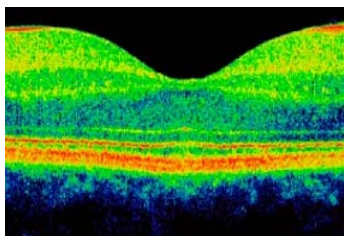## Slide 1

# Optical Coherence Tomography
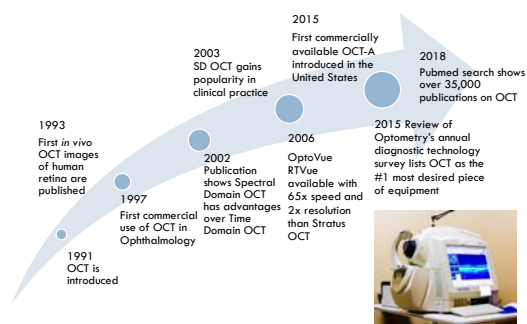


Caroline B. Pate, OD, FAAO
Associate Professor
UAB School of Optometry
Birmingham, Alabama

## Slide 2

# Too good to be true?

- Non-contact
- Non-invasive
- Painless
- No radiation
- Fast
- Reliable
- Detection of pathology that cannot be seen ophthalmoscopically
- Sensitive….micrometer resolution!

## Slide 3

# History of Optical Coherence Tomography

1991
OCT is introduced

1993
First *in vivo* OCT images of human retina are published

1997
First commercial use of OCT in Ophthalmology

2002
Publication shows Spectral Domain OCT has advantages over Time Domain OCT

2003
SD OCT gains popularity in clinical practice

2006
OptoVue RTVue available with 65x speed and 2x resolution than Stratus OCT

2015
First commercially available OCT-A introduced in the United States

2015 Review of Optometry's annual diagnostic technology survey lists OCT as the #1 most desired piece of equipment

2018
Pubmed search shows over 35,000 publications on OCT

## Slide 4

# Time Domain vs. Spectral (Fourier) Domain OCT

- Slower than eye movements (>1sec image acquisition speed)
- Sequential – 1 pixel at a time

- Faster than eye movements (milliseconds)
- Simultaneous – 2048 pixels at a time
- Higher resolution



D. Huang, USC

## Slide 5
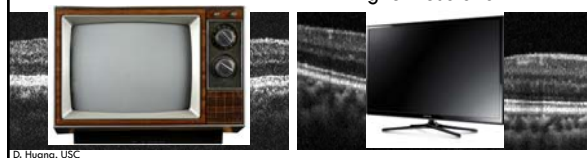
# Lots of options - Spectral Domain OCT

| Model (Manufacturer) | Cirrus HD-OCT 5000 (Carl Zeiss Meditec) | 3D OCT – 1 Maestro (Topcon Medical Systems) | Spectralis SD-OCT (Heidelberg Engineering) | Avanti RTVue XR (Optovue) |
| --- | --- | --- | --- | --- |
| Scanning Speed (A-scans per second) | 27,000-68,000 | 50,000 | 40,000 | 70,000 |
| Axial Resolution (μm in tissue) | 5 | 5-6 | 3.9 | 5 |
| Minimum Pupil Diameter (mm) | 2 | 2.5 | 2.5 | 2.5 |

*Adapted from: Mazzarella & Cole. Review of Optometry Sept 2015.*

## Slide 6

# How does OCT work?

- Uses light rather than sound or radio frequency
  - Faster speed = higher resolution
- Uses principle of low-coherence interferometry to measure optical reflectivity of tissues
- The interferometer integrates data points to construct a tomogram of retinal structures
  - Layers of different optical densities

## Limitations

- Mydriasis may be necessary
- Cataracts and poor tear film can degrade the image
- Accuracy is limited by high refractive error and axial length
- Limited to posterior pole
- Caution comparing measurements from one brand of OCT to another

## Indications

- Diagnosis and detection of pathology
- Monitoring for progression
- Evaluation for need for laser or surgical intervention
- Quantification – evaluation of thickness, volume, surface area
- Monitoring for changes due to medications
- Evaluation of postoperative progress

## Running an OCT

## Obtaining a scan

- Patient fixates on target inside the instrument
- Operator aligns instrument via a camera which allows visualization of the fundus and the scan beam
- Recommended minimum pupil size ~ 3mm, however dilation improves the signal strength and image quality

