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Optical Coherence Tomography: A New and Non-Invasive Diagnostic Tool for Chorio-Retinal Disorders.

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Purpose
Optical coherence tomography (OCT) has revolutionized the clinical practice of ophthalmology. It is a non-invasive imaging technique that provides high resolution, cross-sectional images of the retina, the retinal nerve fiber layer (RNFL) and the optic nerve head. This serves to study the applications of the OCT systems in the diagnosis and management of chorio-retinal diseases.

I. Introduction

It is a non-invasive imaging technique that provides high resolution, cross-sectional images of the retina, the retinal nerve fiber layer (RNFL) and the optic nerve head. With axial resolution in the 5–7 μm range, it provides close to an in-vivo **'optical biopsy'** of the retina.

PRINCIPLE -

OCT employs light from a broadband light source, which is divided into a reference and a sample beam, to obtain a reflectivity versus depth profile of the retina. The light waves that are backscattered from the retina, interfere with the reference beam, and this interference pattern is used to measure the light echoes versus the depth profile of the tissue *in vivo*[1,2].

TYPES –

Time-domain detection was the technique employed by commercially available OCT systems such as the Stratus OCT (Carl Zeiss Meditec, Inc, Dublin, CA). Time-domain OCT (TD-OCT) systems featured scan rates of 400 A-scans per second with an axial resolution of 8–10 μm in tissue[2].

In 2006, the first commercially available spectral-domain (Fourier domain) OCT (SD-OCT) system was introduced. SD-OCT employs detection of the light echoes simultaneously by measuring the interference spectrum, using an interferometer with a high-speed spectrometer. This technique achieves scan rates of 20 000–52 000 A-scans per second and a resolution of 5–7 μm in tissue[3,4].

UHR-OCT uses broadband light sources to achieve 3 μm resolution in tissue[5].

SS-OCT (Swept Source) uses another form of Fourier domain detection to measure light echoes. It employs a tunable frequency swept laser light source, This increases the signal quality in deep tissue by elimination of the sensitivity of a spectrometer to higher frequency modulation as with SD-OCT[6,7-11], thereby improving the visualization of the choroid.

COLOUR CODING IN OCT SCAN –

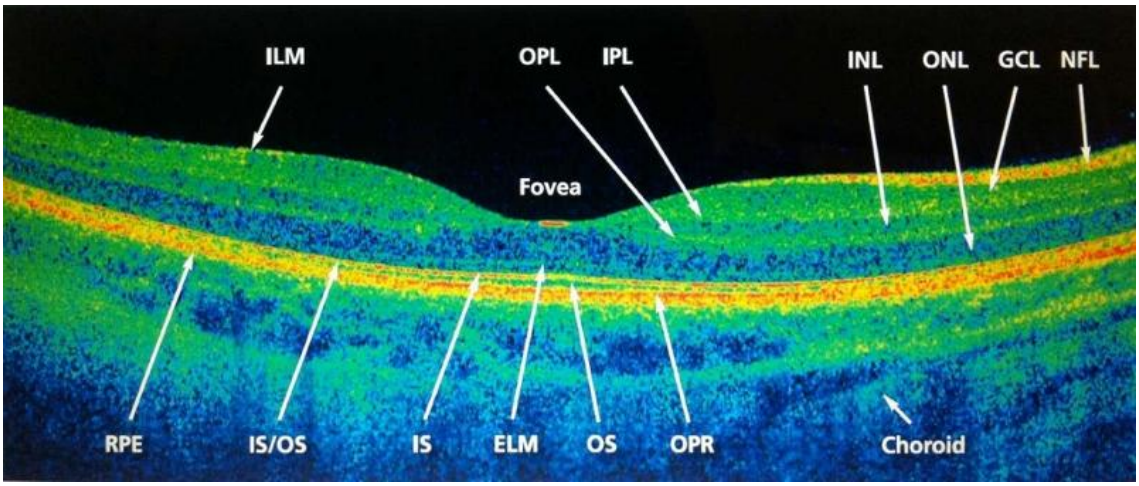
Highly reflective structures are shown in red. Those with low reflectivity are represented by dark colours like black while green represents intermediate reflectivity.

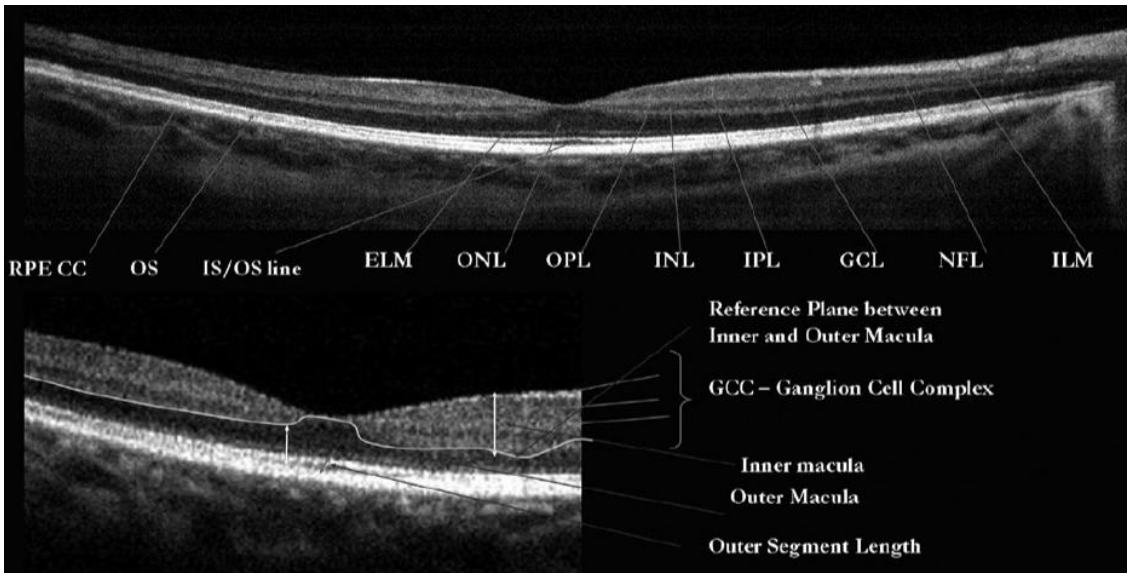
In colour coded macular thickness map, blue colour represents thinner retina while yellow-green represents thicker retina.

INTERPRETATION OF OCT SCAN -

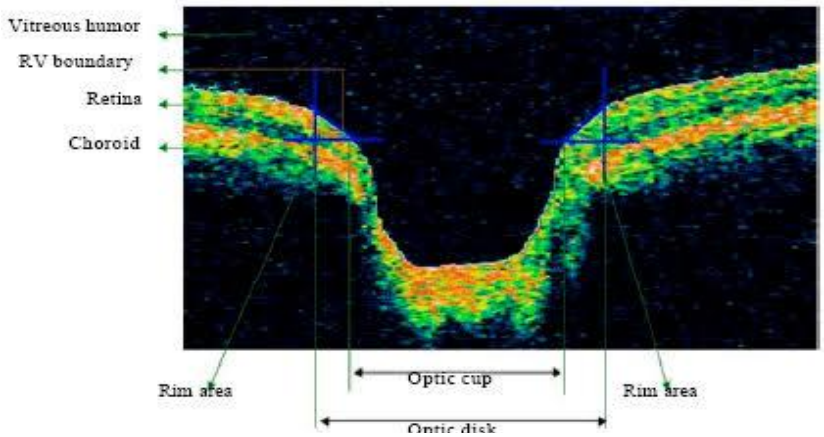
Vitreous is non reflective and seen as dark space. Vitreoretinal interface is well defined due to contrast between non reflective vitreous and retinal backscattering. Fovea has depression and umbo is seen as central hyper reflective dot within foveola.

Retinal layers – RNFL, RPE- choriocapillaries complex is highly reflective and seen as red layer due to bright scattering. Outer segments of photoreceptors are minimally reflective represented by a darkline just anterior tp RPE-choriocapillaries complex. Different intermediate layers of neurosensory retina between dark layer of photoreceptors and red layer of RNFL are seen as alternating layers of moderate and low reflectivity. Choroid,vitreous fluid and blood are minimally reflective and appears black.





In optic disc scan – disc boundaries are defined by termination of choriocapillaries ate lamina cribrosa and optic cup is determined by the termination of nerve fibre layer.



While interpreting an OCT scan, always look for following 4 points -

- Appearance of vitreo-retinal interface -
  - normal,
  - any membrane (single/double),
  - attachment (no attachment/[partial/total attachment)
- Foveal contour -
  - normal,
  - obliterated by pulling (due to overlying membrane) or pushing (due to underlying fluid),
  - widened due to foveal thinning,
  - hole whether lamellar or full thickness.
- Any alteration of retinal architecture –
  - normal,
  - Fluid – intraretinal : diffuse, cystoid; subretinal'
  - Exudates,
  - Schisis.

- Any disruption in the RPE-choriocapillaries complex layer –
  - normal
  - bumpy – drusens
  - fusiform thickening – CNVM
  - elevated – definite green line – serous PED
    indefinite green line – fibrovascular PED
    no green line – hemorrhagic PED

Hyper-reflective lesions within NSR – Hard exudates, cotton wool spots, microaneurysms, hemorrhage, pigments, fibrin, ERM, drusens, neavi, RPE hyperplasia.
Hypo-reflective lesions are – asteroid hyalosis, vitreous hemorrhage, intraretinal fluid, PED.

APPLICATIONS OF OPTICAL COHERENCE TOMOGRAPHY -

OCT imaging is used extensively for imaging the macula, optic nerve and RNFL, and aids in analyzing the morphology and quantifying changes in various disease states.

For example, the automated retinal thickness measurements provided by the OCT systems are used clinically for the monitoring progression of diseases such as wet age-related macular degeneration (AMD) and macular edema from various causes including diabetes and retinal vein occlusion.

The ability to detect fluid within the retina and the thickness alterations induced by this fluid helps direct clinical decisions regarding treatment[(12)]. The diagnosis of macular hole and its differentiation between lamellar holes and pseudomacular holes have become straightforward using OCT[(13)]. In addition, the size and configuration of macular holes, determined by OCT, correlates well with the functional and anatomic outcomes following surgical intervention[(13-16)].

