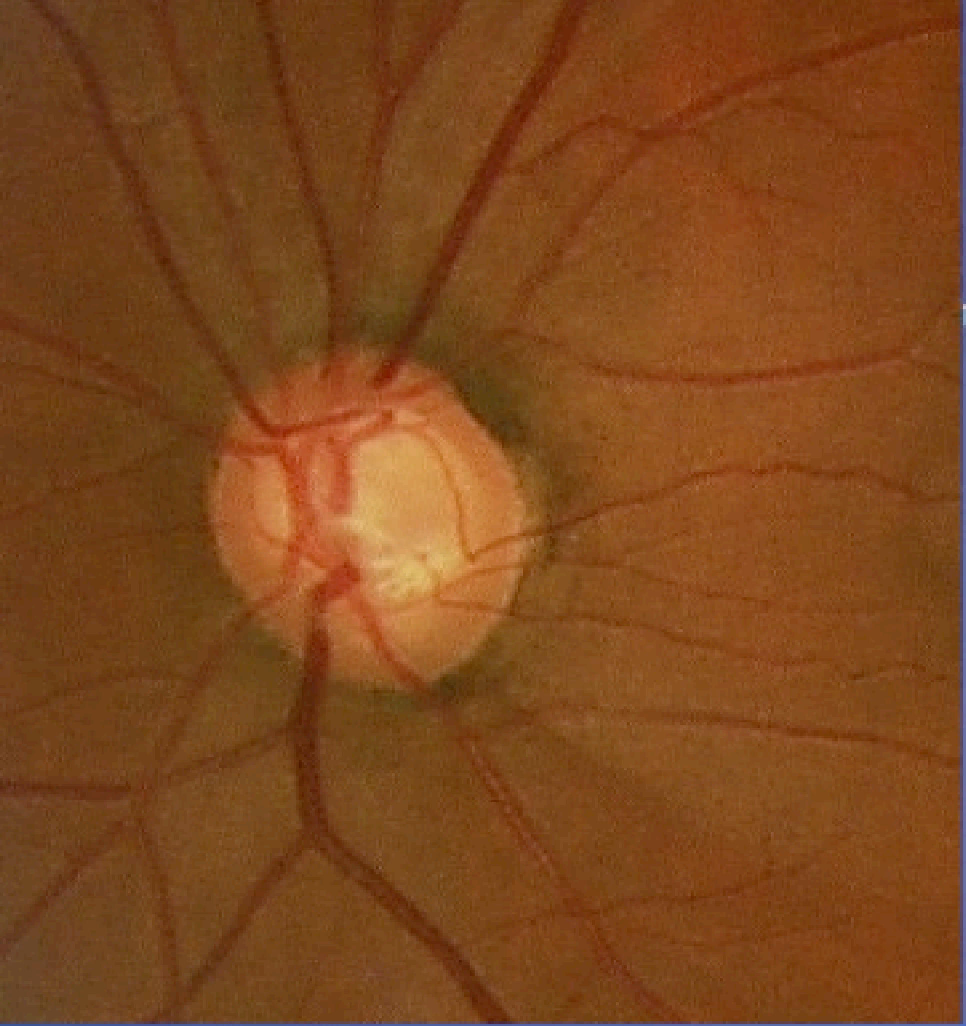


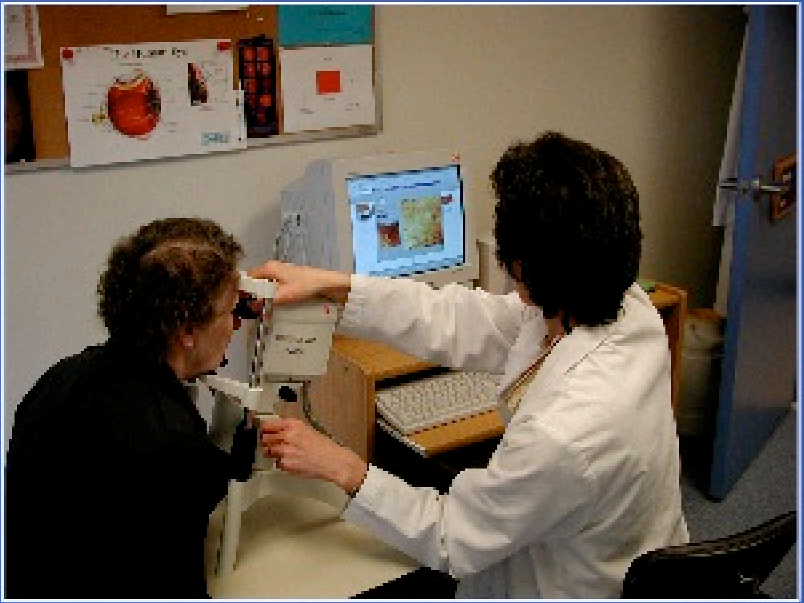
Imaging in Glaucoma

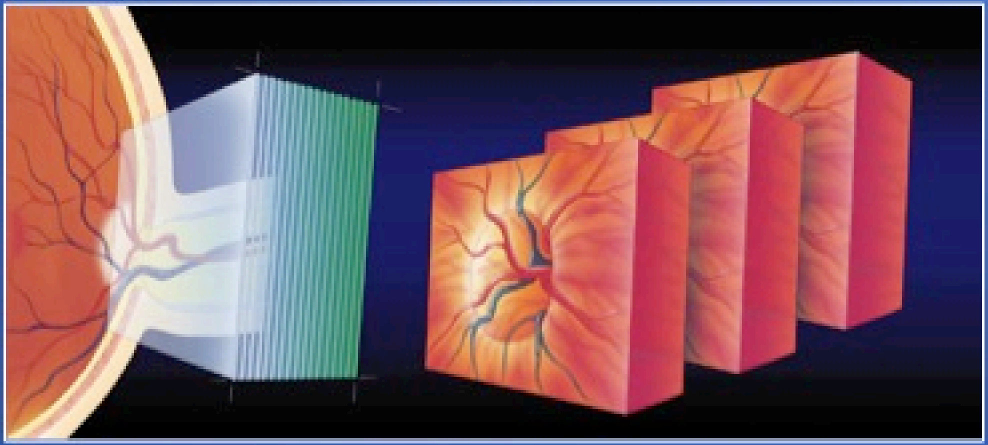
Disc photography, HRT, OCT, GDx, RTA

Shawn Cohen, MD

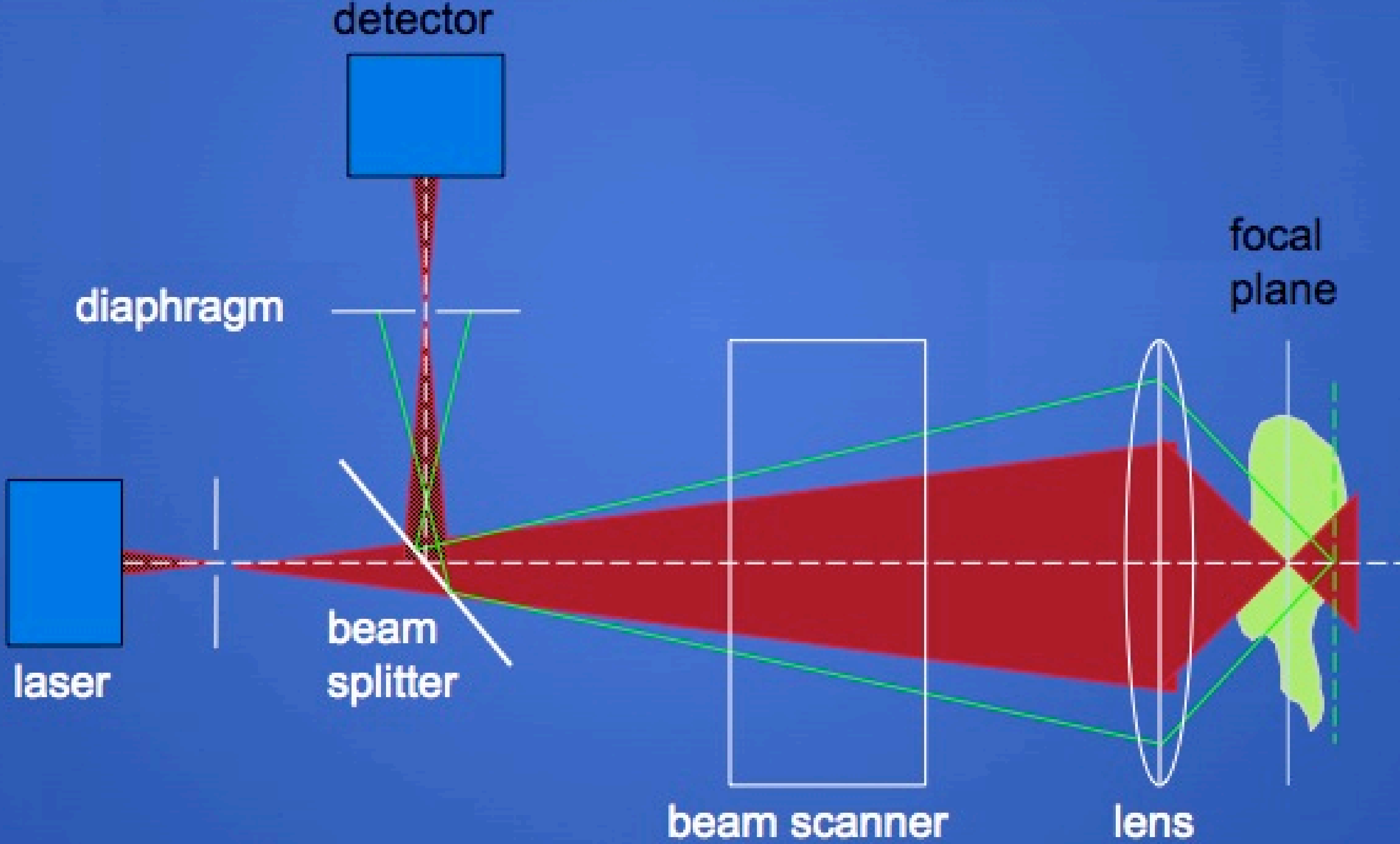
HRT

- Heidelberg Retina Tomograph
- Anterior-Posterior scans
- Reference plane: Future F/U

