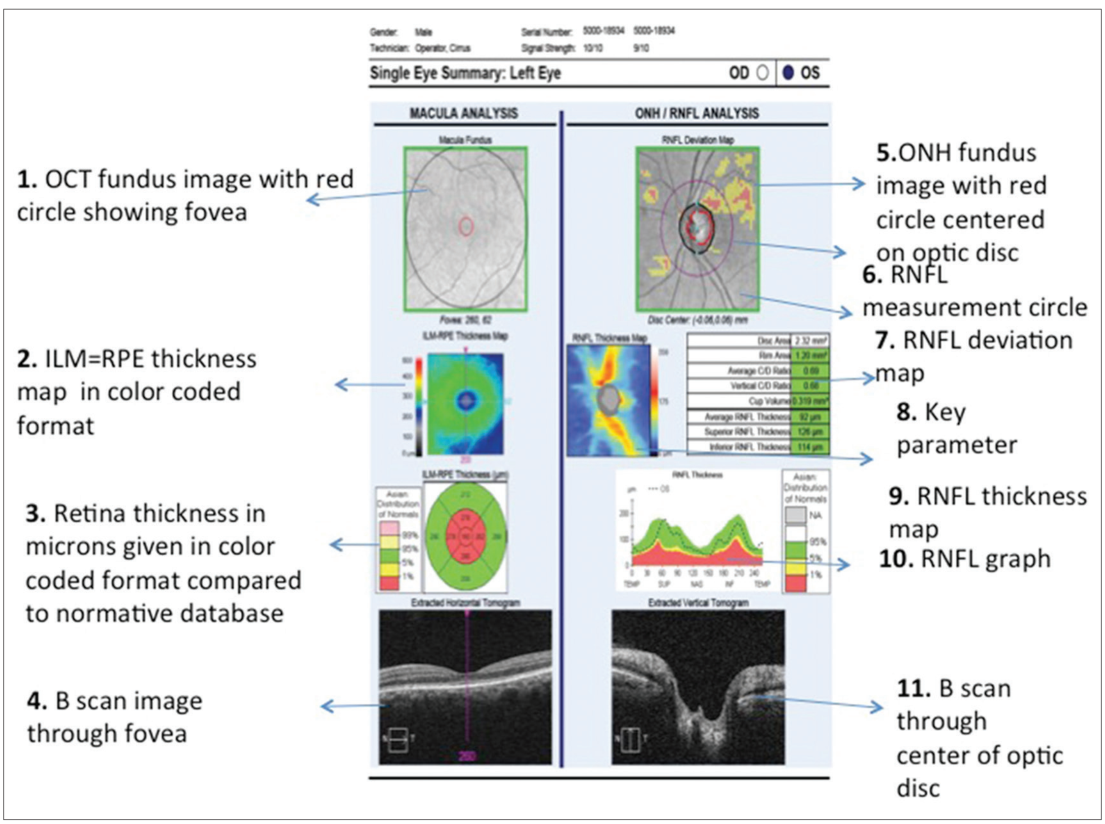

Figure 22: Single eye summary report – Give overview of eye including macula, optic nerve head, and retinal nerve fiber layer analysis

The OCT provides excellent opportunity to study the RNFL objectively which adds to diagnostic evidence to help in clinical assessment and to quantify glaucoma progression; however, limitations related to normative database and imaging artifacts should be kept in mind. Glaucoma should never be diagnosed in isolation based on the OCT only; clinical correlation is essential.