- Numerous scanning protocols
  - Anterior segment and Posterior segment
  - Grid, raster, volume scans, single line, etc
  - Adjustable parameters
- Results
  - Images displayed on monitor representing reflective differences between structures
  - Operator may choose to save image or repeat scan
  - Often compared to normative database

## What can we see with the OCT?

## Know the anatomy!
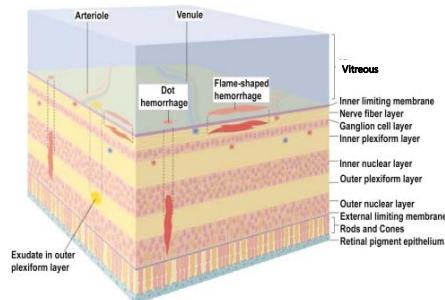


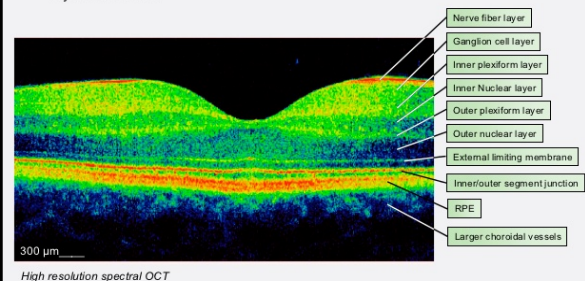Gabaeff SC. *WestJEM* 16(7): 2010.
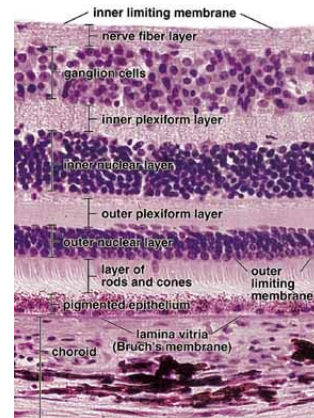


Ross MH, Kaye GI, Pawlina W: Histology, a Text and Atlas. 4th ed. Philadelphia: Lippincott Williams & Wilkins, 2003

## Anatomy of a retinal OCT image
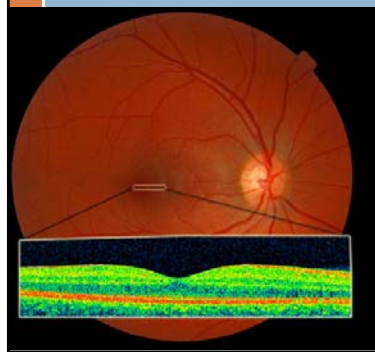


- Reflective interfaces between structures
- Large reflections are warm colors (red, yellow)
- Mild reflections are cool colors (green, blue)
- Absence of reflection is black



Layers of the retina

High resolution spectral OCT
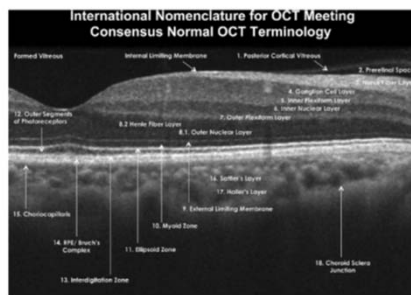


## 3D imaging of ocular structures

- X, Y, and Z axis
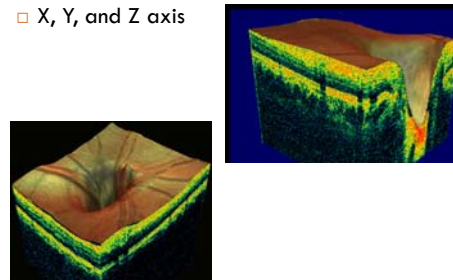
## OCT-Angiography

- Allows for better assessment of retinal and choroidal vascular disease and blood flow
- Useful in diseases such as macular degeneration, diabetic retinopathy, and vein occlusions
- OCT-A systems:
  - AngioPlex (Carl Zeiss Meditec)
  - AngioVue (OptoVue)
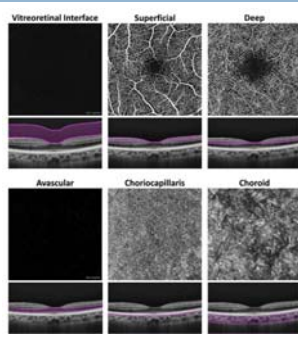