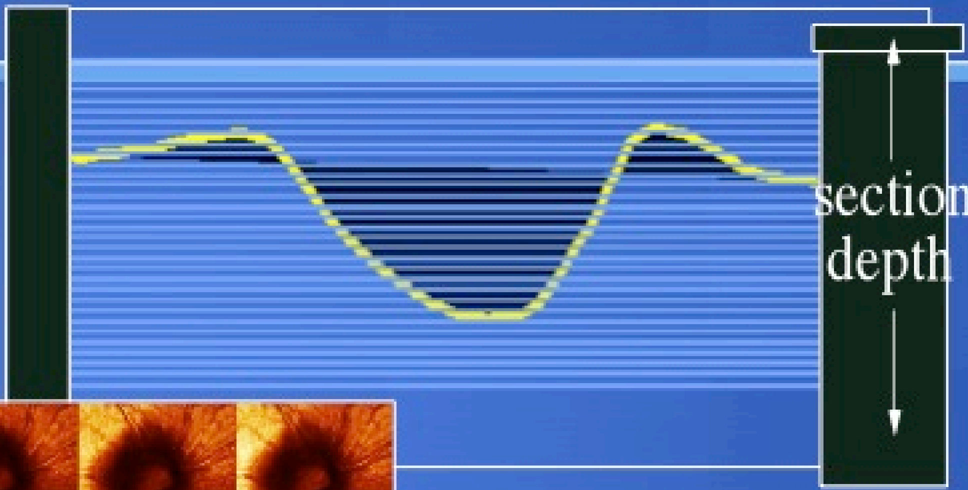


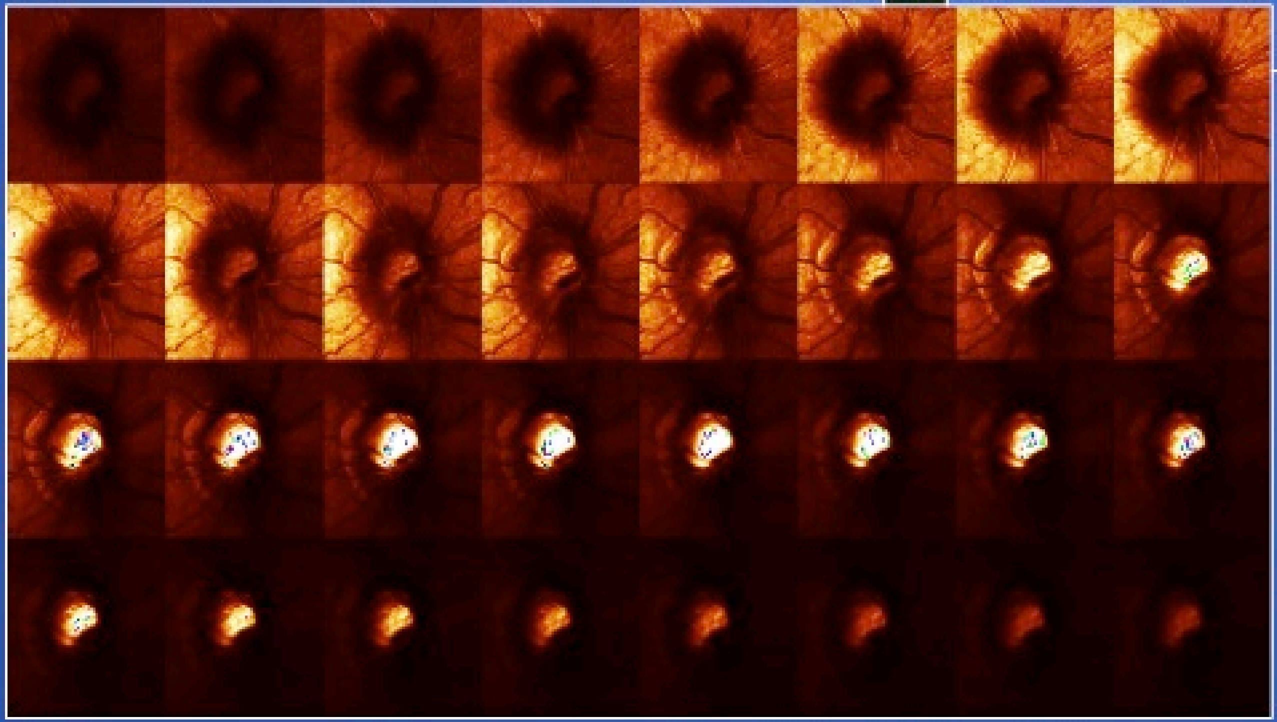


HRT Confocal imaging:
focal plane of laser and detector are conjugate



Confocal sections



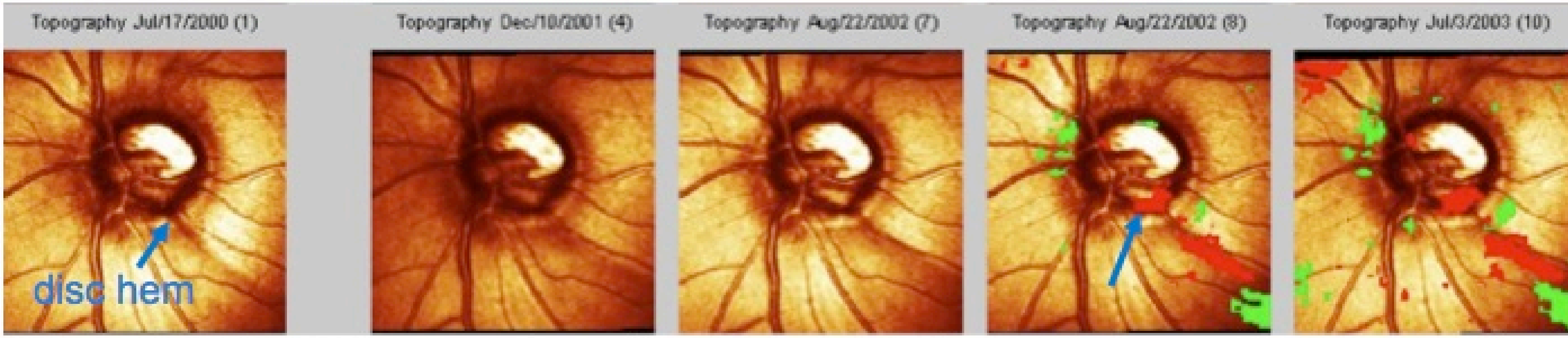


Confocal section images

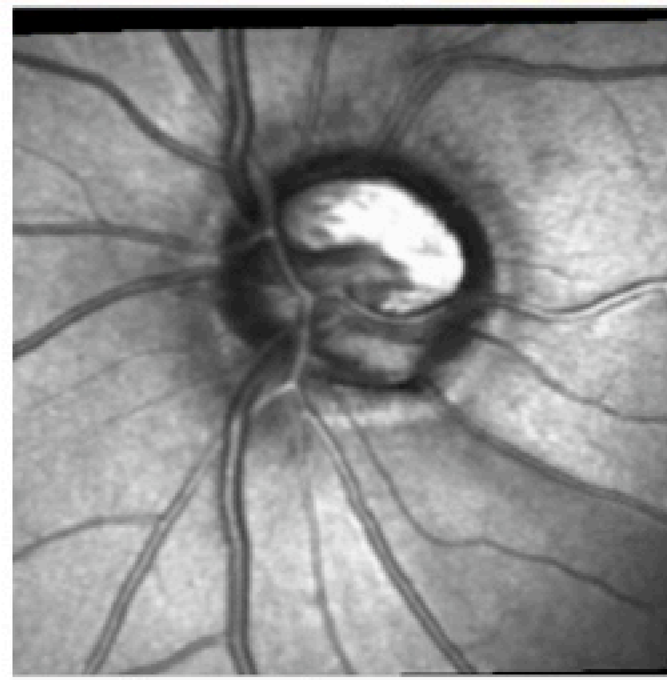
Topography image

Reflectivity image

Progression after disc hemorrhage



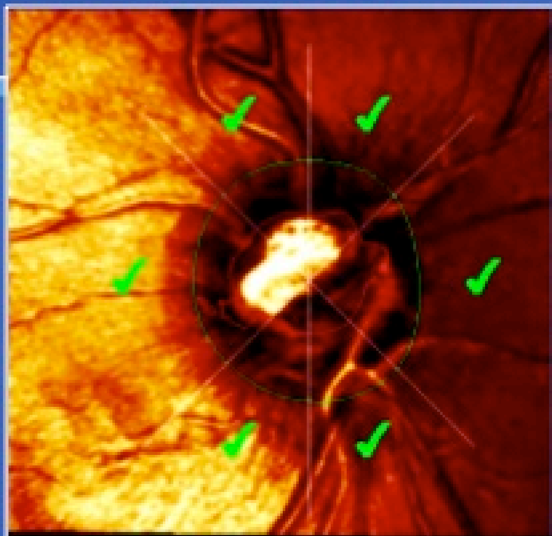
aselirte

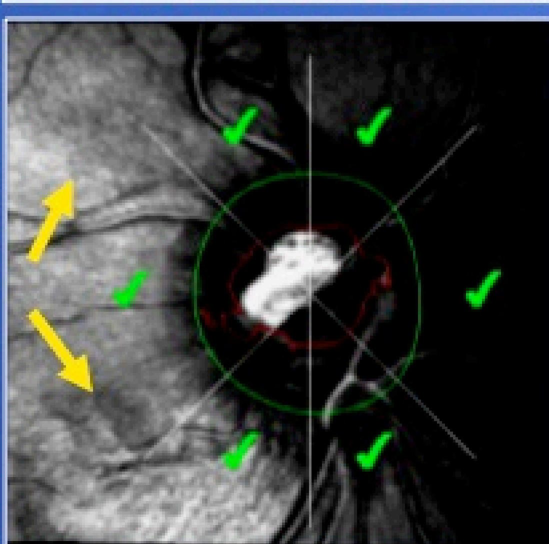


follow-up (3 years)