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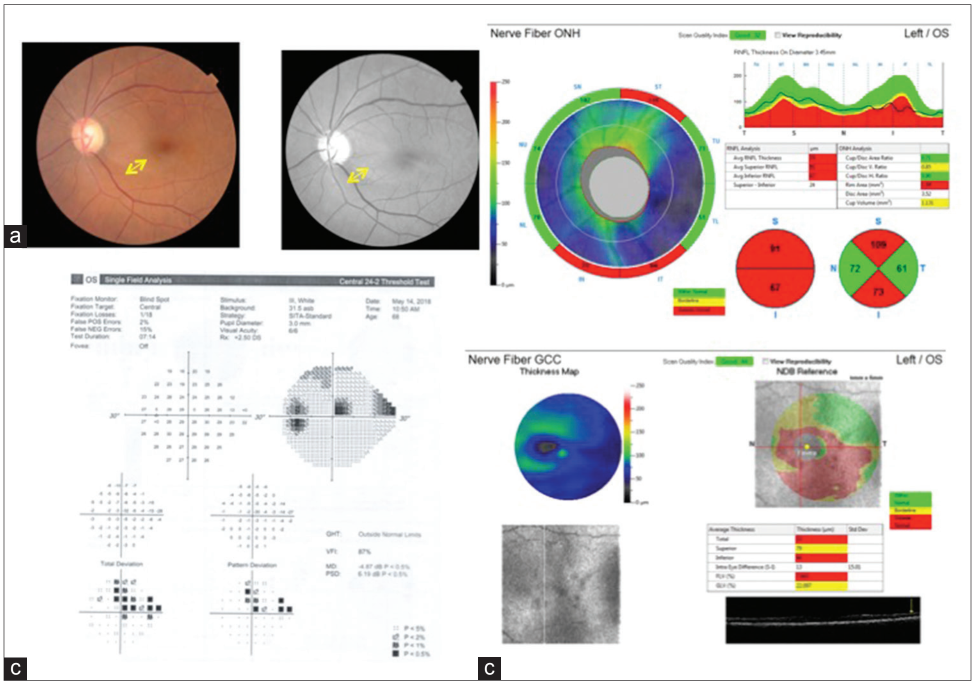

Figure 23: (a) Fundus photo shows vertical cup diameter ratio 0.7, thinning of neuroretinal rim with wedge-shaped inferior retinal nerve fiber layer defect. (b) Visual field shows superior scotoma. (c) Optovue- iVue optical coherence tomography optic nerve head analysis shows reduction in retinal nerve fiber layer thickness in the superotemporal and inferior quadrant with corresponding depression in the TSNIT graph and reduction of ganglion cell complex thickness

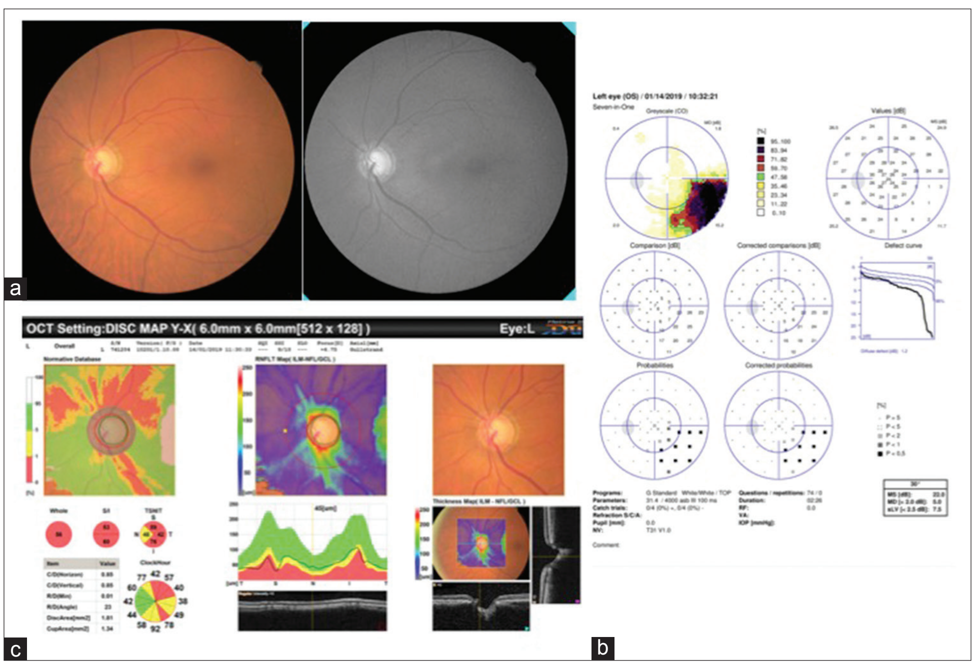

Figure 24: (a) Fundus photo of a primary angle-closure glaucoma patient post Yag - PI shows vertical cup diameter ratio 0.7, thinning of neuroretinal rim more in the superior quadrant. (b) Visual field shows scotomas more in the inferior quadrant. (c) Nidek optical coherence tomography optic nerve head analysis shows reduction in retinal nerve fiber layer thickness in the superior and inferior quadrant with corresponding depression in the TSNIT graph

Conflicts of interest

There are no conflicts of interest.

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