Review of Optometry, 2017
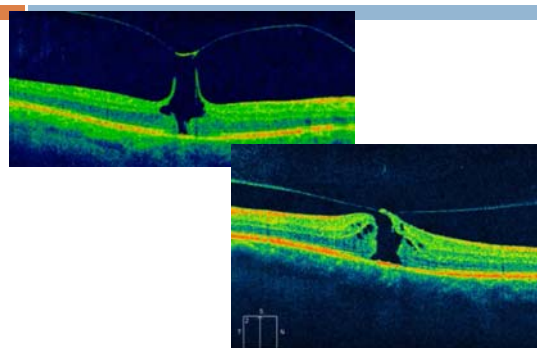
## Retinal examination

## Clinical applications

- 1. **Macular disorders** – especially helpful in confirming those that are not evident clinically
- 2. **Macular hole** – allows for confirmation of diagnosis and staging and monitoring through treatment
- 3. **Macular edema** – characterized by areas of increased thickening and decreased reflectivity
  - diabetes, vein occlusion, uveitis, post cataract surgery
  - Quantitative measurements allow for monitoring for progression/resolution

## 

- 4. **Macular degeneration**
  - Detection of RPE changes and disruption in dry AMD
  - Detection of subretinal fluid and choroidal neovascularization in wet AMD
- 5. **Medications**
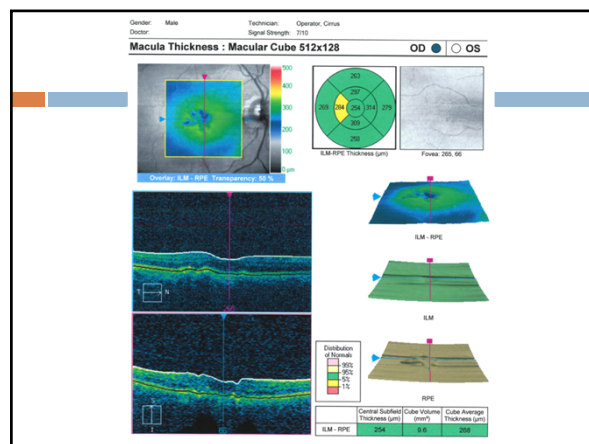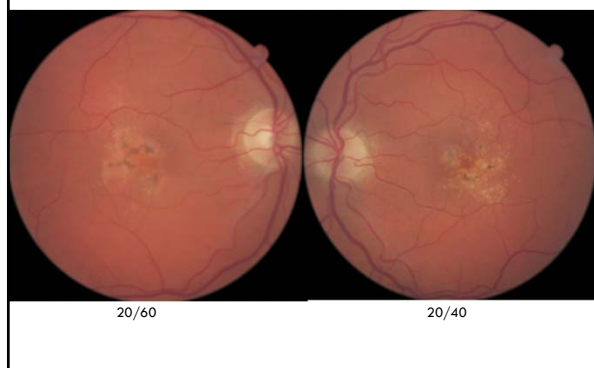  - Response to treatment
  - Side effects of systemic medications

## Vitreous detachment vs. Vitreomacular Traction



## Macular hole

## Epiretinal membrane



20/80 BCVA, noticed vision worsening over past few months



## 26 yo AA F, 34 weeks pregnant

- Type 1 DM
- Pre-eclampsia



20/400          20/100





## 68 yo AA M, sudden vision loss OS
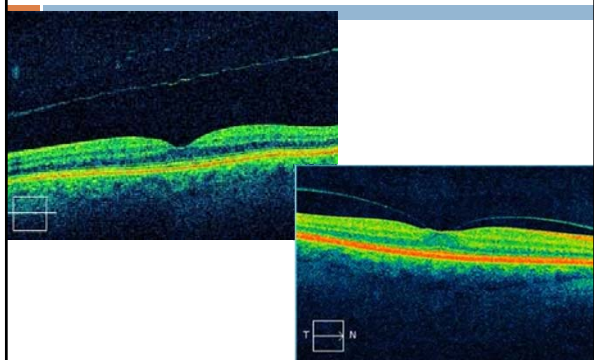
## 76 yo WM, being followed for AMD



20/60        20/40



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### American Academy of Ophthalmology Statement

**Recommendations on Screening for Chloroquine and Hydroxychloroquine Retinopathy (2016 Revision)**



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## Recommendations for patients on Plaquenil