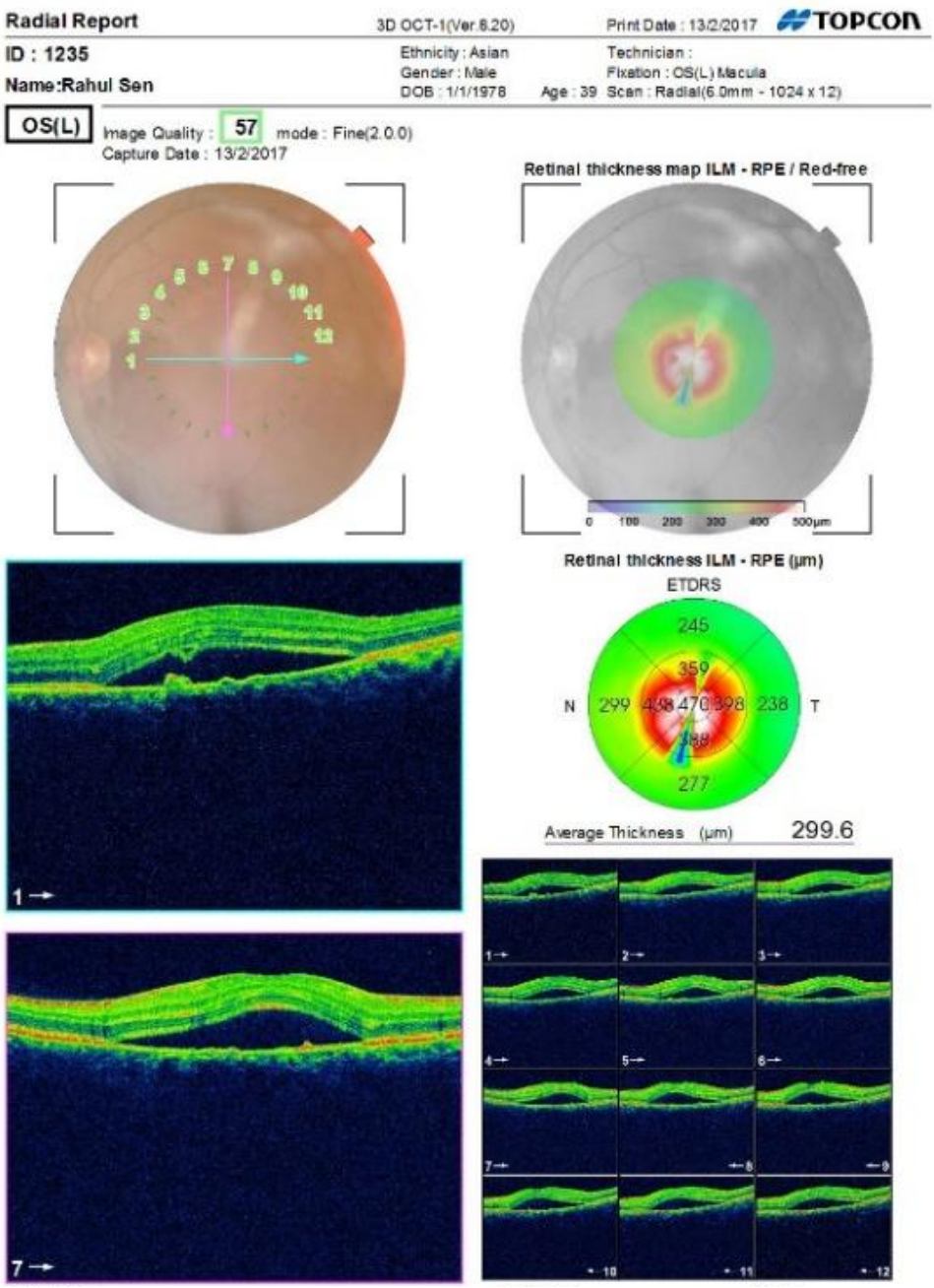
Evaluation of the vitreoretinal interface using OCT is important in the evaluation and treatment of diseases of the vitreomacular interface such as epiretinal membranes and vitreomacular traction[(17)].

In addition, optic disc morphology and RNFL thickness measurements, using OCT, monitor the progression and helps quantitatively assess the treatment response in patients with glaucoma[(18,19)].

Thus OCT is useful in diagnosing, monitoring the progression and response to treatment in -

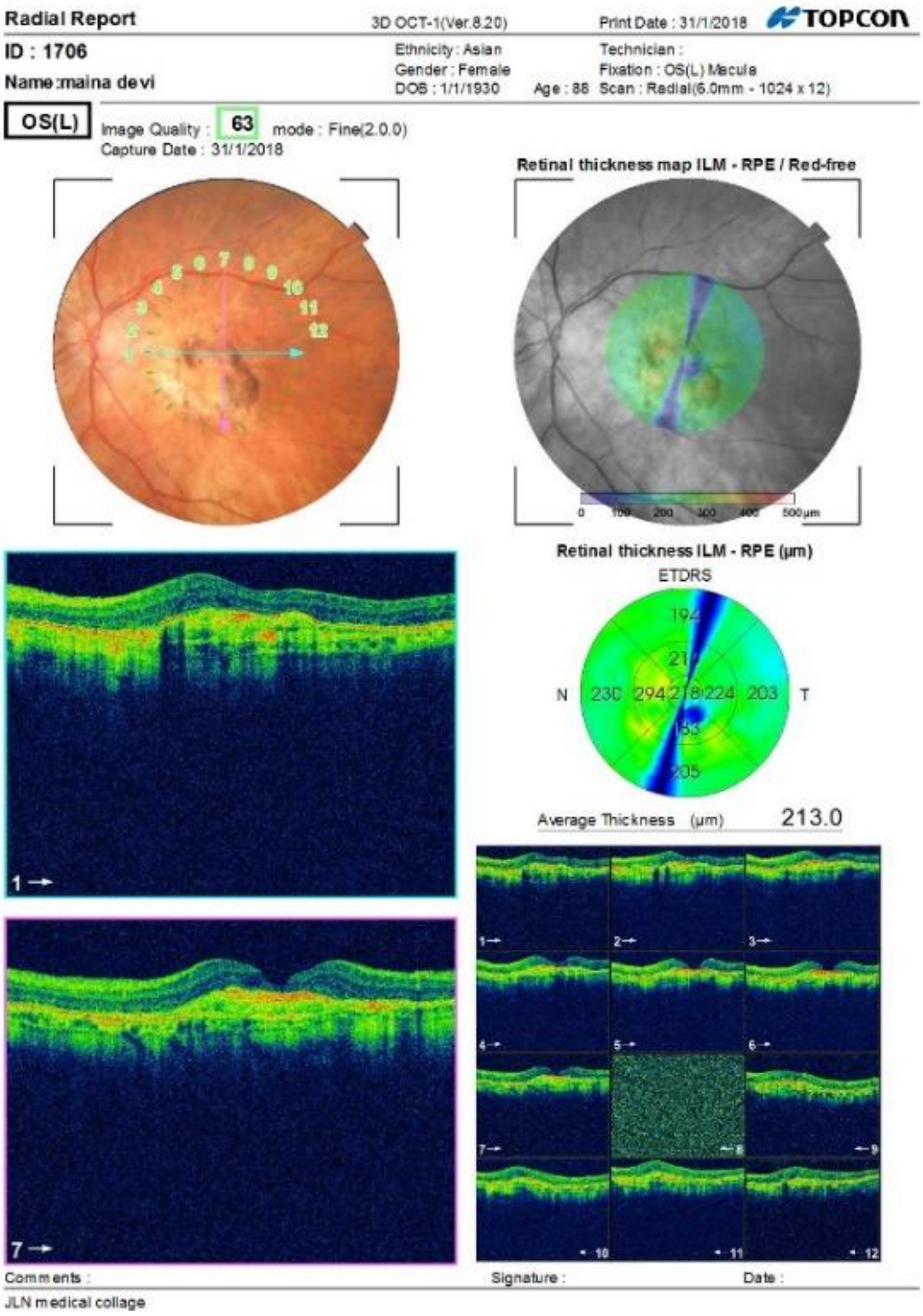
- ✓ Macular hole.
- ✓ Macular pucker.
- ✓ Macular edema.
- ✓ Age related macular degeneration.
- ✓ Glaucoma.
- ✓ Central serous retinopathy.
- ✓ Diabetic retinopathy.
- ✓ Vitreous traction.
- ✓ Epiretinal membranes.

CENTRAL SEROUS RETINOPATHY



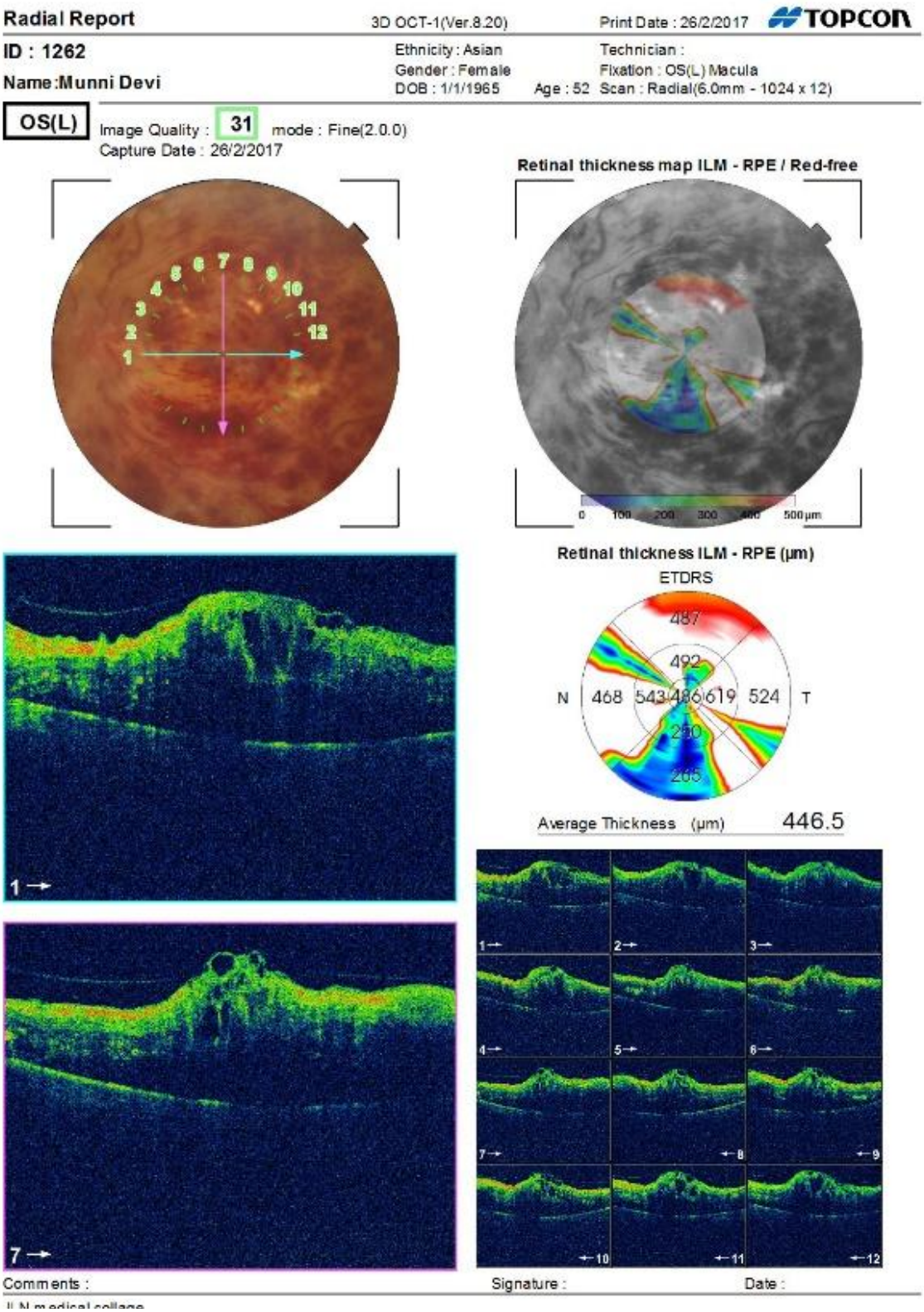
CSR is characterized by area of decreased reflectivity (optically empty) between the two highly reflective layers – neurosensory retina and RPE/ choriocapillaries.