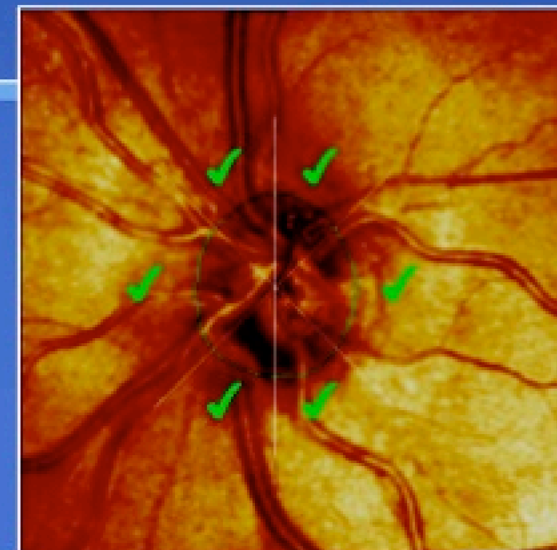
SLT and RNFL

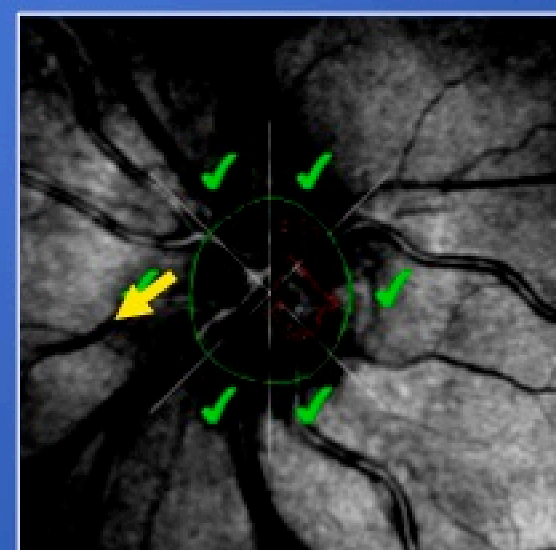
IM,
42 yrs



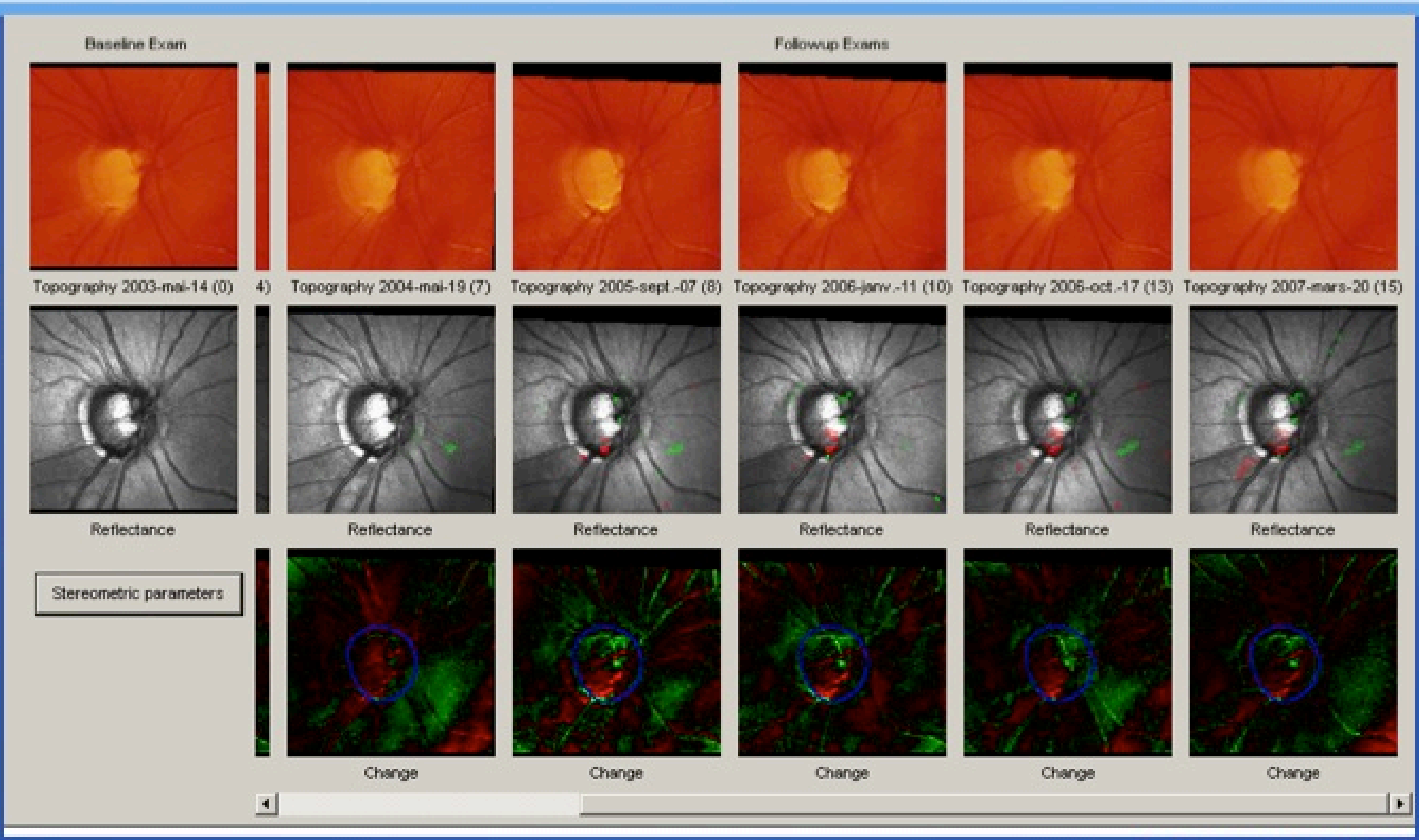


DS,
48 yrs



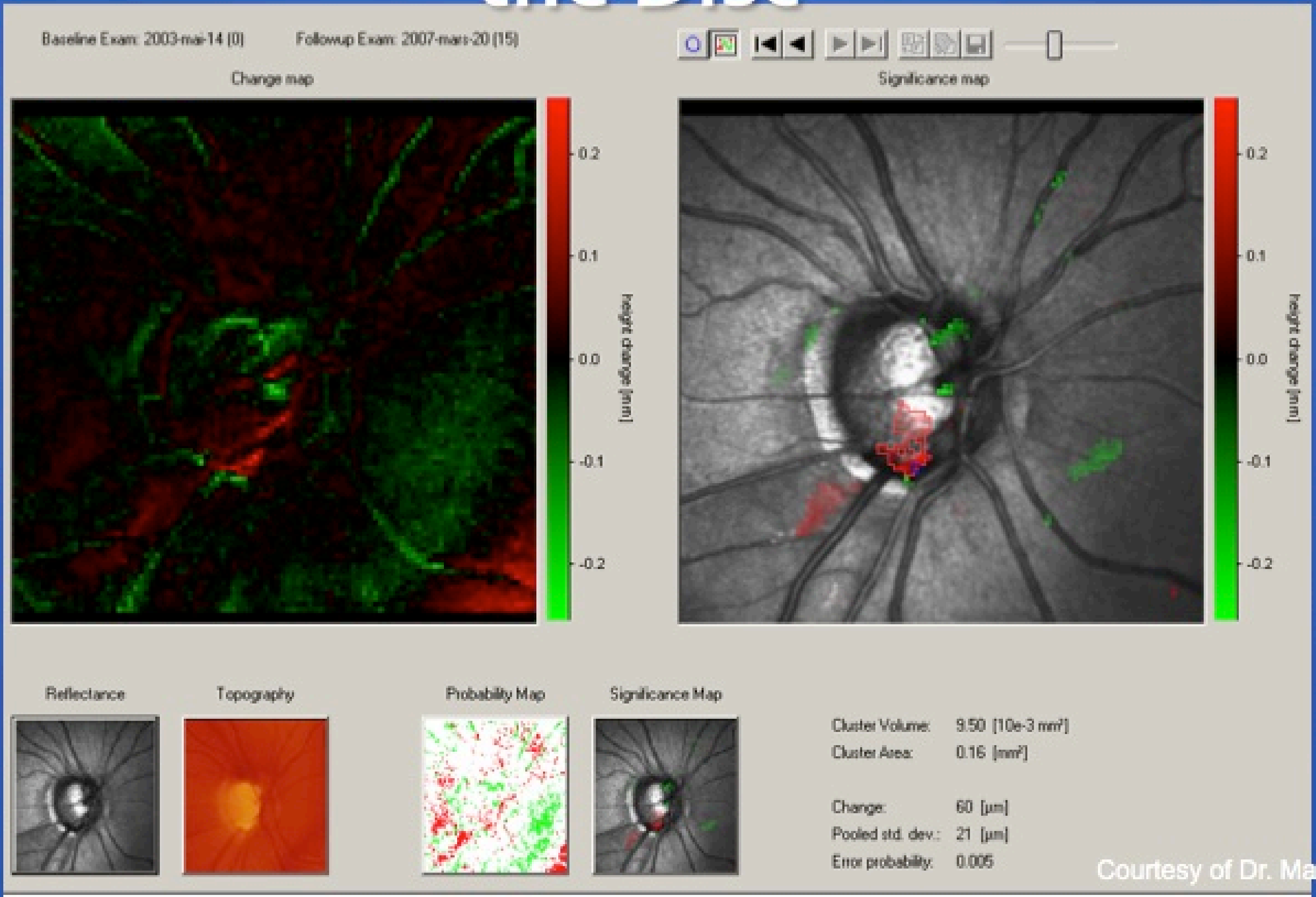


HRT Confirms Disc Progression



Courtesy of Dr. Mark Lesk

HRT Cluster Analysis Shows Extent of Reproducible Change of the Disc



Courtesy of Dr. Mark Lesk

HRT

- Strengths
  - Stable technology
  - Low variability
  - Relationship to function and morphology
  - Clinically validated and accessible
- Weaknesses
  - Cost
  - Evolving algorithms?

Heidelberg Retina Tomograph II
Initial Report

HEIDELBERG ENGINEERING

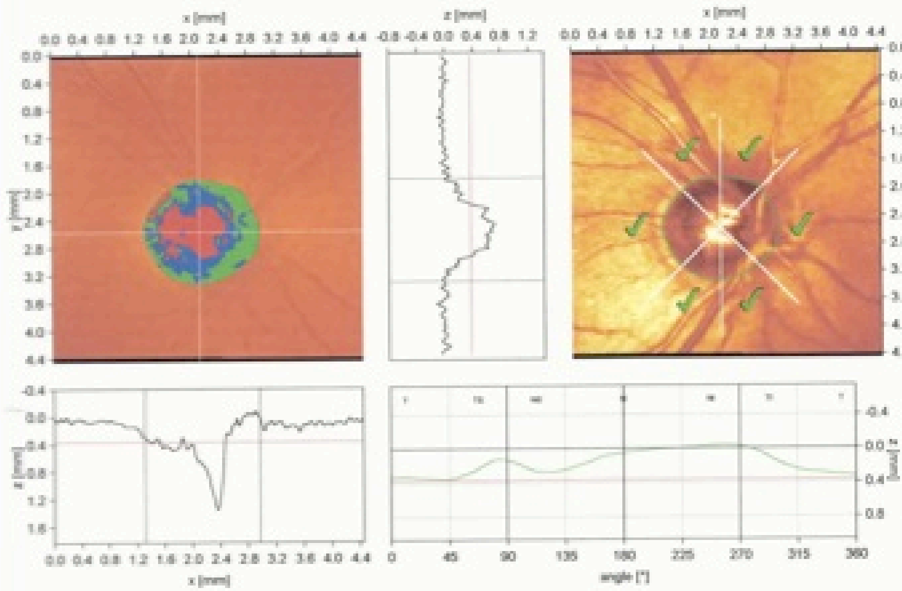
Patient: [redacted]

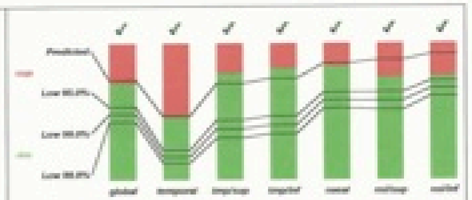
Sex: male DOB: Nov/ 7/1933 Pat-ID: ---

OD

Examination: Date: Apr/ 5/2002

Scan: Focus: -2.00 dpt Depth: 3.50 mm Operator: TRACY





Stereometric Analysis ONH	
Disk Area	1.957 mm²
Cup Area	0.566 mm²
Rim Area	1.391 mm²
Cup Volume	0.098 cmm
Rim Volume	0.291 cmm
Cup/Disk Area Ratio	0.289
Linear Cup/Disk Ratio	0.538
Mean Cup Depth	0.190 mm
Maximum Cup Depth	0.713 mm
Cup Shape Measure	-0.256
Height Variation Contour	0.391 mm
Mean RNFL Thickness	0.201 mm
RNFL Cross Sectional Area	0.999 mm²
Reference Height	0.365 mm
Topography Std Dev.	28 µm

Comments: Borderline
no glasses worn

Date: Apr/ 5/2002 Signature:

Classification: Within normal limits (*)

(*) Moorfields regression classification (Ophthalmology 1998;105:1557-1563)
Classification based on statistics. Diagnosis is physician's responsibility.

Heidelberg Retina Tomograph II
Initial Report

HEIDELBERG ENGINEERING

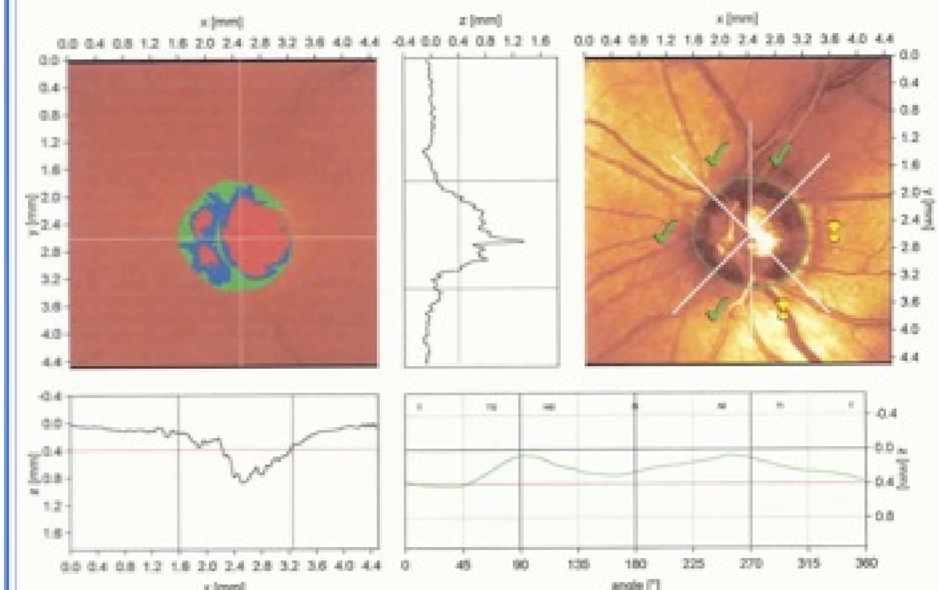
Patient: [redacted]

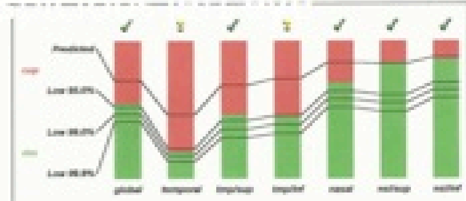
Sex: male DOB: Nov/ 7/1933 Pat-ID: ---

OS

Examination: Date: Apr/ 5/2002

Scan: Focus: -2.00 dpt Depth: 3.50 mm Operator: TRACY





Stereometric Analysis ONH	
Disk Area	2.101 mm²
Cup Area	0.941 mm²
Rim Area	1.160 mm²
Cup Volume	0.184 cmm
Rim Volume	0.267 cmm
Cup/Disk Area Ratio	0.448
Linear Cup/Disk Ratio	0.669
Mean Cup Depth	0.231 mm
Maximum Cup Depth	0.681 mm
Cup Shape Measure	-0.157
Height Variation Contour	0.369 mm
Mean RNFL Thickness	0.163 mm
RNFL Cross Sectional Area	0.840 mm²
Reference Height	0.398 mm
Topography Std Dev.	14 µm

Comments: Borderline
no glasses worn

Date: Apr/ 5/2002 Signature:

Classification: Borderline (*)

(*) Moorfields regression classification (Ophthalmology 1998;105:1557-1563)
Classification based on statistics. Diagnosis is physician's responsibility.

Heidelberg Retina Tomograph II
Follow-Up Report

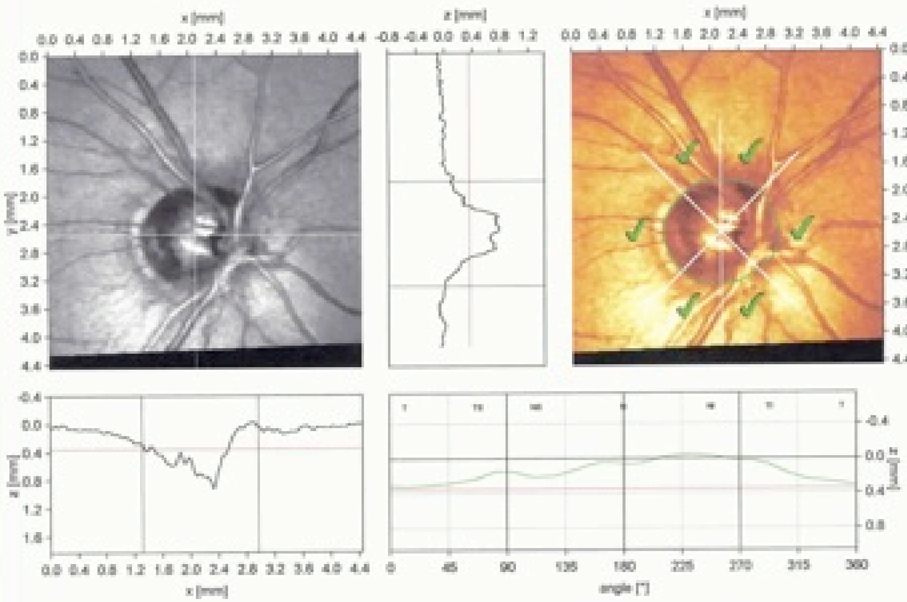
HEIDELBERG ENGINEERING

Patient:
Sex: male DOB: Nov/ 7/1933 Pat-ID: ---

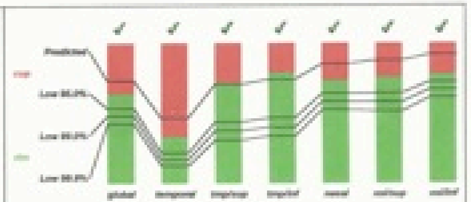
OD

Examination: Baseline: Apr/ 5/2002 **FollowUp: Apr/ 5/2002** Time elapsed: 0 months

Scan: Focus: -3.00 dpt Depth: 2.75 mm Operator: TRACY



Stereometric Analysis ONH		Change	
Disk Area	1.957	0.000	mm²
Cup Area	0.698	0.132	mm²
Rim Area	1.259	-0.132	mm²
Cup Volume	0.135	0.039	cmm
Rim Volume	0.257	-0.034	cmm
Cup/Disk Area Ratio	0.357	0.068	
Linear Cup/Disk Ratio	0.597	0.059	
Mean Cup Depth	0.227	0.037	mm
Maximum Cup Depth	0.679	-0.034	mm
Cup Shape Measure	-0.185	0.071	
Height Variation Contour	0.369	-0.022	mm
Mean RNFL Thickness	0.206	0.005	mm
RNFL Cross Sectional Area	1.023	0.024	mm²
Reference Height	0.352	-0.013	mm
Topography Std Dev.	10		µm



Comments:

Date: Jul/ 5/2002 Signature:

Classification: Within normal limits (*)

(*) Moorfields regression classification (Ophthalmology 1998;105:1557-1563)
Classification based on statistics. Diagnosis is physician's responsibility.