- Risk of toxicity increases sharply towards 7.5% after 5-7 yrs of use, or cumulative dose of 1000 g HCQ
- Initial baseline exam with DFE, then annual screenings after 5 years
- Screening:
  - Regular exams with DFE
  - 10-2 SS (white stimulus)
  - 24-2 SS or 30-2 SS (white stimulus) for Asian patients
  - SD OCT*, FAF or mfERG
    - *most objective, lowest variability
  - No longer recommending Amsler Grid



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## "Flying Saucer Sign"

Disruption to the ellipsoid zone line/parafoveal thinning
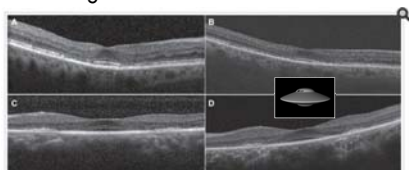


Spectral domain optical coherence tomography (SD OCT) images taken with different commercially available SD OCT machines demonstrate the "flying saucer" sign is consistent in different individuals with hydroxychloroquine retinopathy. A) Heidelberg Spectralis SD OCT in patient 9, OD. B) Zeiss Cirrus SD OCT in patient 9, OD. C) Heidelberg Spectralis SD OCT in patient 4, OS. D) Zeiss Cirrus SD OCT in patient 4, OS.

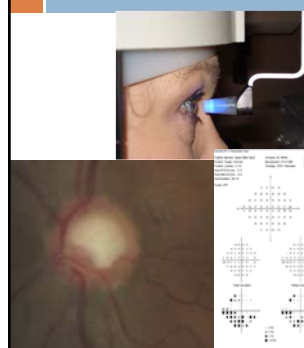Chen E, et al. Clinical Ophthalmology 2010.

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## Optic nerve evaluation

## Optic disc scan

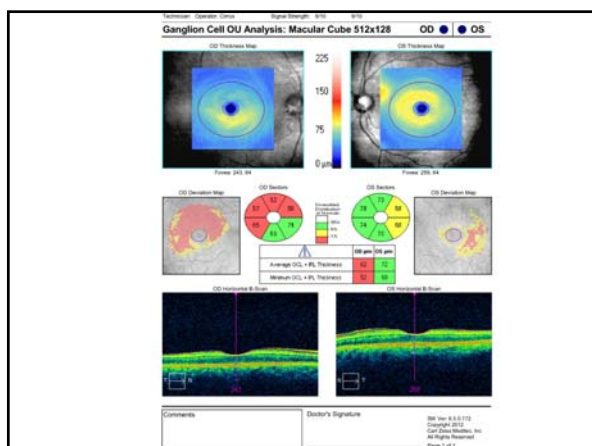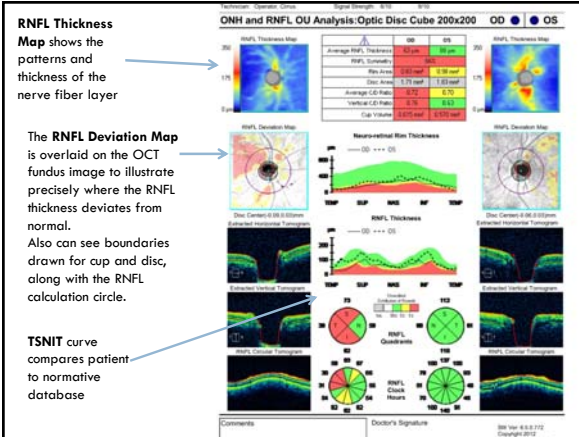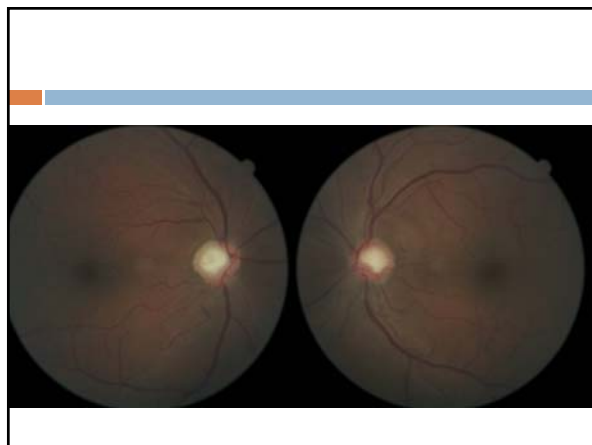- High resolution imaging with OCT allows for an accurate assessment of:
  - Size of the optic cup
  - Disc area
  - C/D ratio
  - Volume of the cup
  - RNFL thickness
- Serial measurements are useful to monitor for glaucomatous changes