CNVM IN WET ARMD



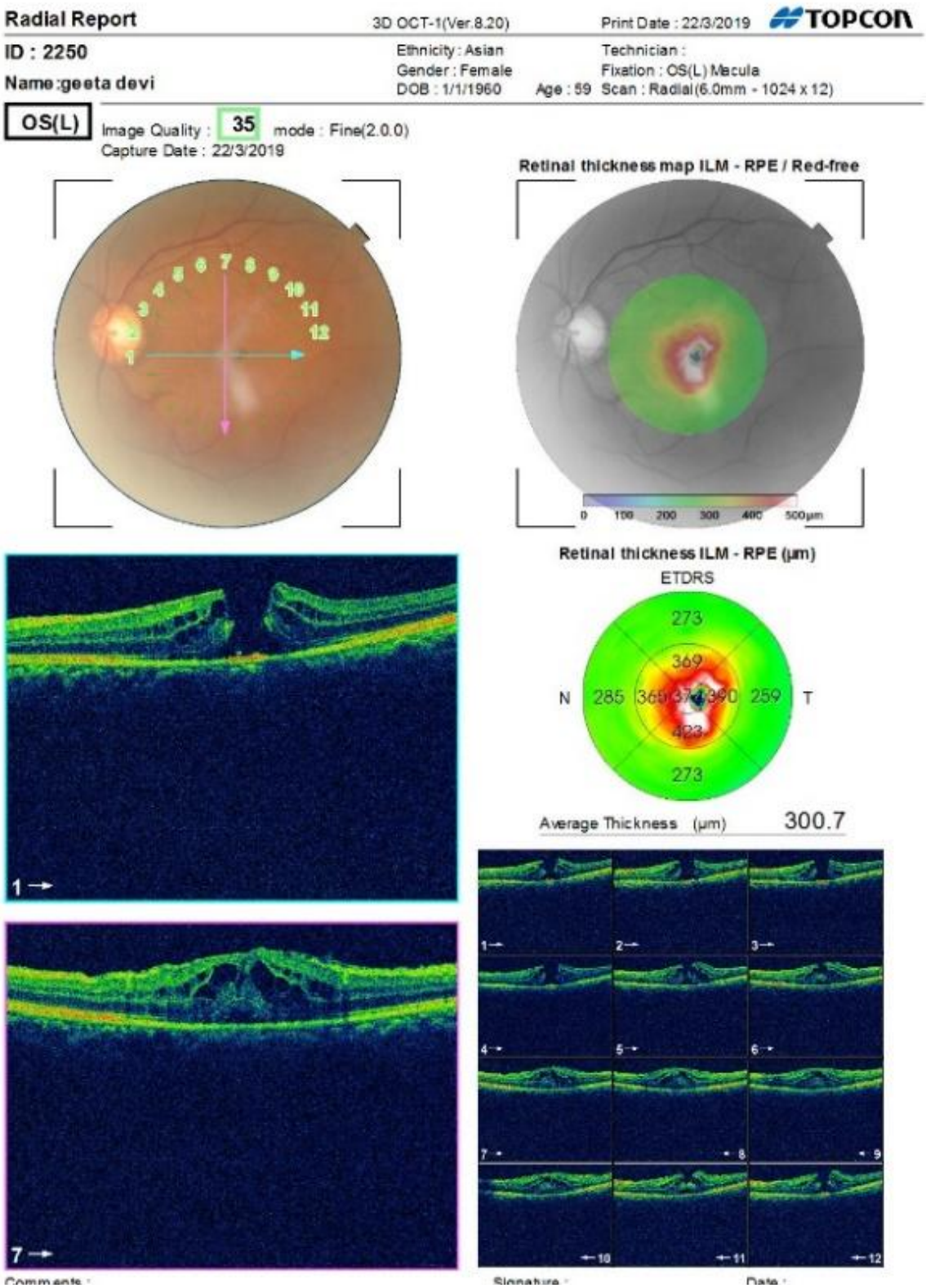
CNVM is characterized by hyper-reflective lesion fusiform in shape, increased intra-retinal thickening and sub-retinal fluid adjacent to the CNVM.

SPONGIFORM MACULAR EDEMAIN CRVO



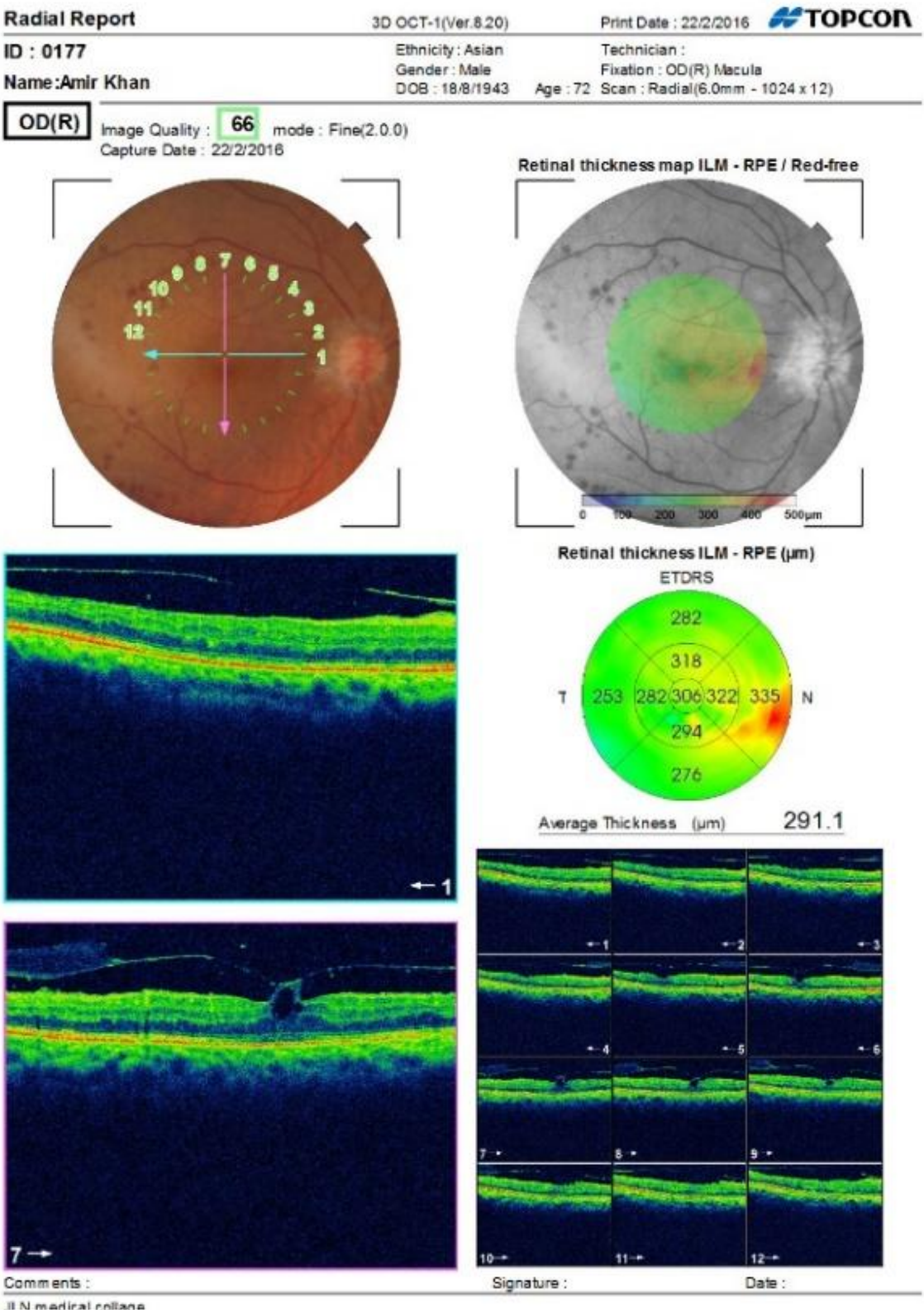
Typically seen as spongy macula with intraretinal areas of decreased reflectivity and round optically clear areas within the neurosensory retina with CRVO diagnosed on fundus examination. Quantative assessment allows monitoring the course.

MACULAR HOLE



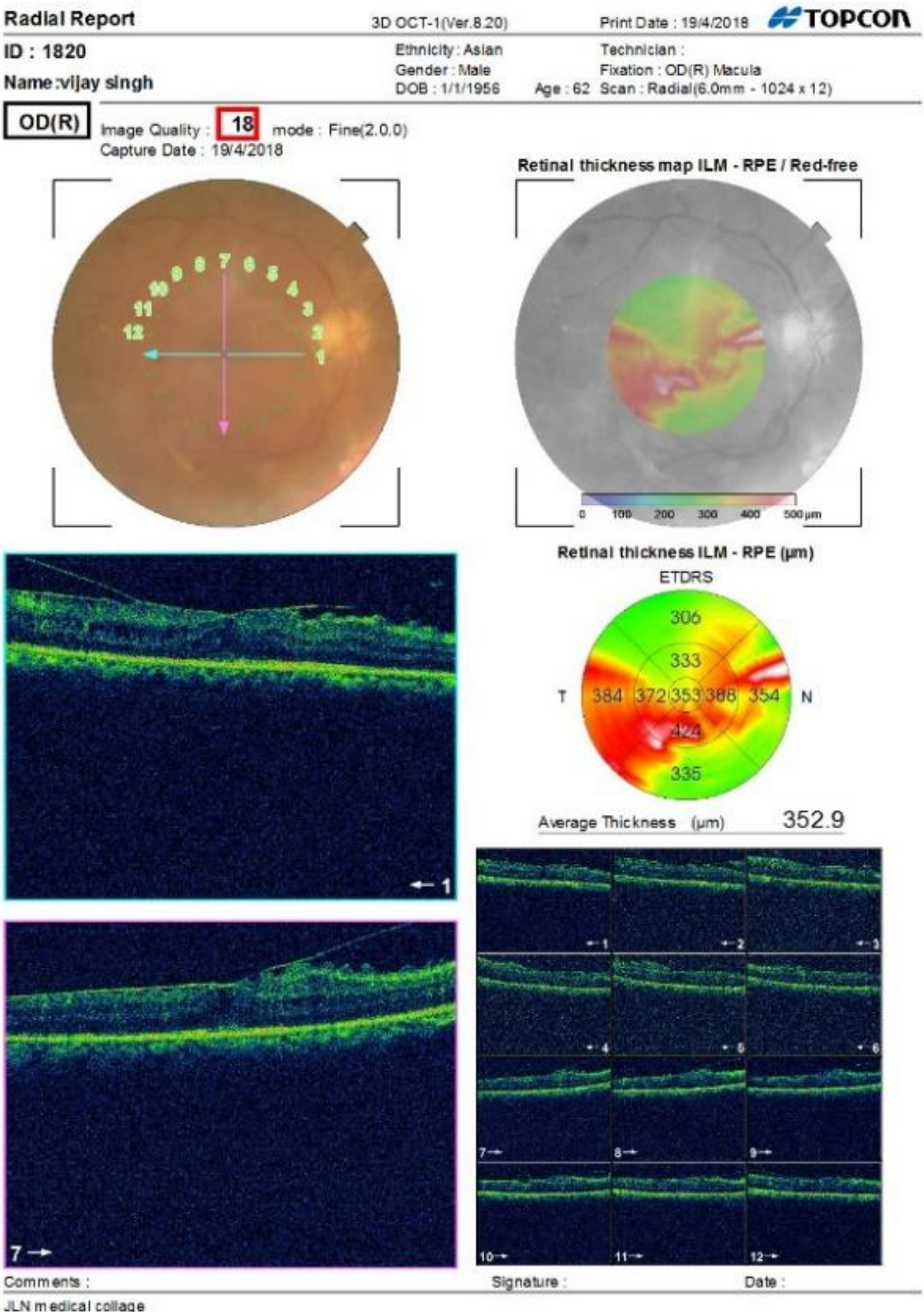
OCT allows confirmation of macular hole & differentiates it from clinically simulating conditions such as lamellar hole & pseudocyst. It is also useful in monitoring the course of the disease and response to surgical intervention.