Heidelberg Retina Tomograph II
Follow-Up Report

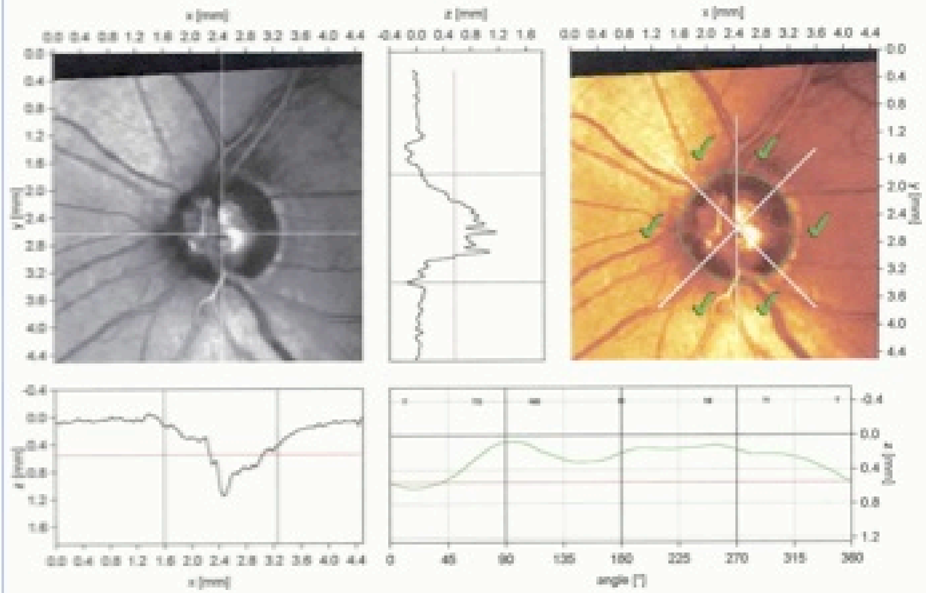
HEIDELBERG ENGINEERING

Patient:
Sex: male DOB: Nov/ 7/1933 Pat-ID: ---

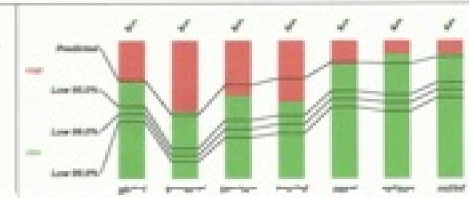
OS

Examination: Baseline: Apr/ 5/2002 **FollowUp: Apr/ 5/2002** Time elapsed: 0 months

Scan: Focus: -2.00 dpt Depth: 3.00 mm Operator: TRACY



Stereometric Analysis ONH		Change	
Disk Area	2.101	0.000	mm²
Cup Area	0.626	-0.315	mm²
Rim Area	1.475	0.315	mm²
Cup Volume	0.107	-0.077	cmm
Rim Volume	0.370	0.163	cmm
Cup/Disk Area Ratio	0.298	-0.150	
Linear Cup/Disk Ratio	0.546	-0.123	
Mean Cup Depth	0.247	0.016	mm
Maximum Cup Depth	0.880	-0.001	mm
Cup Shape Measure	-0.137	0.020	
Height Variation Contour	0.544	0.175	mm
Mean RNFL Thickness	0.277	0.114	mm
RNFL Cross Sectional Area	1.426	0.586	mm²
Reference Height	0.550	0.154	mm
Topography Std Dev.	14		µm



Comments:

[illegible] 5/2002 Signature:

Classification: Within normal limits (*)

(*) Moorfields regression classification (Ophthalmology 1998;105:1557-1563)
Classification based on statistics. Diagnosis is physician's responsibility.

OCT: Michelson Interferometer

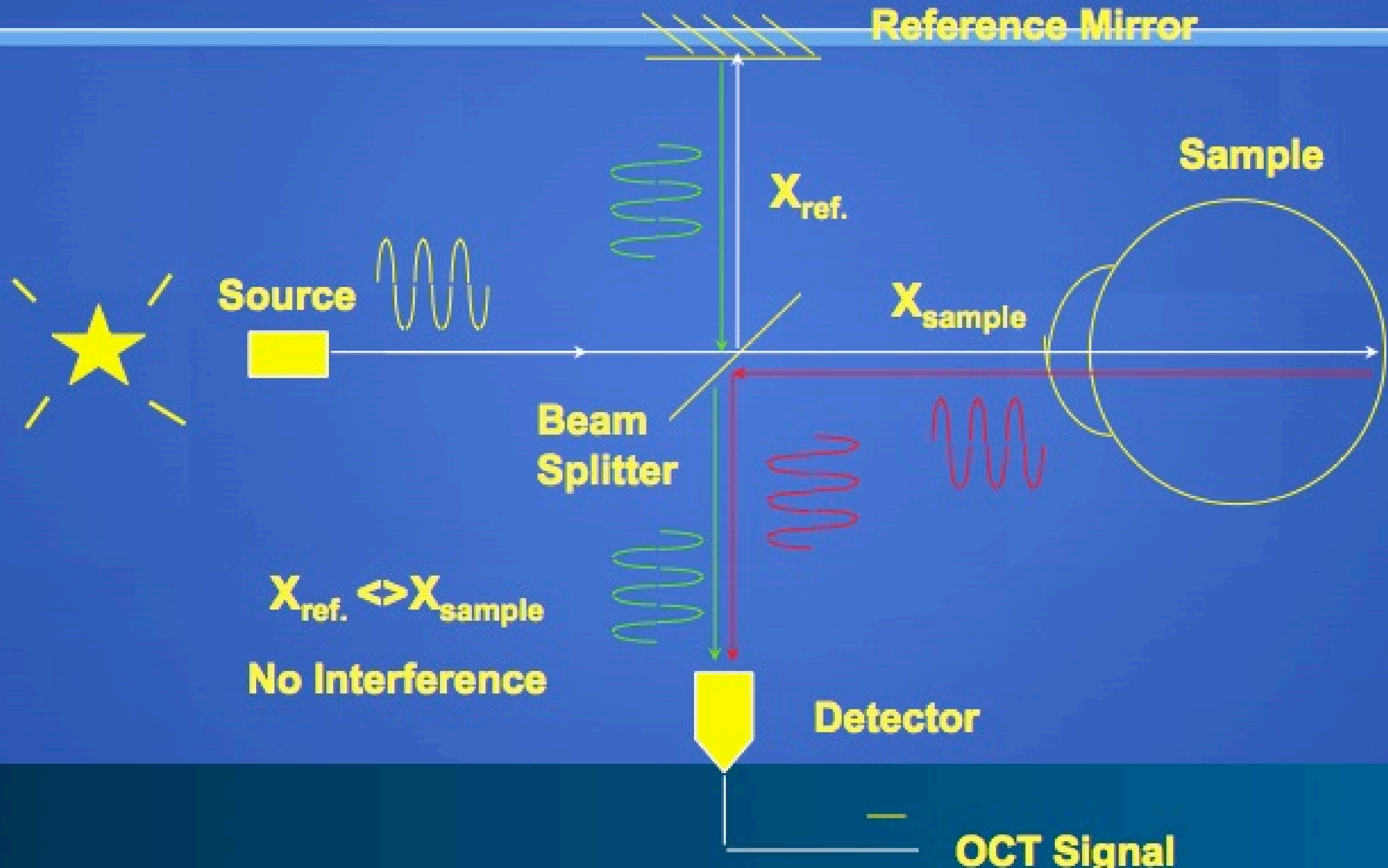
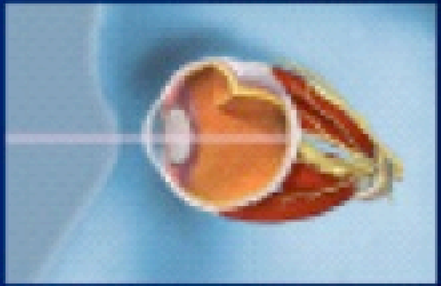
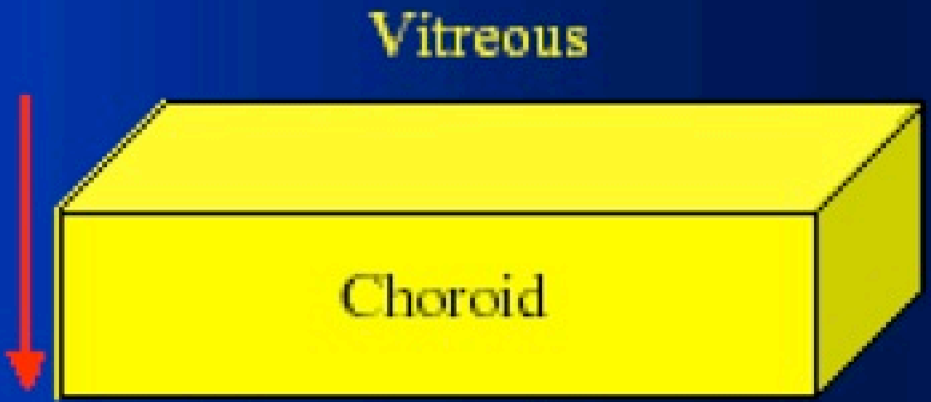