## Traditional methods of evaluating a patient for glaucoma



- Measuring IOP
  - The <u>one</u> risk factor that can be controlled
- Stereoscopic optic nerve evaluation
- Visual field testing
  - Patient <u>must</u> cooperate for accurate results





**RNFL Thickness Map** shows the patterns and thickness of the nerve fiber layer

The **RNFL Deviation Map** is overlaid on the OCT fundus image to illustrate precisely where the RNFL thickness deviates from normal.
Also can see boundaries drawn for cup and disc, along with the RNFL calculation circle.

**TSNIT** curve compares patient to normative database
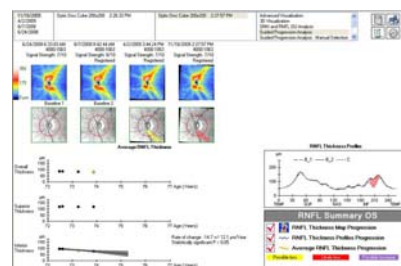


## Importance of scan placement

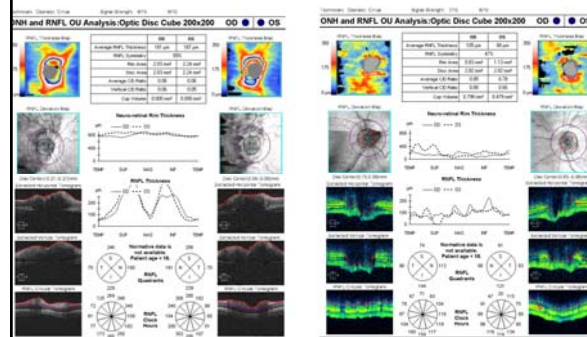- 2 scans of same eye
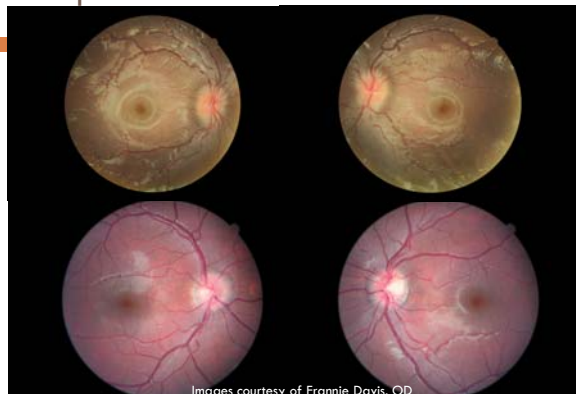- 1st scan is well centered; 2nd scan is not centered
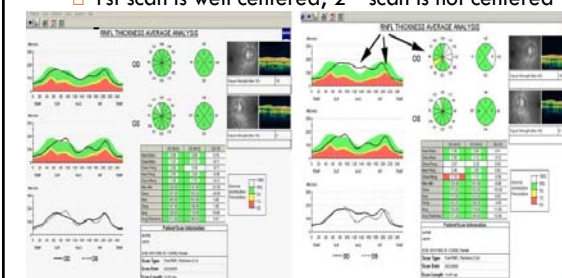
## Function vs. Structure
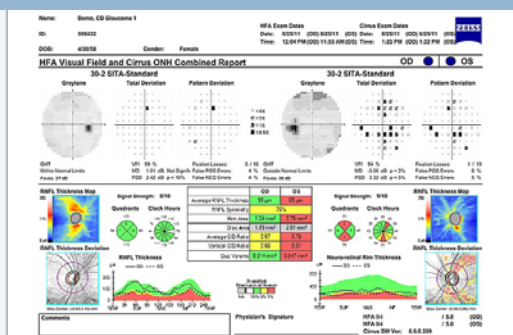