VITREO-MACULAR TRACTION



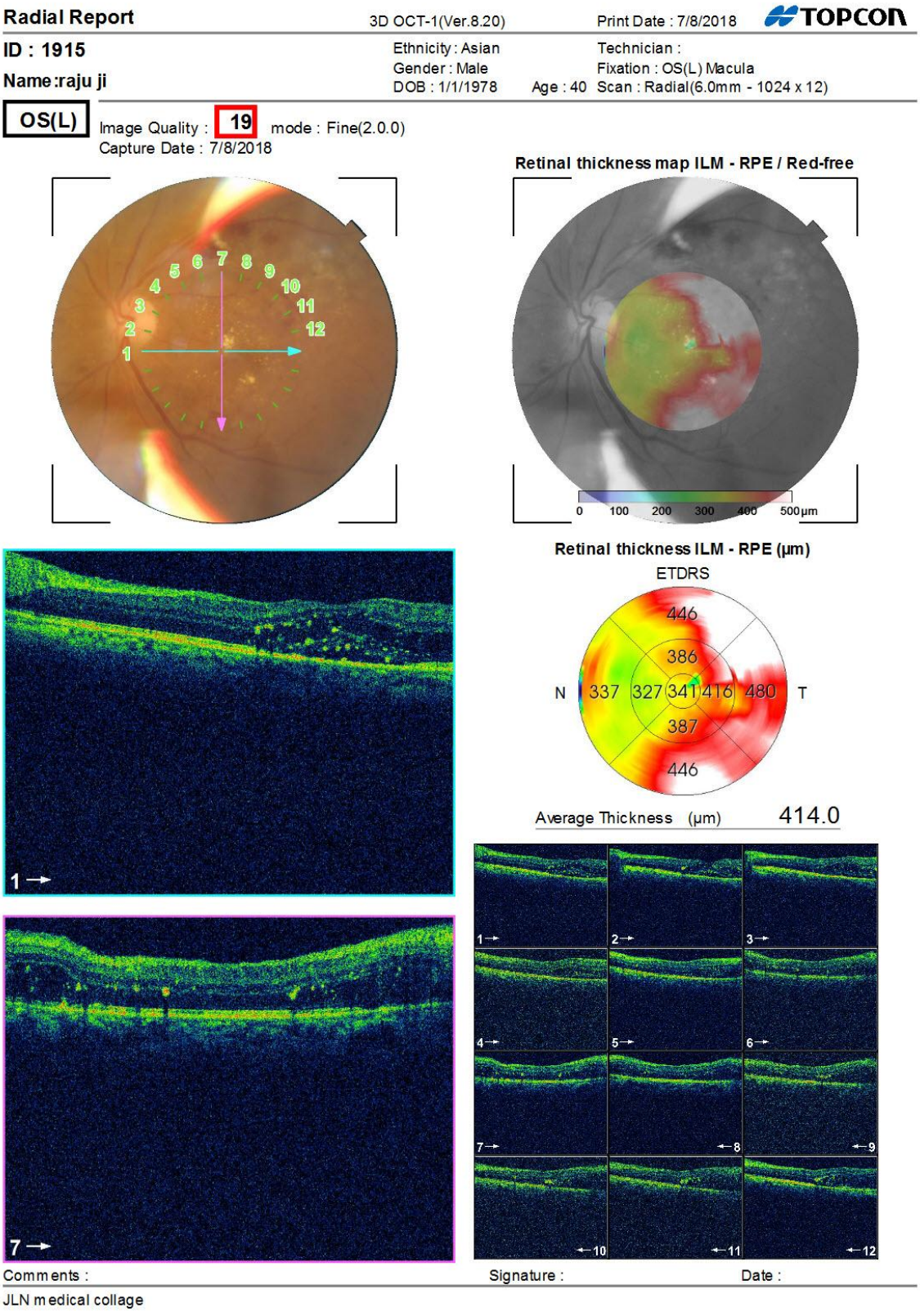
OCT showing vitreomacular traction syndrome with foveal cystoid changes involving the inner retina and preservation of outer retinal morphology. It also helps in grading of VMTS.

EPIRETINAL MEMBRANE



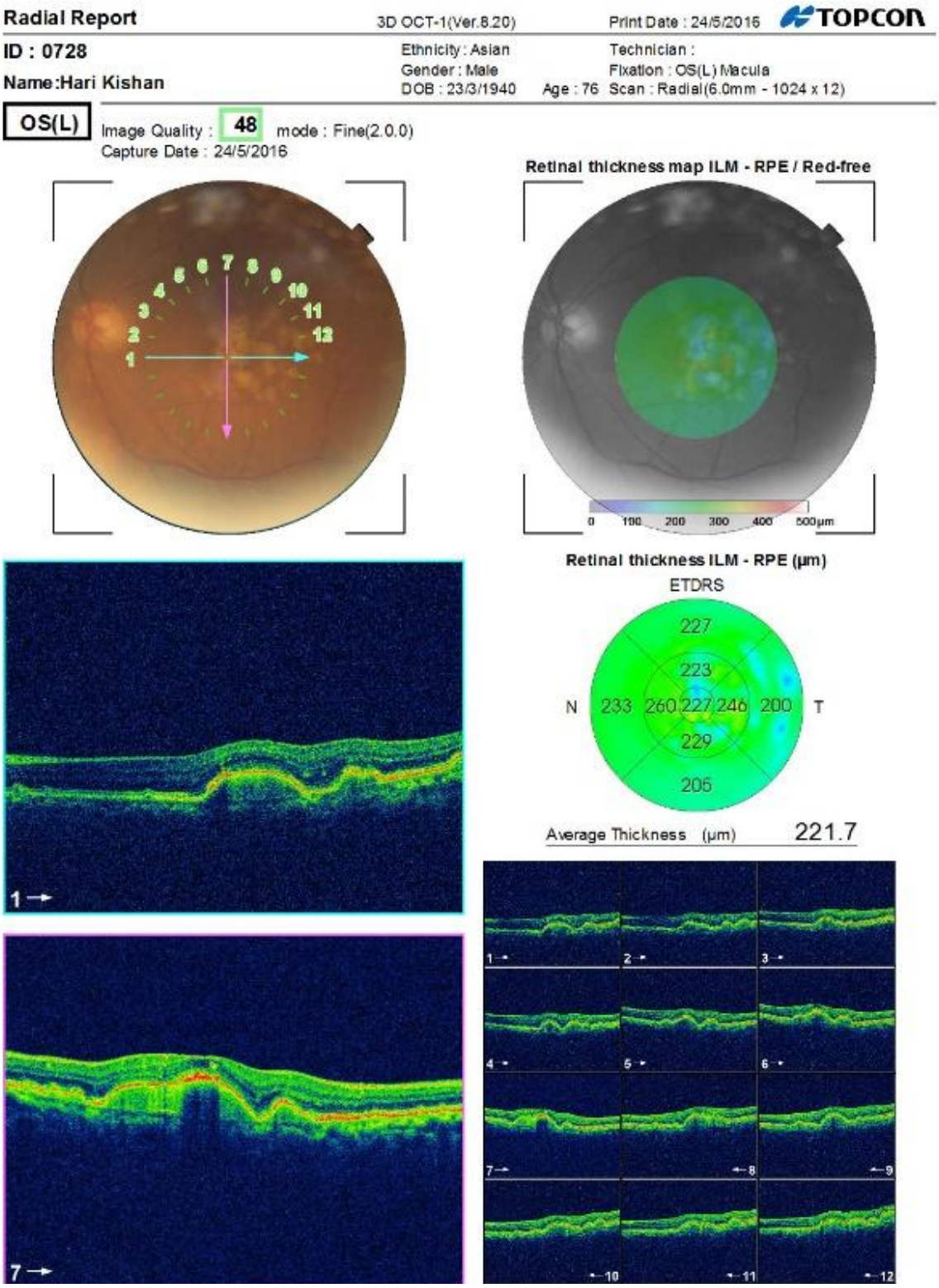
ERM is diagnosed on OCT by the presence of a highly reflective diaphanous membrane over the surface of retina. OCT provides information about membrane thickness, cystic changes and its adherence to retinal surface.

DIABETIC MACULAR EDEMA



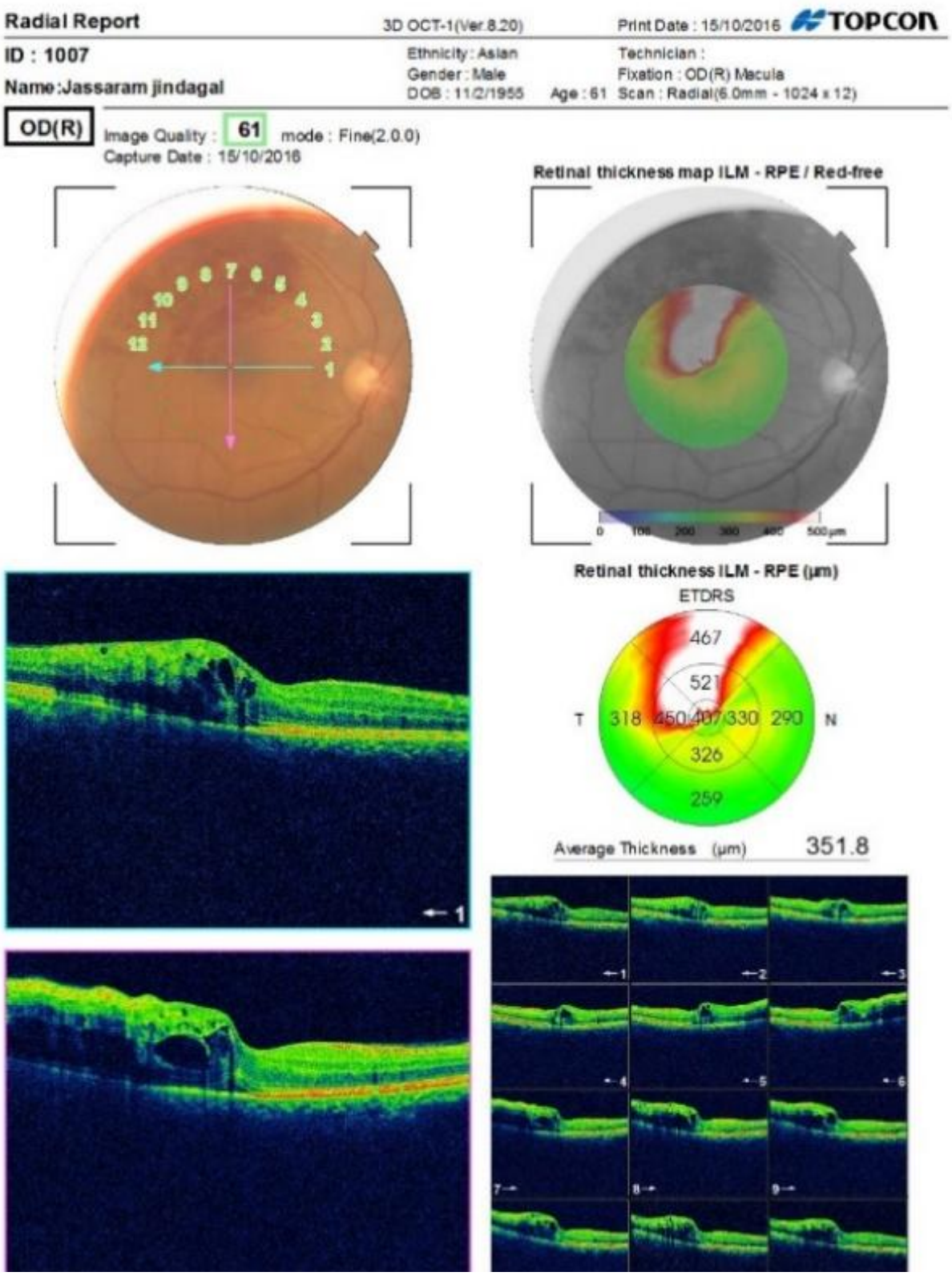
Characterized by presence of subretinal fluid and intraretinal fluid along with cystic spaces supported by typical diabetic fundus picture.