Image Formation

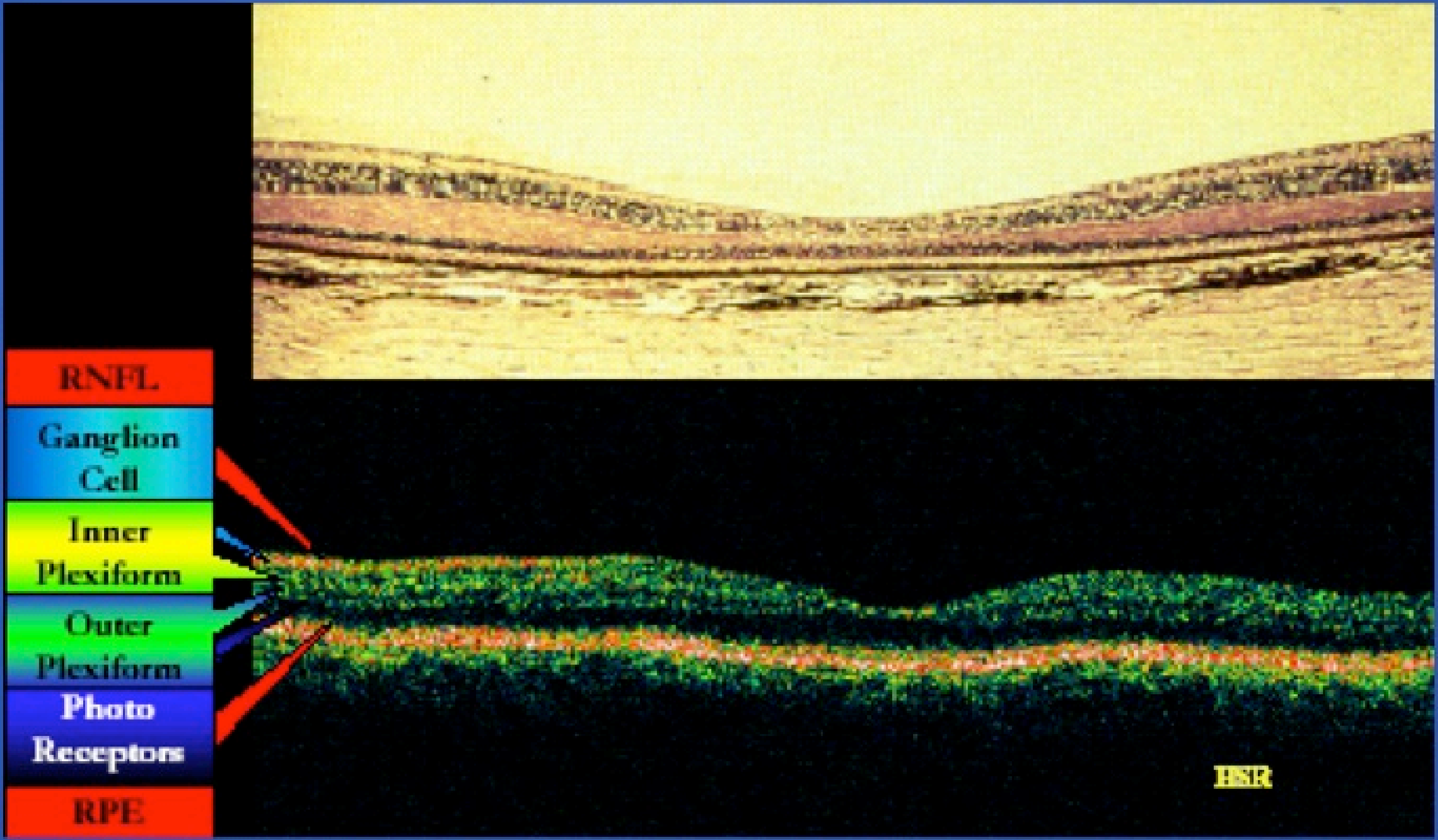


- Z axis samples tissue with 1024 datapoints over a 2 mm depth

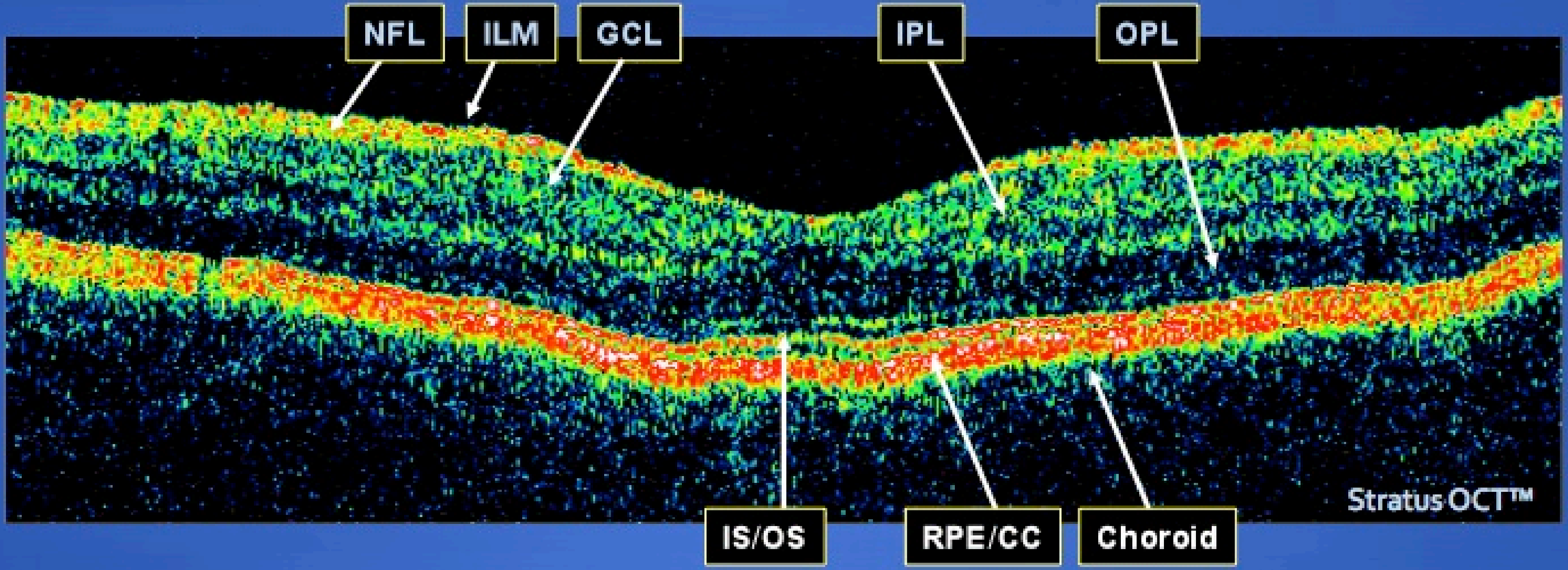


- X-Y axis takes a sample of tissue every 5-60 microns using up to 512 datapoints

Retinal Histology / OCT



Identification of Retinal Layers



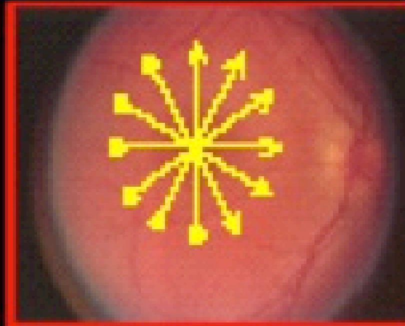
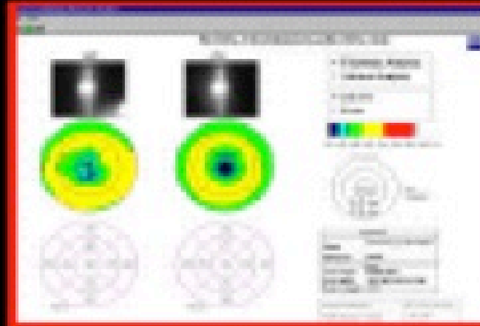
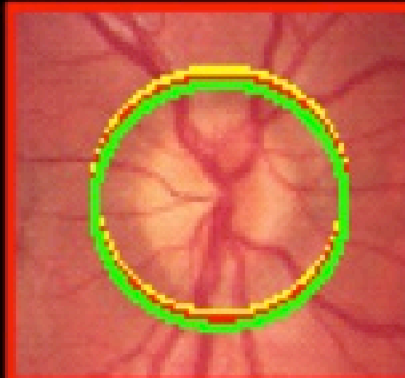
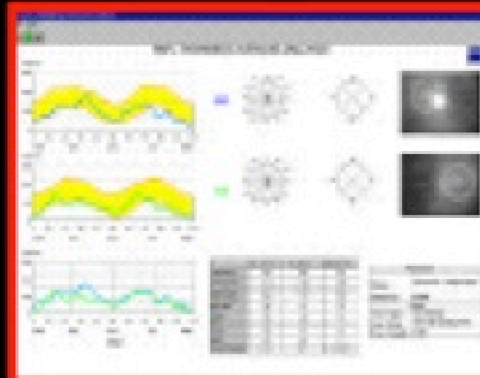
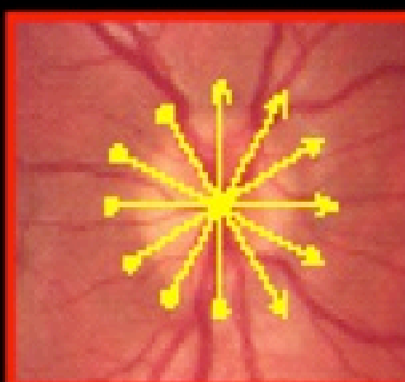
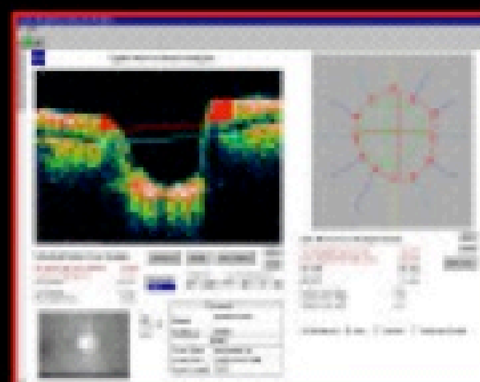
NFL: Nerve Fiber Layer
ILM: Inner Limiting Membrane
GCL: Ganglion Cell Layer

IS/OS: Junction of inner and outer photoreceptor segments
RPE: Retinal Pigment Epithelium
CC: Choriocapillaris

IPL: Inner Plexiform Layer
OPL: Outer Plexiform

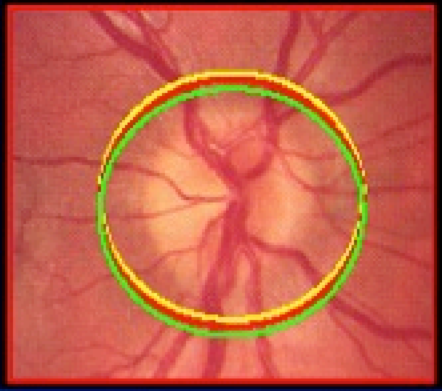
Cross-sectional image of live tissue; a virtual biopsy

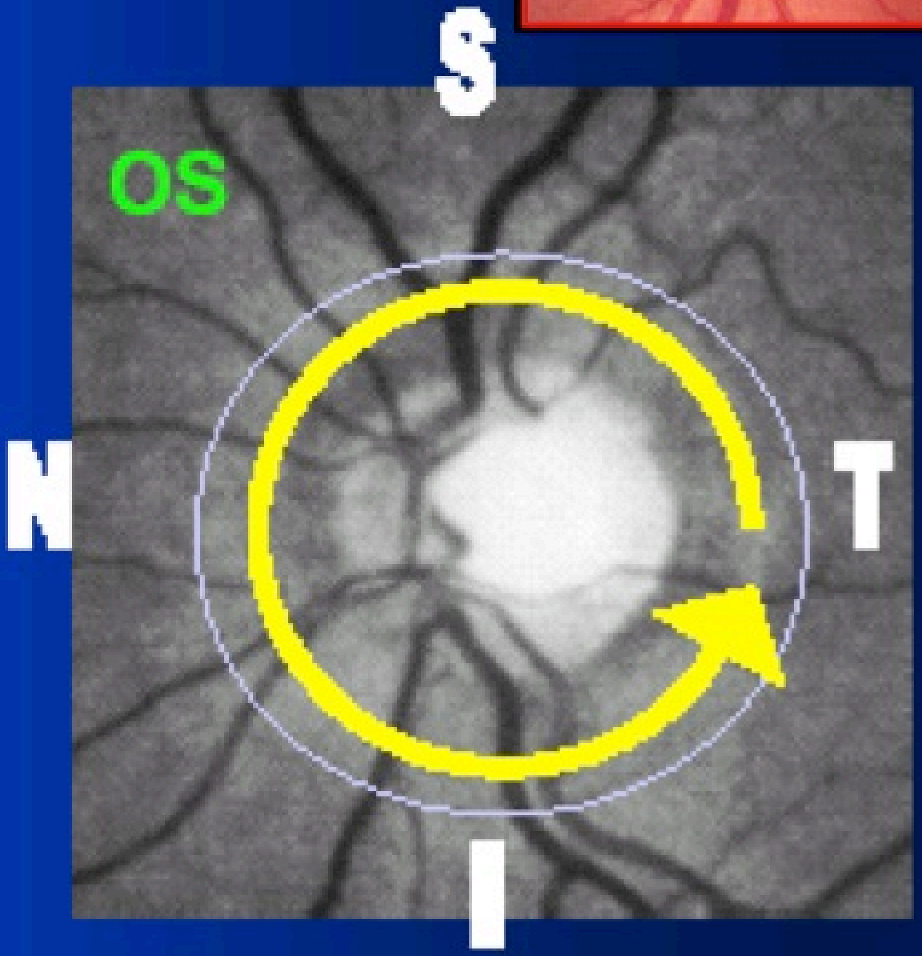
OCT Status Printouts

Macular Analysis (Bilateral)	Acquire (6) 6mm radial line scans		
RNFL Analysis (Bilateral)	Acquire 3 or more 1.73mm radius circle scans		
ONH Disk Topography Analysis (Monocular)	Acquire (6) 4mm Disk Topography line scans		