## Guided progression analysis



## Papilledema vs. ONH drusen



Images courtesy of Frannie Davis, OD



Images courtesy of Frannie Davis, OD

## Anterior Segment Imaging

## Anterior Segment OCT

- Tear height
- Pachymetry
- LASIK
- Corneal disease
- Custom design and evaluation of specialty contact lenses
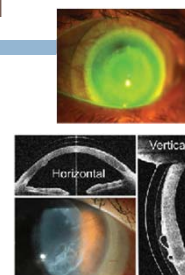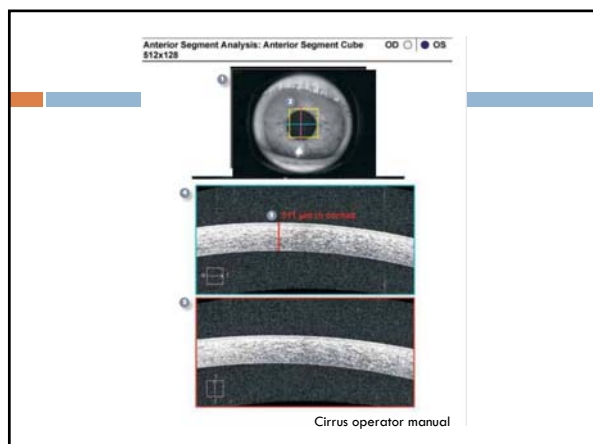- IOL/implant imaging
- Anterior chamber depth, angles
  - Glaucoma



Image from: Baldwin, Moyer Review of Cornea & Contact Lenses 2012
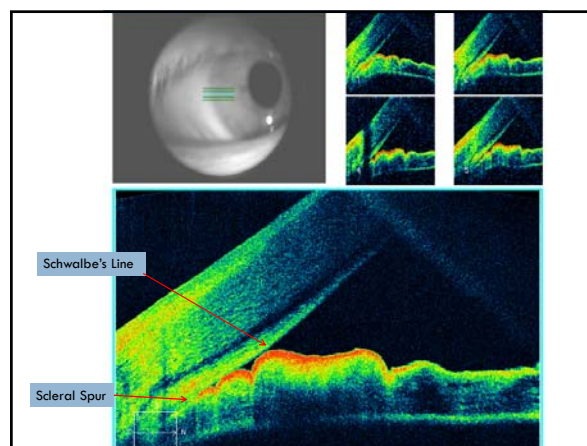
Cirrus operator manual

## CASE EXAMPLE

- 23 year old Optometry Student
- Ocular history:
  - Suspected latent hyperope
  - Reports a headache after dilation
  - Gets dilated 1-2 times per week !!
- VH angles— 1:1/8 or less
- IOP-16/17





Temporal Angle--

Gonio: Ant TM
OCT: SS

Schwalbe's Line

Scleral Spur
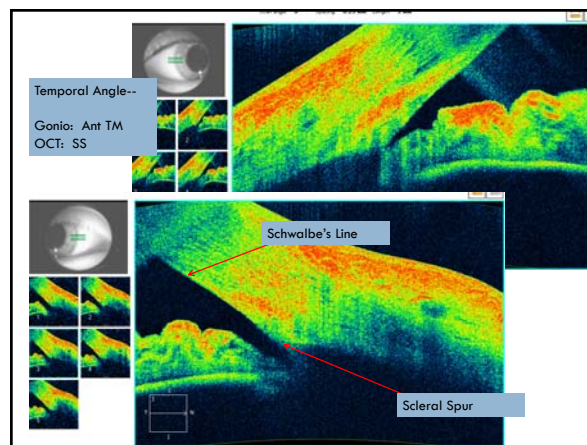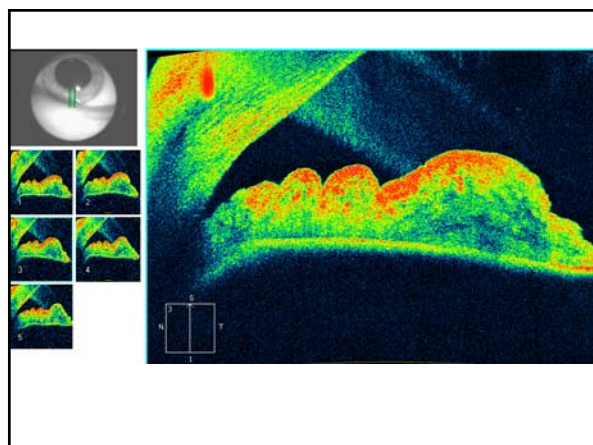
## Case Example #2

- 29 WF, lab tech
- PHx: Turner Syndrome (X)
- FHx: Father melanoma
- Hyperope
- Steady increase in IOPs over last 6 years—11 to 13 to 18 to 21mmHg
- Narrow angles with vH (1:1/4 to 1/8)
- Longstanding Hx large choroidal nevus