MULTIPLE PEDs



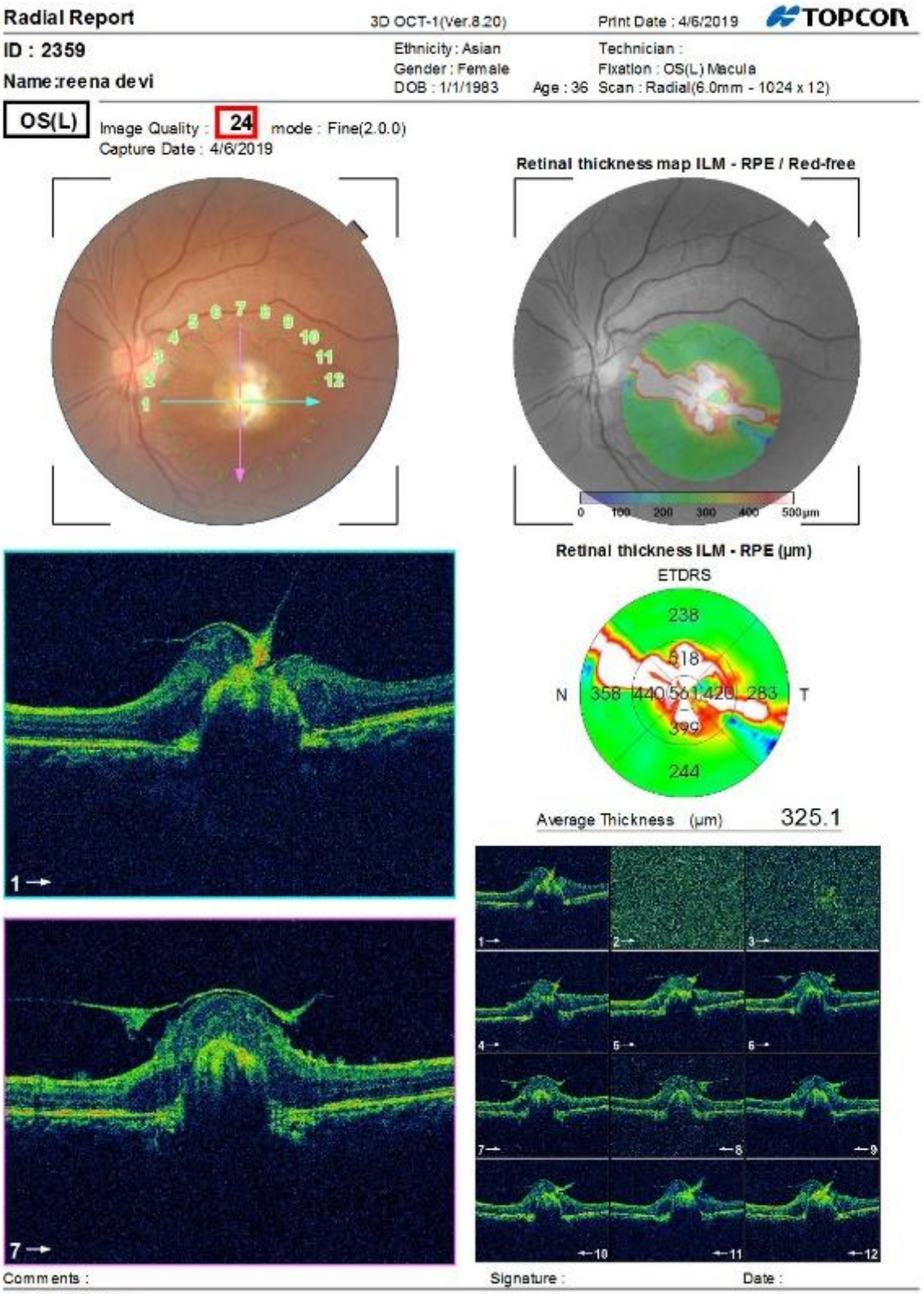
Drusens seen between the bruch's membrane and the RPE characterized by hyper-reflective bumpy RPE with PEDs.

CME IN BRVO



Characteristic findings of BRVO on OCT are cystoid macular edema, intraretinal hyperreflectivity from hemorrhages, shadowing from edema and hemorrhages, and occasionally subretinal fluid. The edema is typically localized to the involved site.

PED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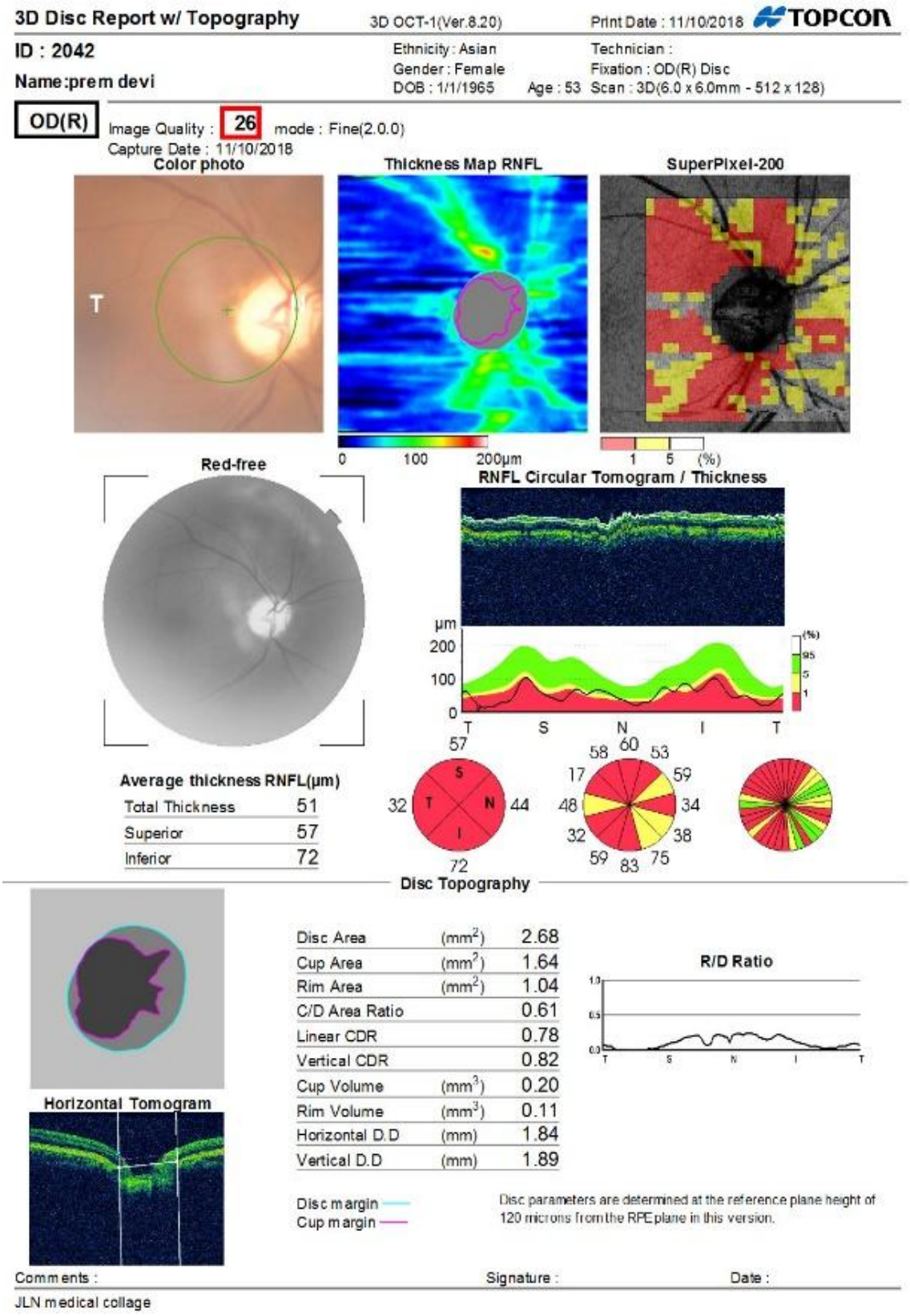
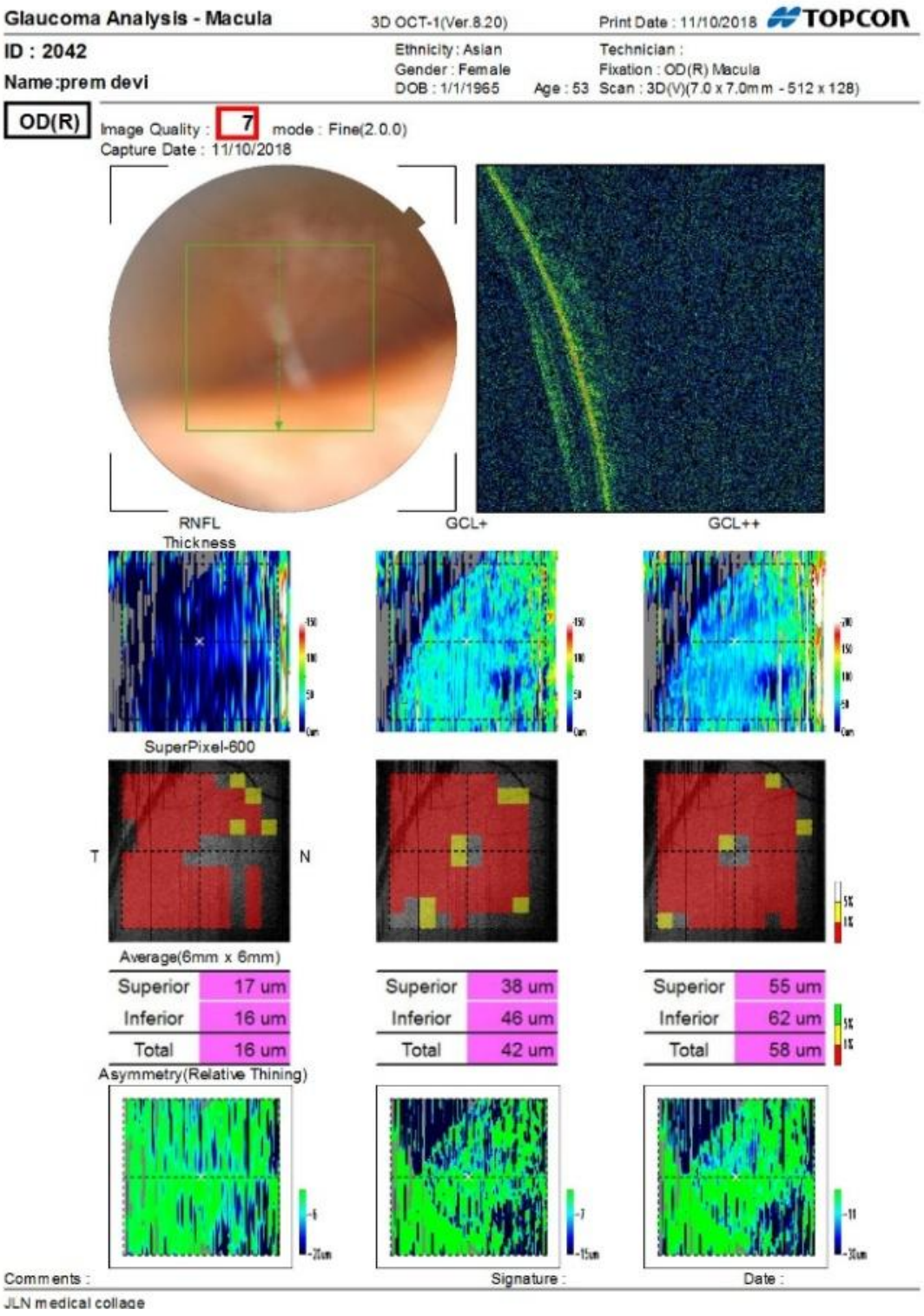
3D OCT-1(Ver.8.20)
Print Date : 4/6/2019
TOPCON
ID : 2359
Name:reena devi
Ethnicity : Asian
Gender : Female
DOB : 1/1/1983
Age : 36
Technician :
Fixation : OS(L) Macula
Scan : Radial(6.0mm - 1024 x 12)
OS(L)
Image Quality : 24
mode : Fine(2.0.0)
Capture Date : 4/6/2019
Retinal thickness map ILM - RPE / Red-free
0 100 200 300 400 500μm
Retinal thickness ILM - RPE (μm)
ETDRS
238
318
N
358
440
561
420
283
T
399
244
Average Thickness (μm)
325.1
1
7
Comments :
Signature :
Date :