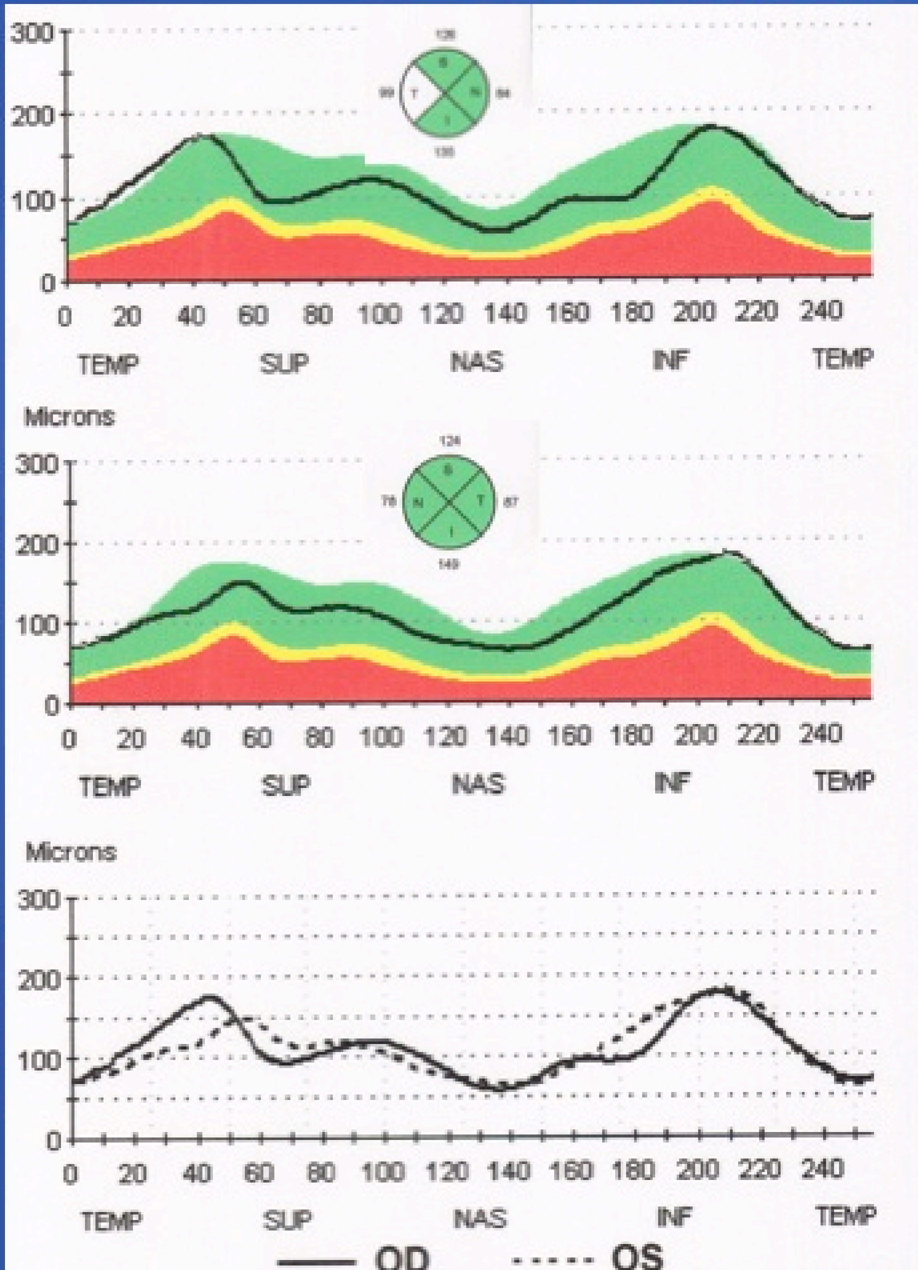
RNFL Analysis

- Circular scans around ONH at a radius of 1. 73mm
- Scan begins temporally
- Three scans are acquired and data is averaged

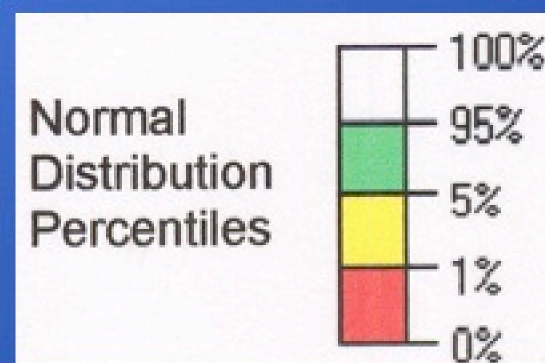




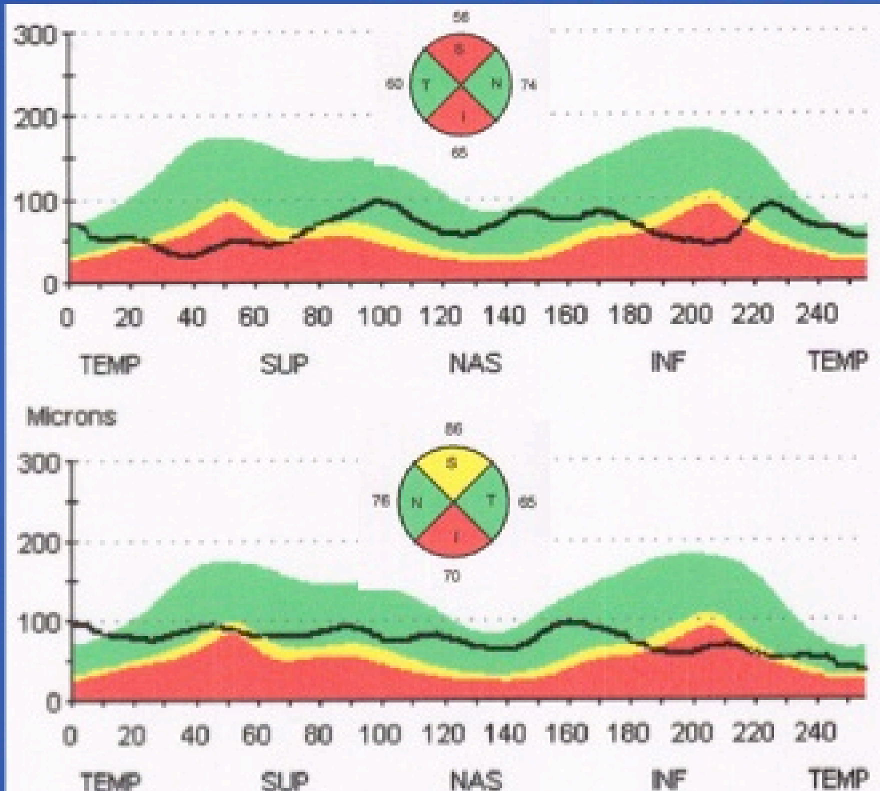
OCT RNFL Thickness Analysis



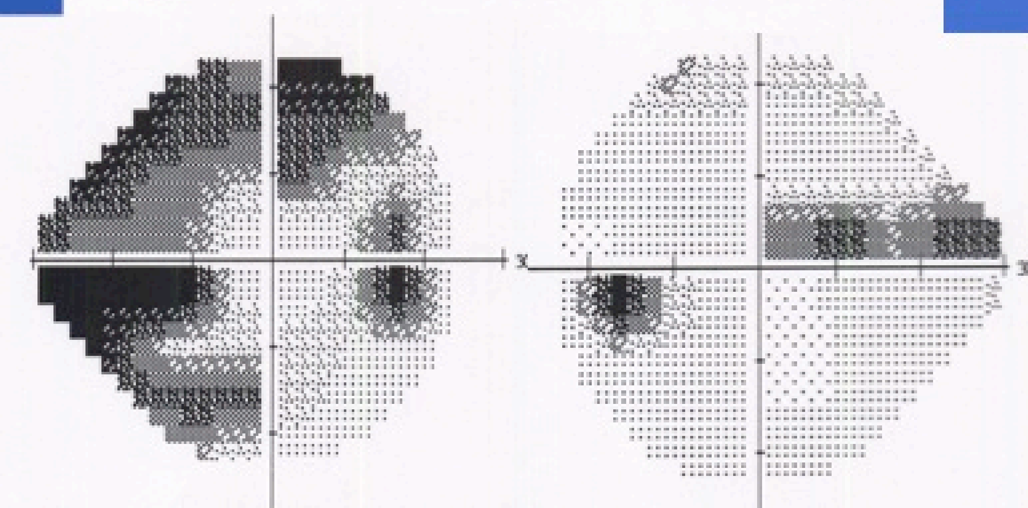
	OD (N=3)	OS (N=3)	OD-OS
Imax/Smax	1.02	1.22	-0.20
Smax/Imax	0.98	0.82	0.16
Smax/Tavg	1.77	1.71	0.06
Imax/Tavg	1.80	2.08	-0.28
Smax/Navg	2.08	1.91	0.17
Max-Min	120.00	118.00	2.00
Smax	174.00	149.00	25.00
Imax	178.00	181.00	-3.00
Savg	126.00	124.00	2.00
Iavg	135.00	149.00	-14.00
Avg.Thick	111.02	109.63	1.39