Schwalbe's Line

Scleral Spur

**High Definition Images: Anterior Segment 5 Line Raster**
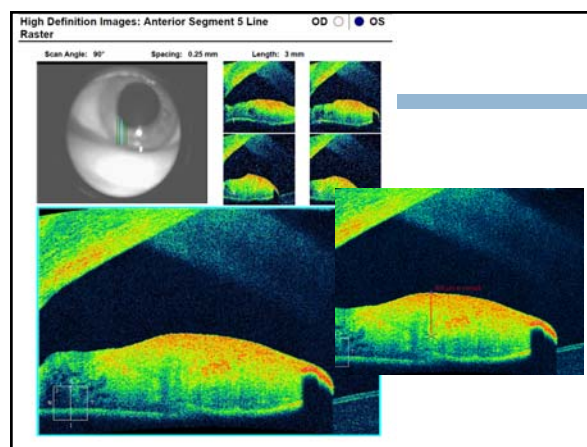
Scan Angle: 0°  Spacing: 0.25 mm  Length: 3 mm

Temporal Angle--

Gonio: SL
OCT: Ant TM

Schwalbe's Line

Scleral Spur
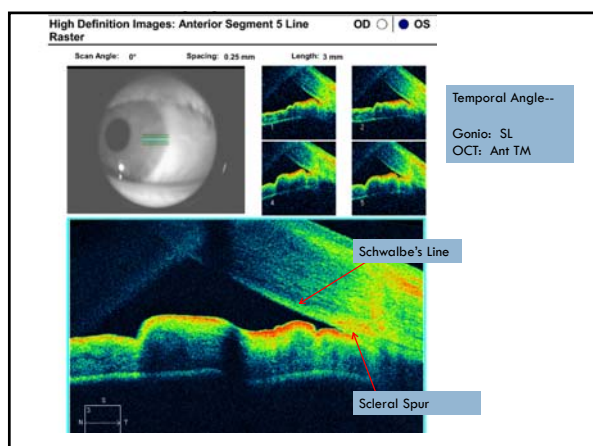
## Angle to Angle Viewing



## Iris Melanoma

- 56 YO Caucasian Female
- Routine eye exam
- Pupil distortion
- (-)iris transillumination
- IOP: 17/16
- 3-Mirror angle and retinal exam: clear



**High Definition Images: Anterior Segment 5 Line Raster**

Scan Angle: 90°  Spacing: 0.25 mm  Length: 3 mm



## Tips and Tricks

- Signal strength score is not the same as a scan quality score
  - Make sure image is centered with no missing or weak signal areas
- Know your targets to help you better direct the patient
- Dilation greatly improves the quality of the scan
- Good idea to have artificial tears nearby in case dry eye is contributing to a poor quality scan
- Remind patient to keep eyes open wide between blinks
- In cases of poor central vision in the eye being tested, the external fixation wand can be used for the other eye
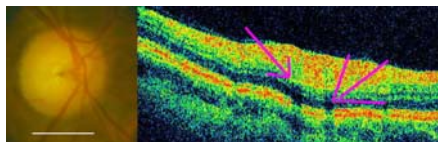
## Artifacts…watch for the unusual

- Anomalies in the scan that are not actual physical structures, but instead due to an external agent or action
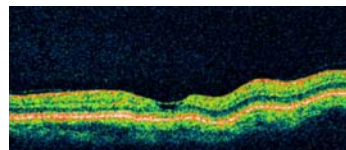- Examples:
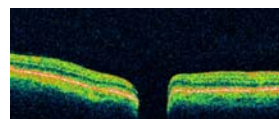


Patient blinked during scan acquisition
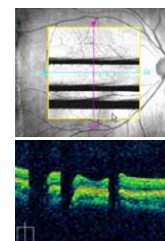
## Shadows



blood vessels casting a shadow



"Waves" in retinal contour = eye movement

## What if the scan isn't "perfect"?

- Decentration
- Media opacities
- Lower signal strength/lower quality image
- Blinks/shifts in gaze
- Artifacts

.............THE SCAN MAY STILL BE <u>USEFUL</u>!!

## Insurance/Billing

- Bilateral codes
  - Anterior 92132
  - ONH 92133
  - Retina 92134
- Generally cannot perform same day as fundus photography or as each other
- Check with local carrier for frequency
- Wide variety ICD-10 codes accepted

## Helpful Resources

Thank you!