GLAUCOMA

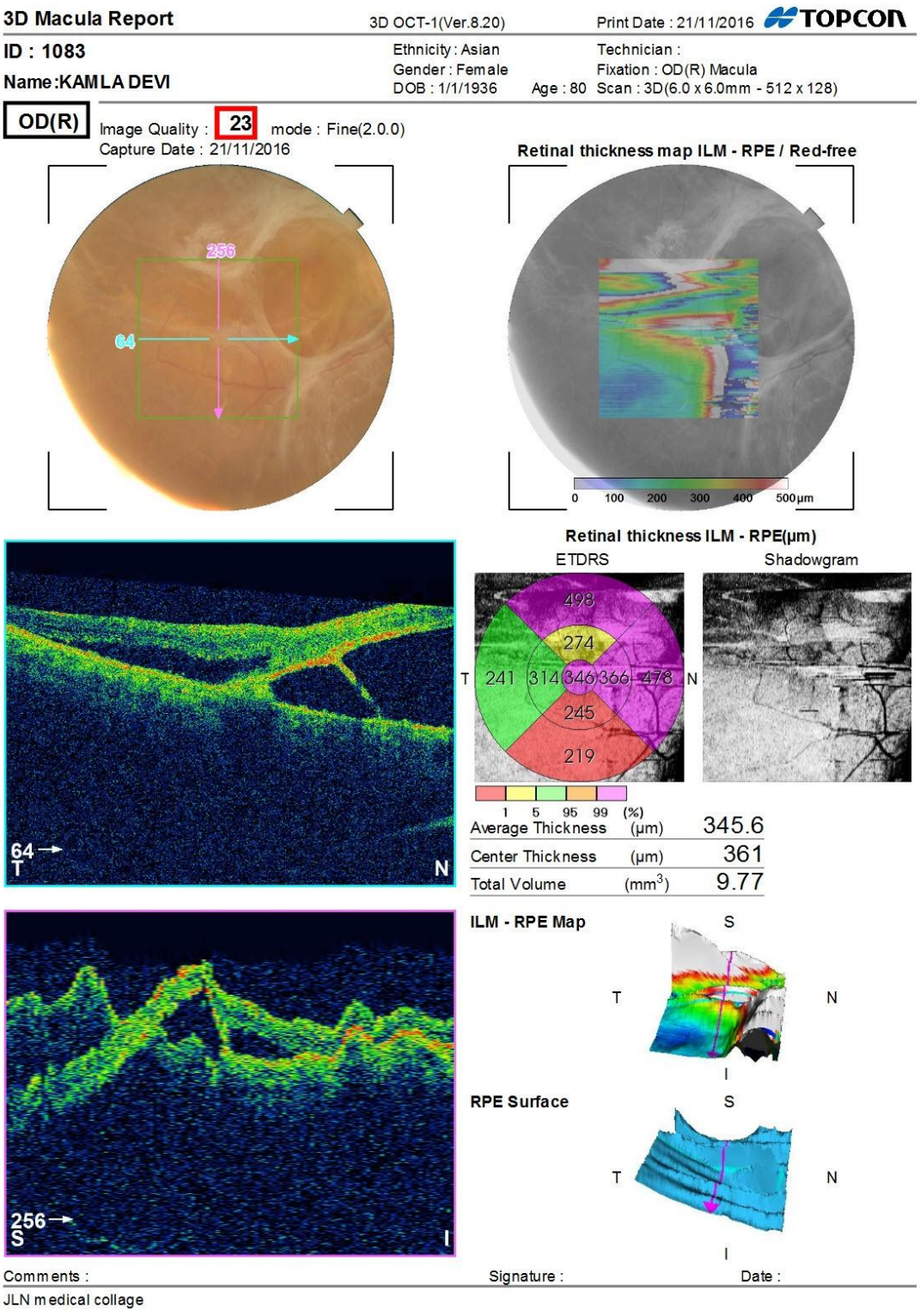

3D Disc Report w/ Topography
3D OCT-1(Ver.8.20)
Print Date : 11/10/2018
TOPCON
ID : 2042
Name:prem devi
Ethnicity : Asian
Gender : Female
DOB : 1/1/1965
Age : 53
Technician :
Fixation : OD(R) Disc
Scan : 3D(6.0 x 6.0mm - 512 x 128)
OD(R)
Image Quality : 26
mode : Fine(2.0.0)
Capture Date : 11/10/2018
Color photo
Thickness Map RNFL
SuperPixel-200
T
0
100
200µm
1
5
(%)
Red-free
RNFL Circular Tomogram / Thickness
µm
200
100
0
T
S
N
I
T
Average thickness RNFL(µm)
Total Thickness 51
Superior 57
Inferior 72
57
32
44
72
58
60
53
17
59
48
34
32
38
59
83
75
Disc Topography
Horizontal Tomogram
Disc Area (mm²) 2.68
Cup Area (mm²) 1.64
Rim Area (mm²) 1.04
C/D Area Ratio 0.61
Linear CDR 0.78
Vertical CDR 0.82
Cup Volume (mm³) 0.20
Rim Volume (mm³) 0.11
Horizontal D.D (mm) 1.84
Vertical D.D (mm) 1.89
R/D Ratio
Disc margin
Cup margin
Disc parameters are determined at the reference plane height of 120 microns from the RPE plane in this version.
Comments :
Signature :
Date :
JLN medical collage



Optic disc scan is very useful in diagnosing and monitoring glaucomatous changes. It is also useful in evaluating the RNFL for early (pre-perimetric) glaucoma detection. It provides accurate assessment of size of optic cup, disc area, C:D ratio, volume of the cup.

Other uses Include –

Detection, study and follow up of macular changes in hypotony induced maculopathy after glaucoma and Evaluation of cystoid macular edema after combined cataract and glaucoma surgery.**PDR WITH TRD**