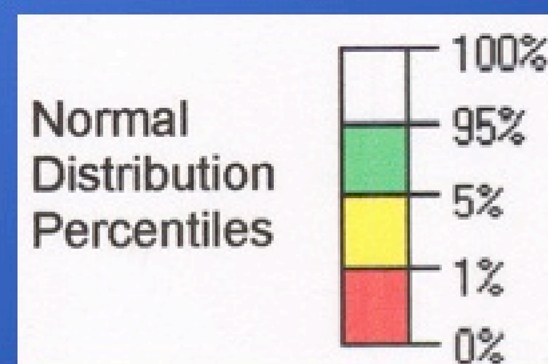


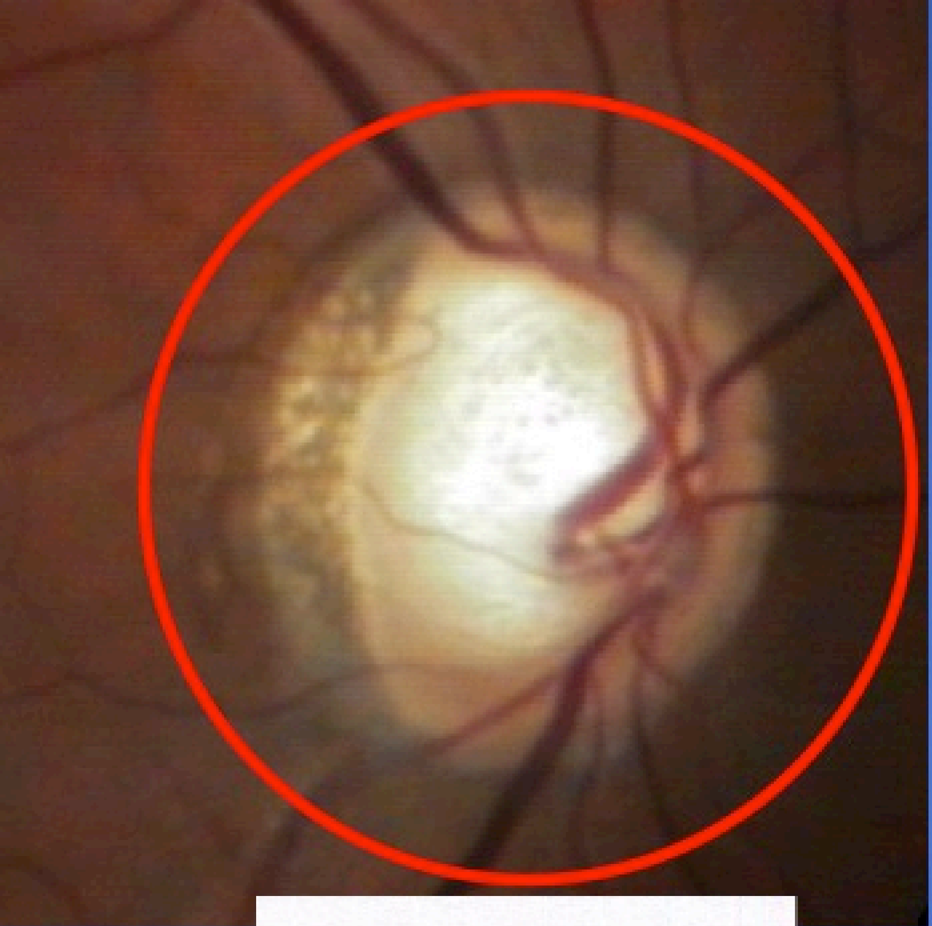
OCT RNFL Thickness Analysis

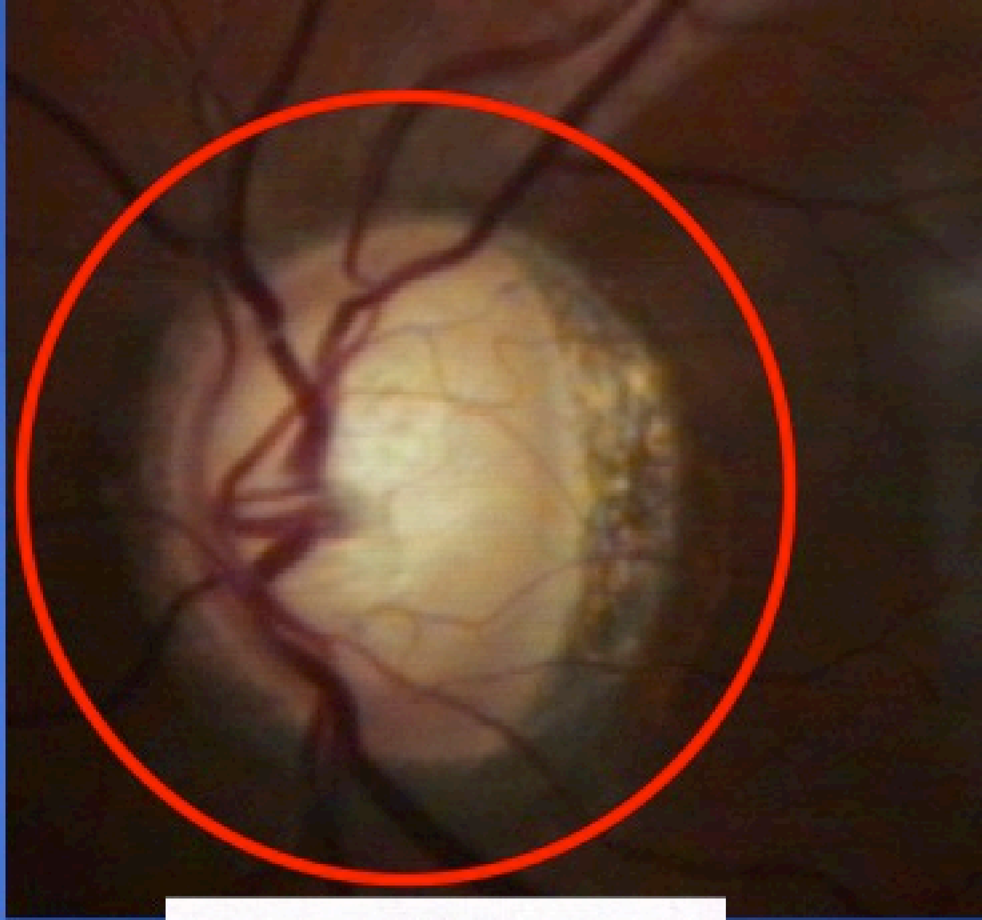


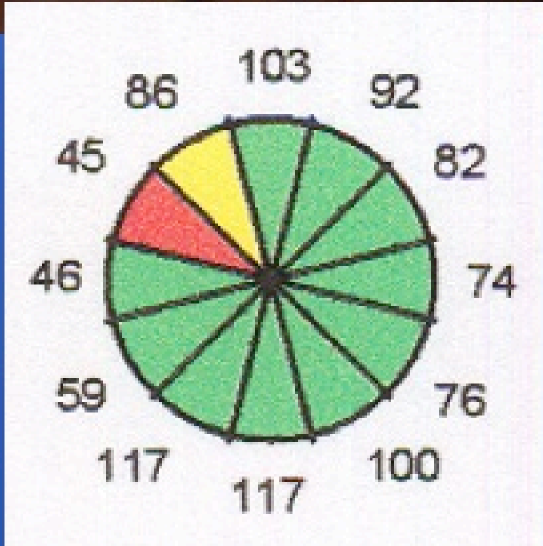
	OD (N=3)	OS (N=3)	OD-OS
Imax/Smax	0.99	1.03	-0.04
Smax/Imax	1.01	0.97	0.04
Smax/Tavg	1.54	1.44	0.10
Imax/Tavg	1.52	1.48	0.04
Smax/Navg	1.25	1.23	0.01
Max-Min	62.00	62.00	0.00
Smax	92.00	94.00	-2.00
Imax	91.00	96.00	-5.00
Savg	56.00	86.00	-30.00
Iavg	65.00	70.00	-5.00
Avg.Thick	63.69	74.04	-10.35