3D Macula Report
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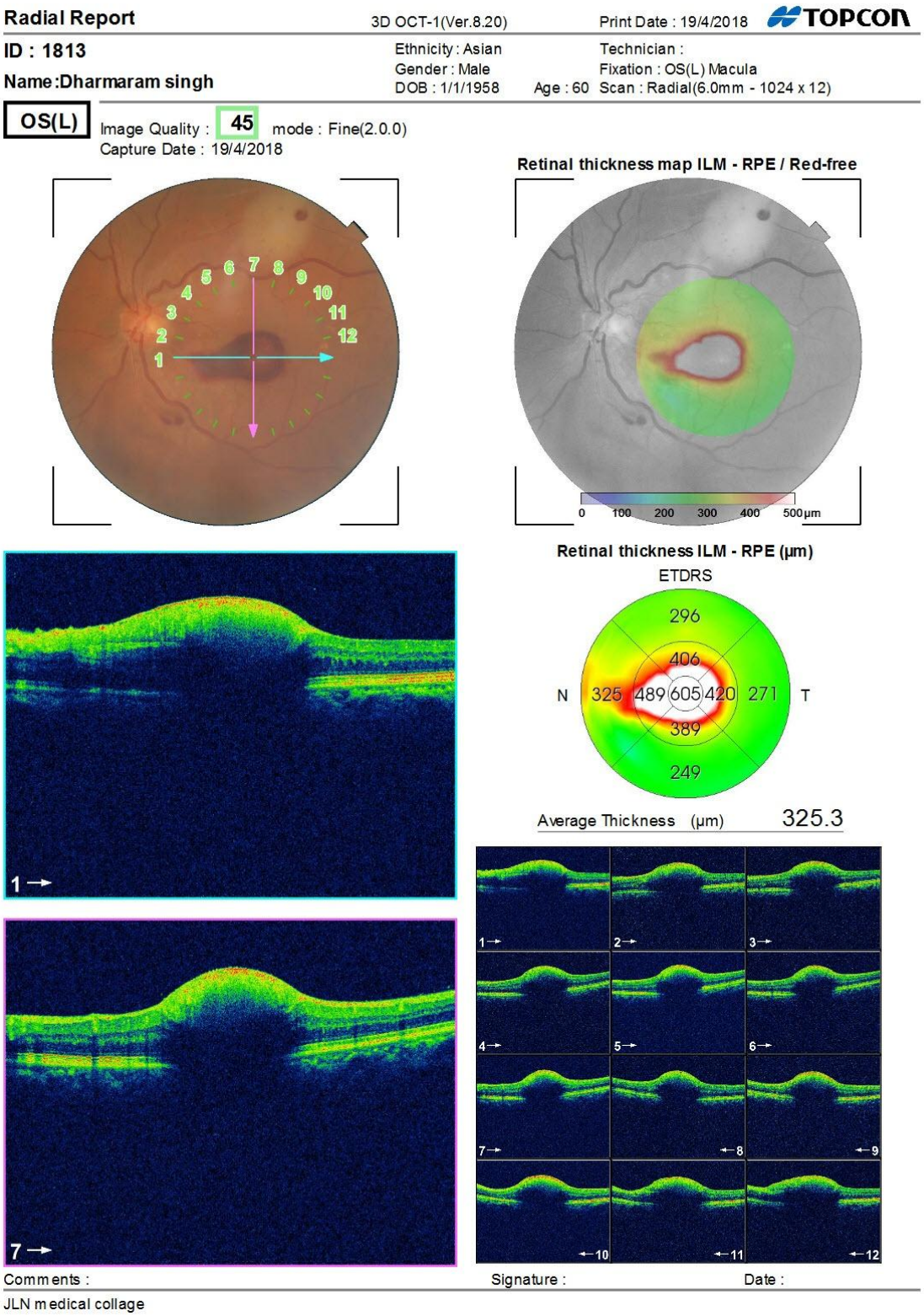
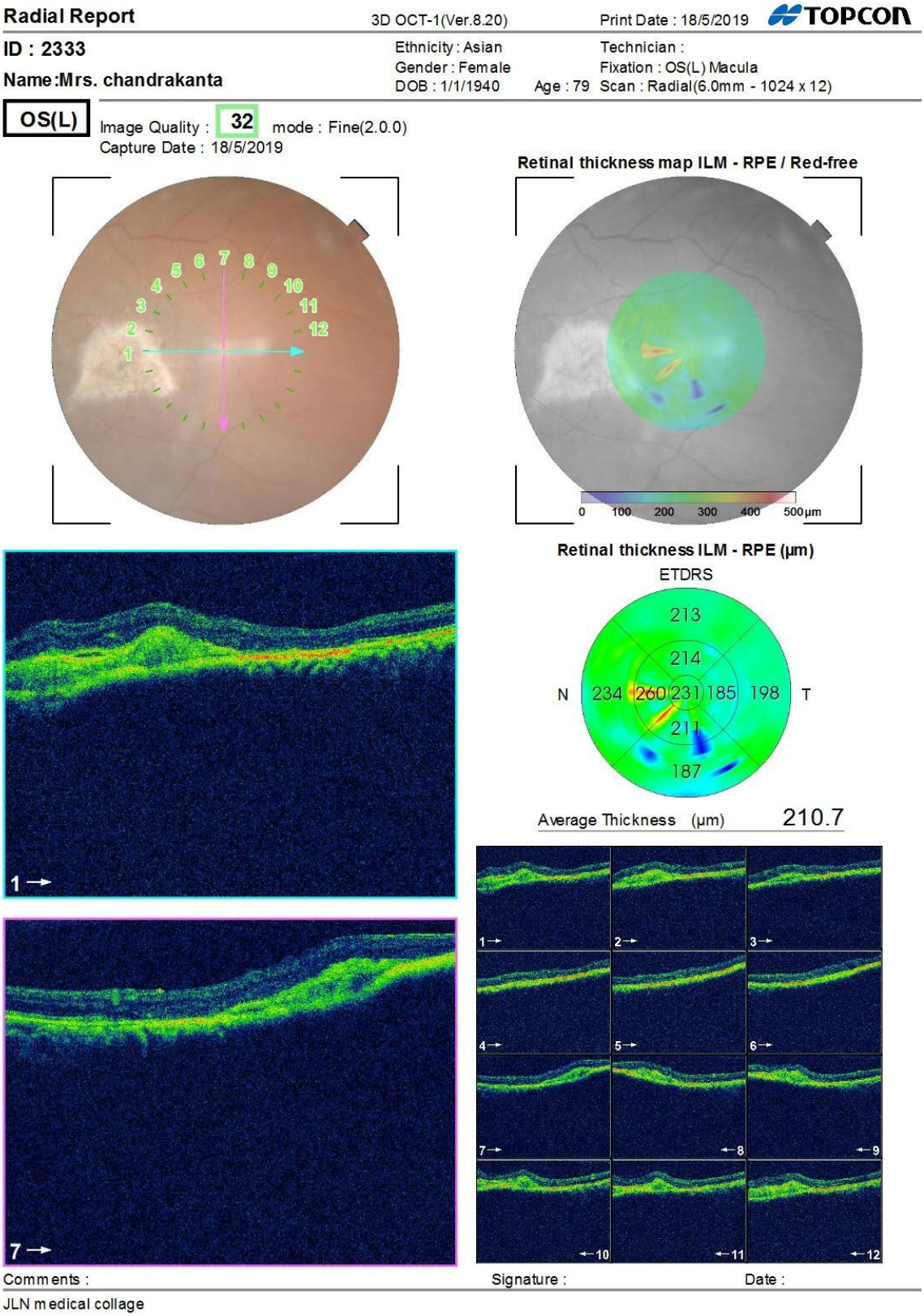
Print Date : 21/11/2016
TOPCON
ID : 1083
Name:KAMLA DEVI
Ethnicity : Asian
Gender : Female
DOB : 1/1/1936
Age : 80
Technician :
Fixation : OD(R) Macula
Scan : 3D(6.0 x 6.0mm - 512 x 128)
OD(R)
Image Quality : 23
mode : Fine(2.0.0)
Capture Date : 21/11/2016
Retinal thickness map ILM - RPE / Red-free
256
64
0 100 200 300 400 500µm
Retinal thickness ILM - RPE(µm)
ETDRS
Shadowgram
498
274
T 241 314 346 366 478 N
245
219
1 5 95 99 (%)
Average Thickness (µm) 345.6
Center Thickness (µm) 361
Total Volume (mm3) 9.77
64
T
N
256
S
I
ILM - RPE Map
RPE Surface
S
T
N
I
Comments :
Signature :
Date :
JLN medical collage

SUBMACULAR HEMORRHAGE

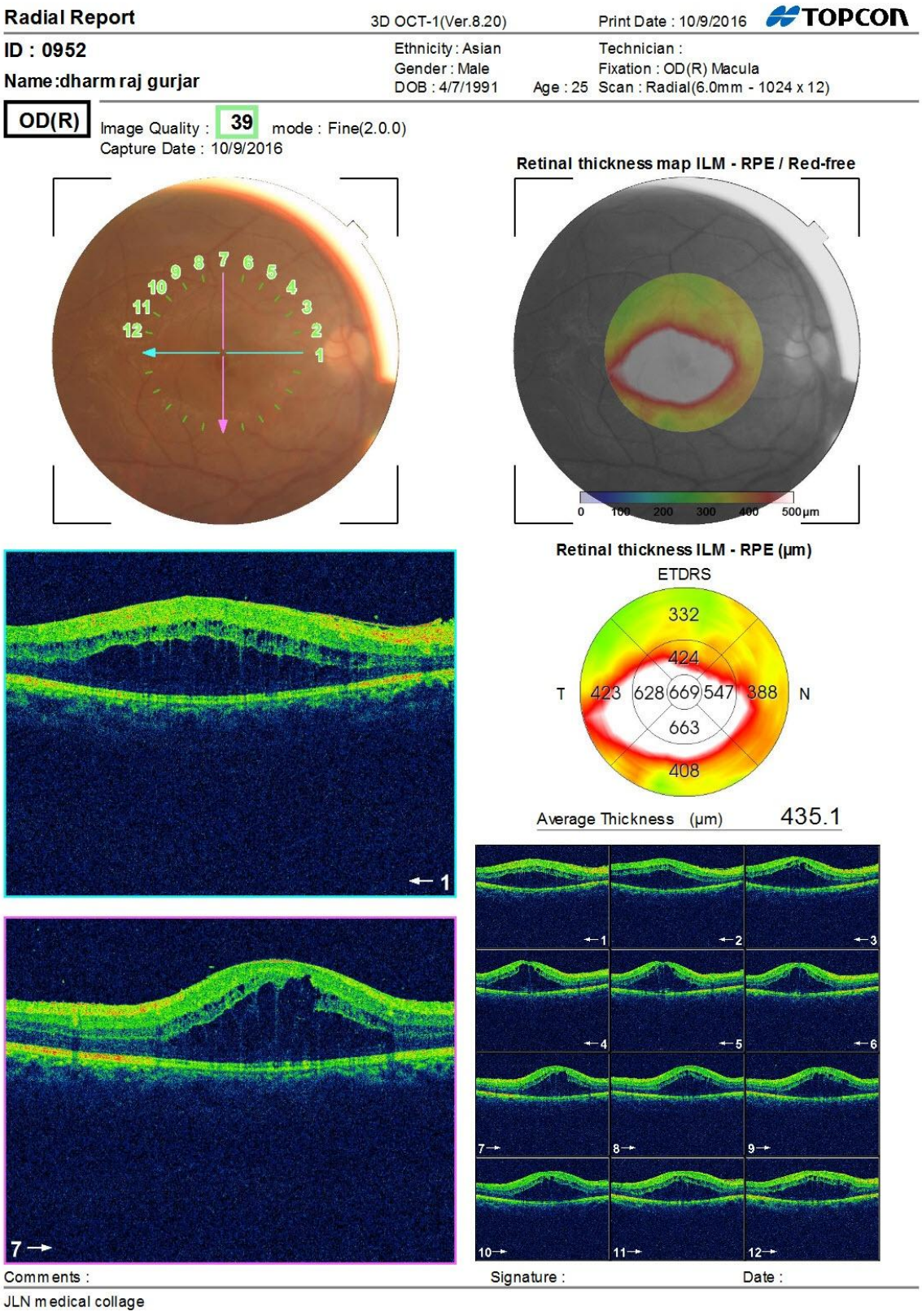


OCT reveals location of the submacular hemorrhage predominantly in the subretinal pigment epithelial space and there can be large hemorrhage with shadowing, obscuring the underlying RPE.

RETINAL SCARRING

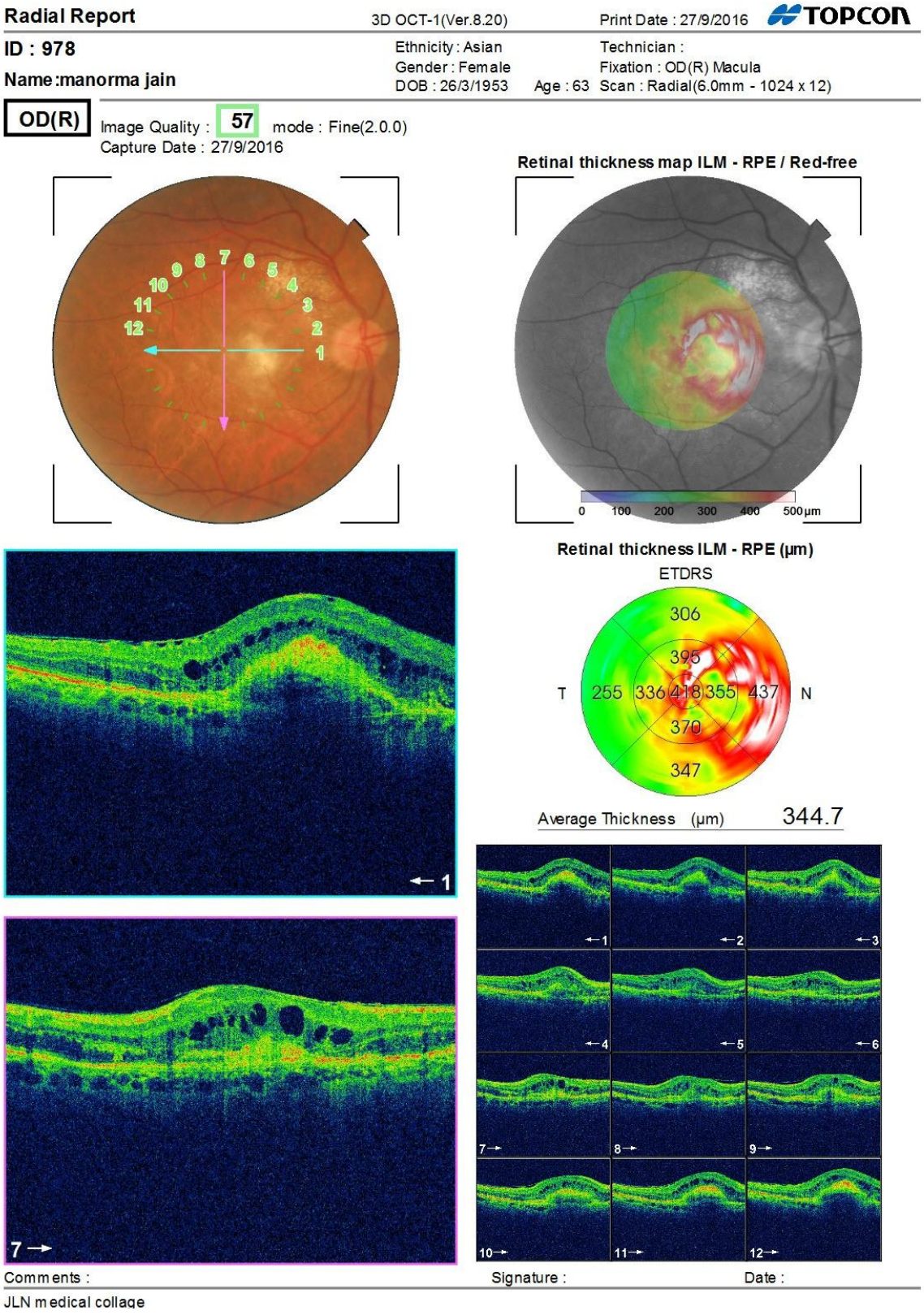


MACULAR EDEMA IN EALE'S DISEASE



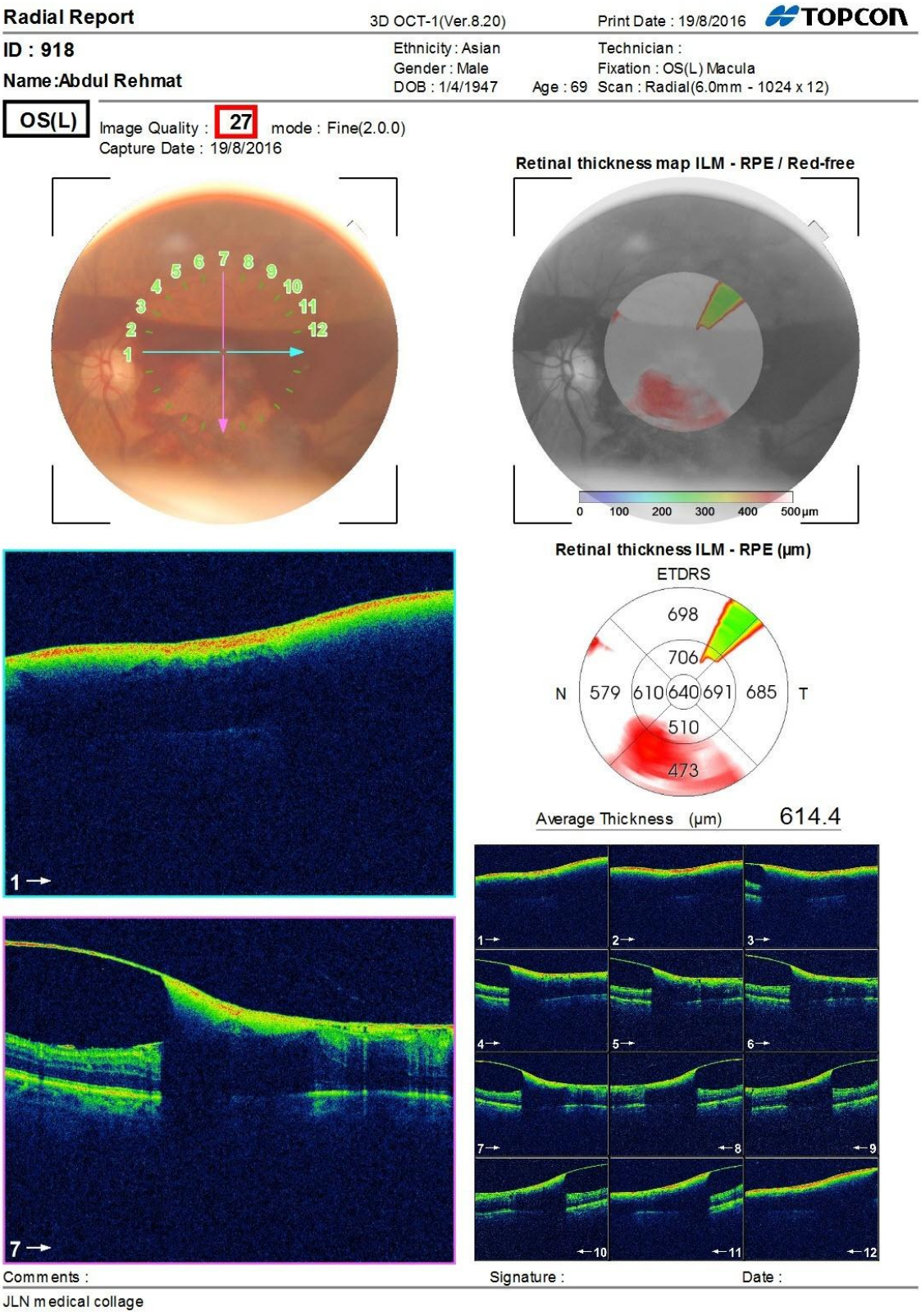
Multiple cystoid spaces with intraretinal fluid in CME of a patient with Eale's disease as evidenced by fundus picture.

CNVM WITH CME AND PED



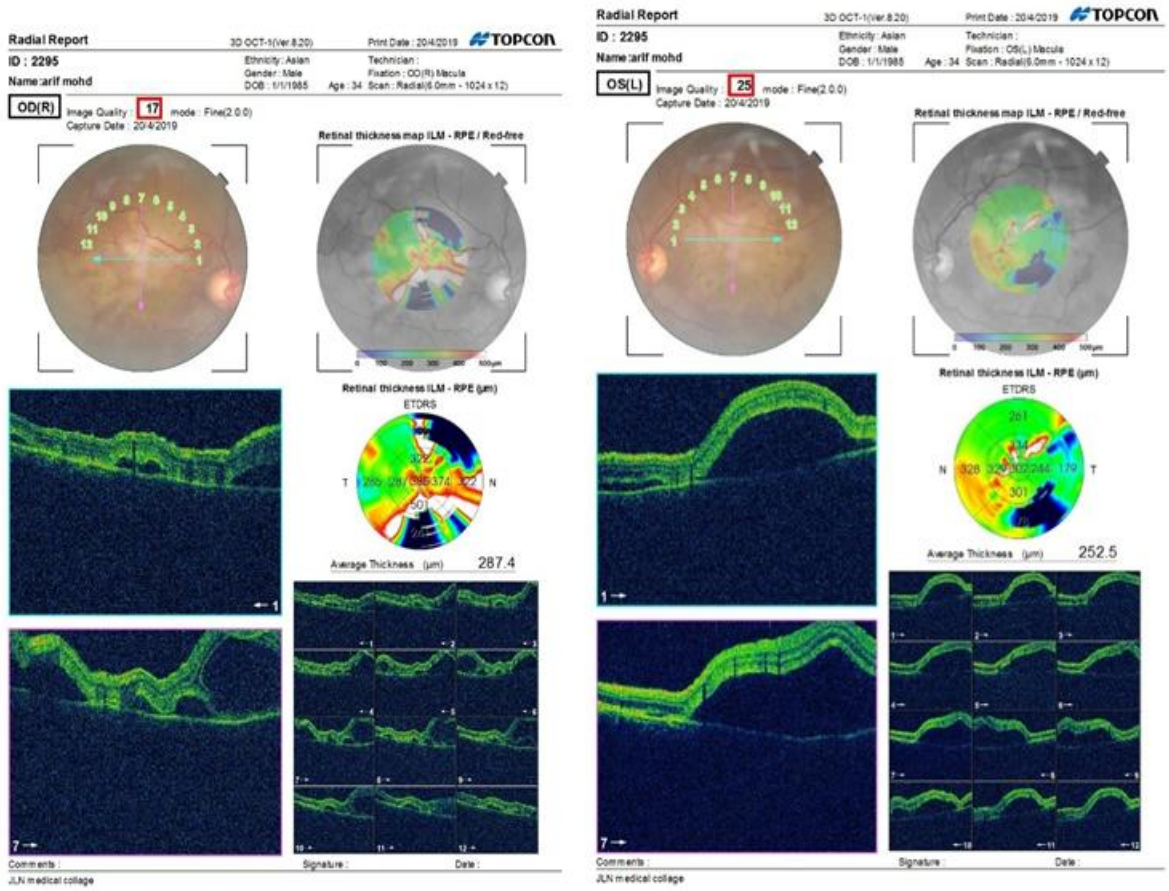
Hyper-reflective fusiform thickening of the RPE-CC layer in CNVM along with multiple cystic optically black areas of CME withindefinite elevated green line of RPE-CC layer typical of fibrovascular PED.

SUBHYALOID HEMORRHAGE



OCT reveals a reflecting posterior hyaloid in the upper border fused with internal limiting membrane over the preretinal hemorrhage. OCT also gives the exact location of hemorrhage – sub-ILM or subhyaloid.

VKH



VKH characterized by bilateral multifocal neurosensory detachments with optically empty spaces.

ADVANTAGES OF OCT -

- Best axial resolution available so far.
- Scan various ocular tissues.
- Tissue sections comparable to histopathology sections.
- Easy to operate.
- Short scanning time.
- Non invasive, non contact.

LIMITATIONS OF OCT -

- Penetration depth of OCT is limited.
- Limited by media opacities.
- Each scan must be taken in range and focus.
- Axial motion is corrected with computer correlation software.
- Unable o visualize neovascular network or analyse if CNV is active.
- OCT images cannot be interpreted in isolation,must be correlated wih fundus photography/ophthalmoscopy.

NEWER ADVANCEMENTS -

- With Longer-wavelength OCT systems including SS-OCT, the visualization of choroid–sclera interface is expected to improve.
- Doppler OCT can evaluate blood flow and volume of retinal and choroidal vasculature[20-24], highlight vessels where the flow is present[25] and evaluate abnormalities in retinal and choroidal vasculature[26].
- En-face OCT provides further detail about the subtle pathological features in the retina and choroid in diseased states[27]. It produces frontal sections of the retinaa layers so also called the 'C-scan OCT'.
- Enhanced depth imaging OCT enables the visualization of structures lying deepe in the eye like choroid.

- Intraoperative OCT helps surgeons to better delineate tissue structures thus reducing surgical time andexcessive illumination.
- Adaptive optics OCT corrects for higher order ocular aberrations during image acquisition allowing improved lateral and near cellular level resolution.
- Optical microangiography (OMGA) technology allows volumetric map acquisition and in combination with widefield OCT can perform vascular perfusion mapping down to capillary level comparable to FFA and ICG.

II. Conclusion

OCT has provided better understanding, monitoring progression and response to various treatment modalities chorio-retinal diseases. This has revolutionized ophthalmic practice over the last decade. Further advancements in technologies are expected so that chorio-retinal diseases can be assessed in more detail.

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