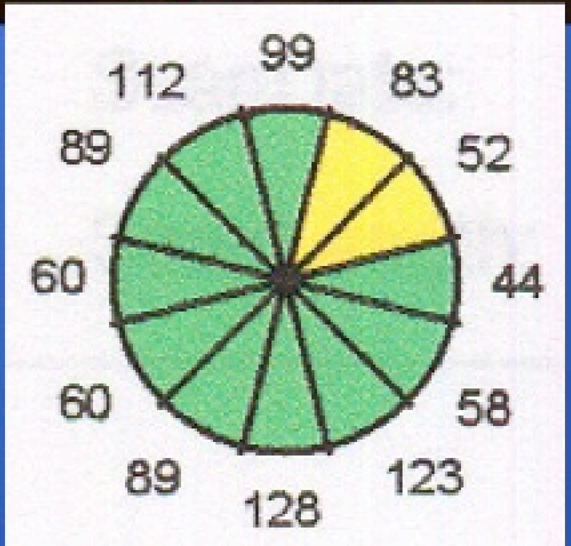




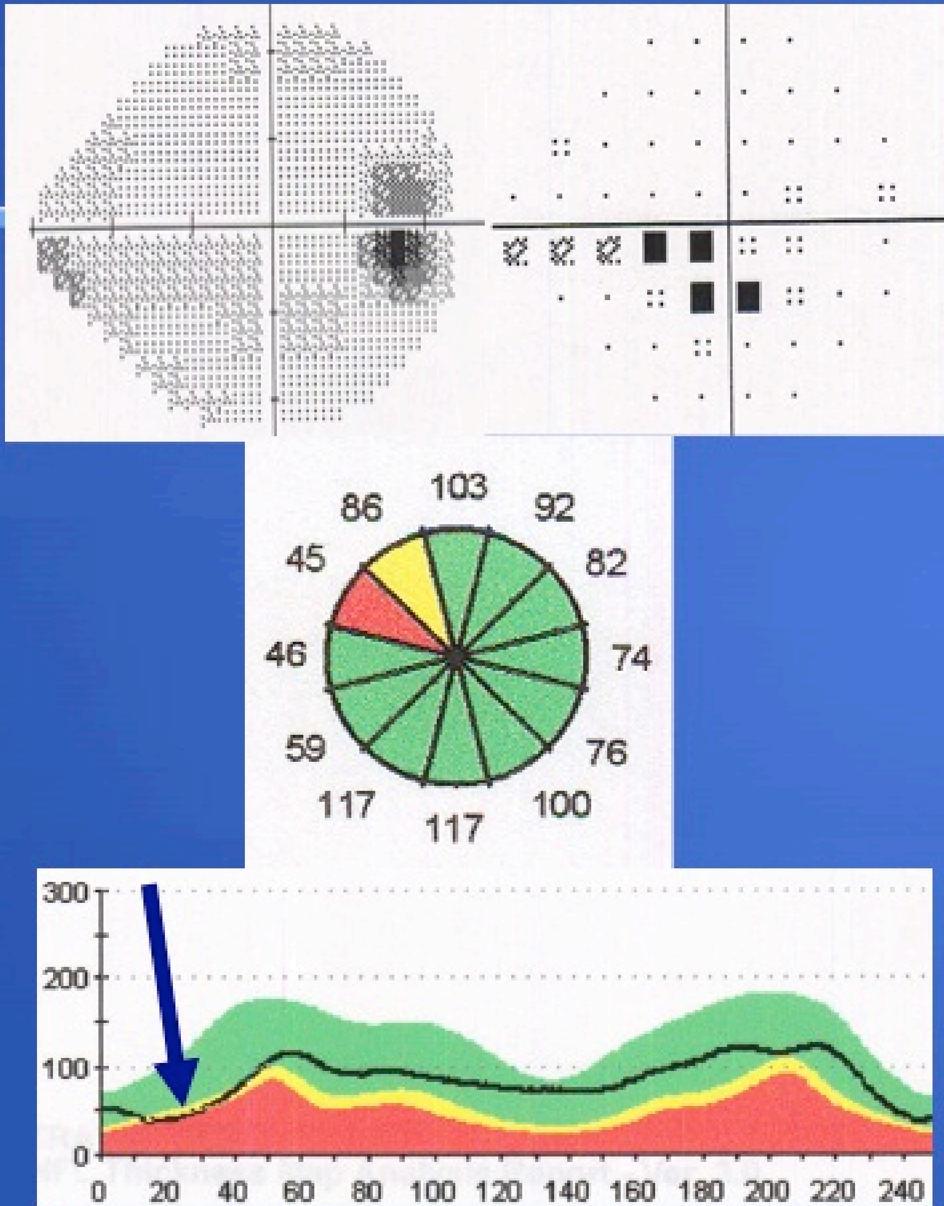




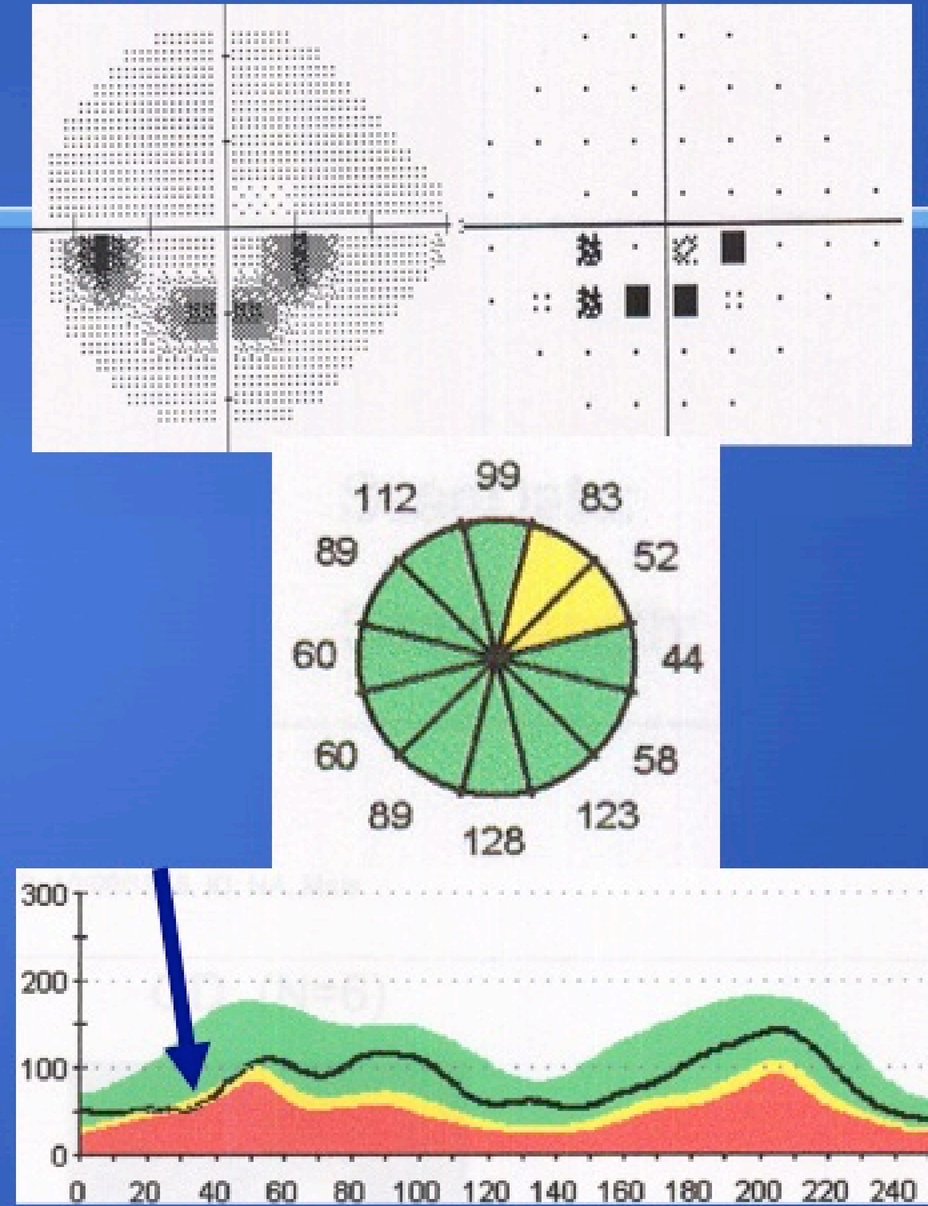

103
92
82
74
76
100
117
117
59
46
45
86


99
83
52
44
58
123
128
89
60
60
89
112

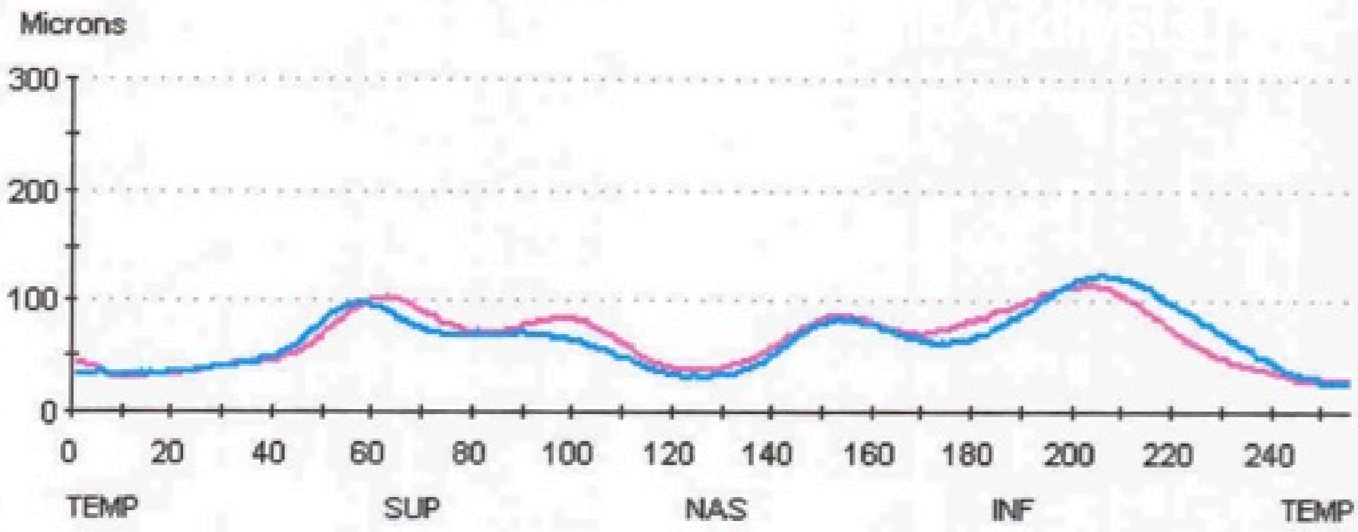
OCT RNFL / Visual Field Correlation



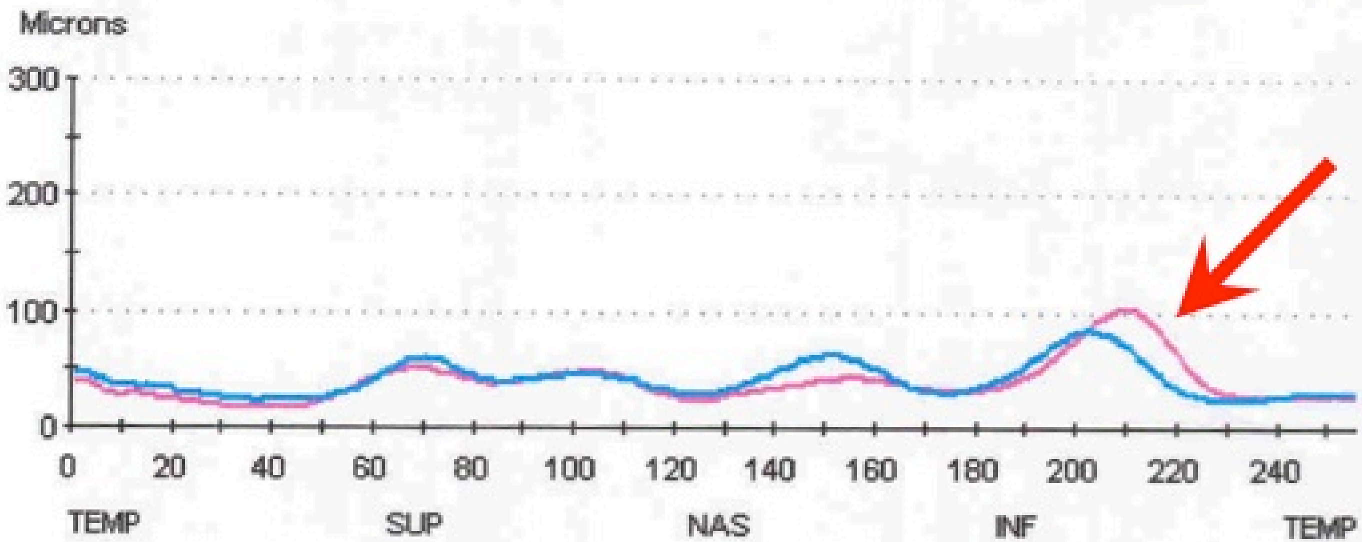
Right Eye



Left Eye



Signal Strength (Max



OCT

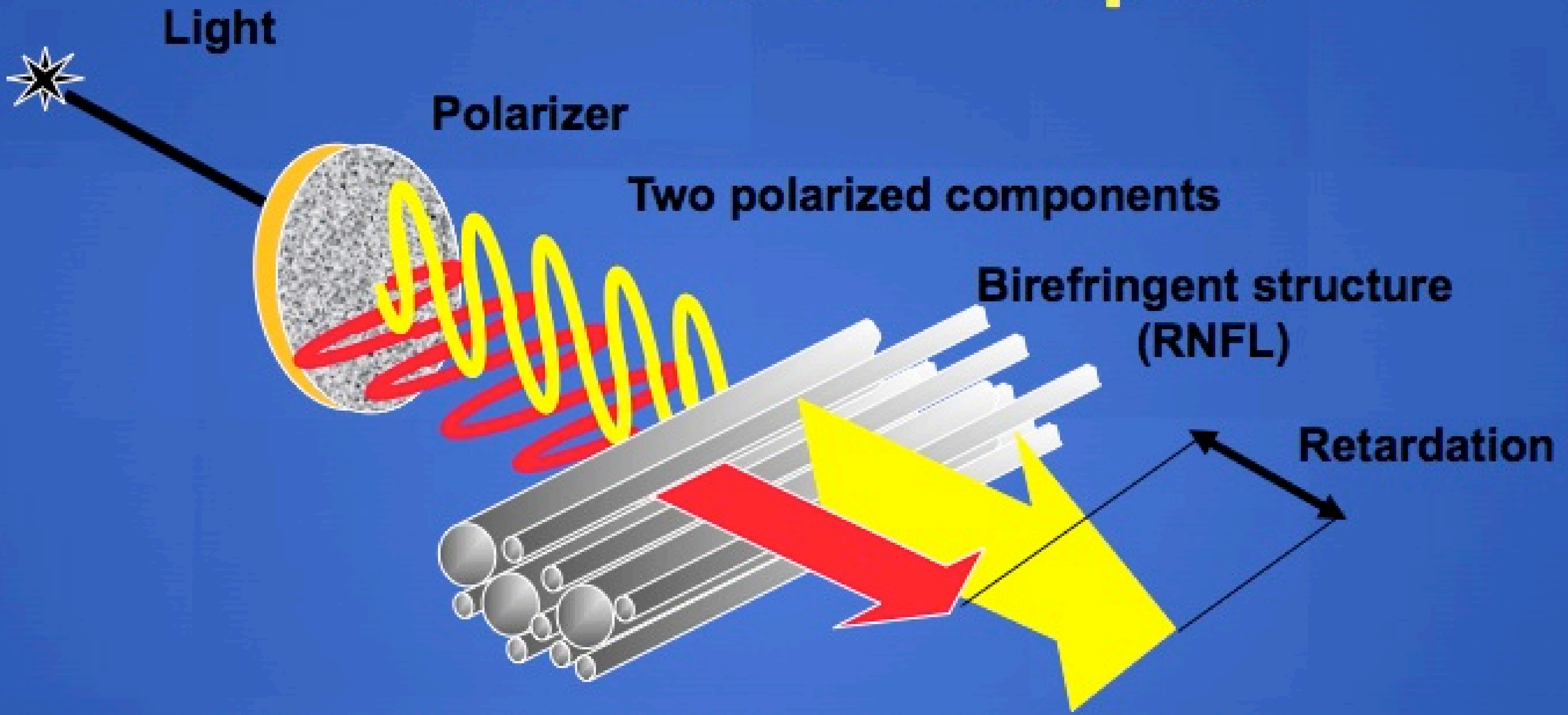
Strengths

- RNFL, disc, and macular assessment
- Exquisite axial resolution
- ONH, RNFL, GC and RNFL complex
- Early defects
  - Very helpful in suspect screening
- No need for contour drawing
- Multiple retina application as well

Weakness

- Poorer transverse resolution
- More technician dependent
- Dense media opacity, small pupil, PPA
- Lack of progression software
- No normative data: macula, ONH
- Artifact with significant peripapillary atrophy

SLP Basic Principles



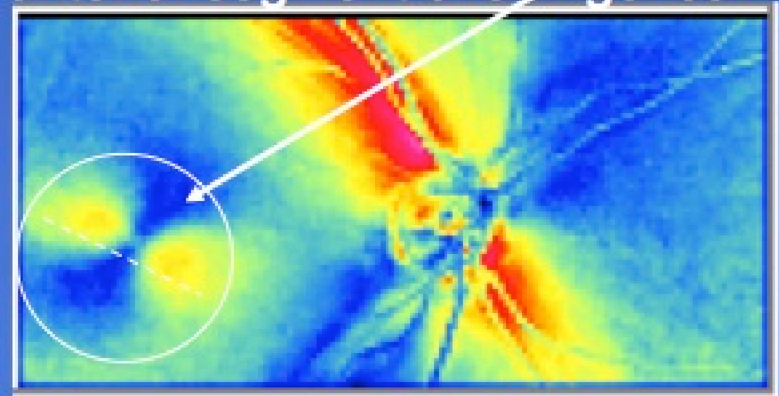
The amount of retardation from the RNFL is directly proportional to the RNFL thickness[1]

[1] Weinreb et al. *Arch Ophthalmol* 1990; 108: 557-560.

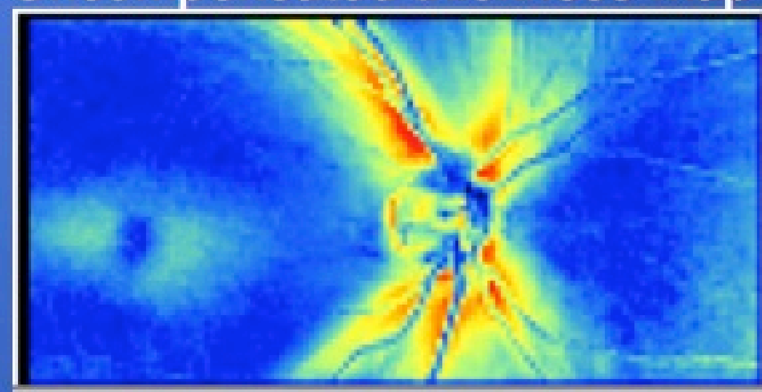
How Variable Corneal Compensation (VCC) Works

- Birefringence around the fovea is uniform due to Henle's layer
- A non-uniform pattern at the fovea is due to birefringence of the cornea
- Cornea axis (dashed line) and magnitude can then be determined[1]
- The variable corneal compensator cancels the cornea birefringence, resulting in uniform retardation around the fovea

The pattern in this circle is caused by anterior segment birefringence.



Uncompensated thickness map



Compensated thickness map

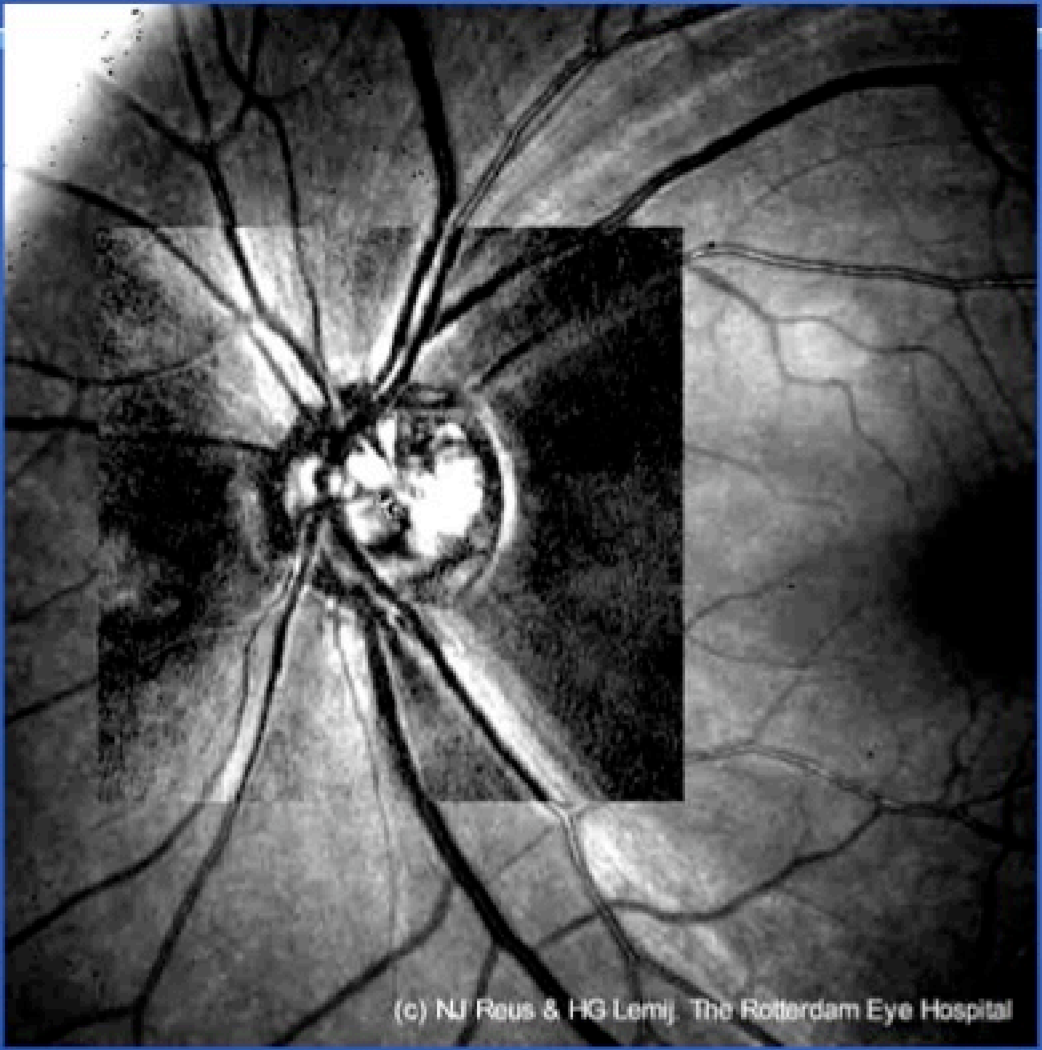
[1] Zhou and Weinreb, *IOVS*. 2002; 43: 2221.

KEY POINTS: GDX-VCC

- Strengths
  - Excellent tool for early structural loss
  - Pts are non-dilated
  - Large and varied normative database
  - The circle same distance diff disc sizes
  - Progression needs ANOVA algorithm and alignment
- Weaknesses
  - Birefringence is also lenticular – concern for long-term changes, changes after cataract surgery
  - Indirect measurement of NFL, not direct as OCT

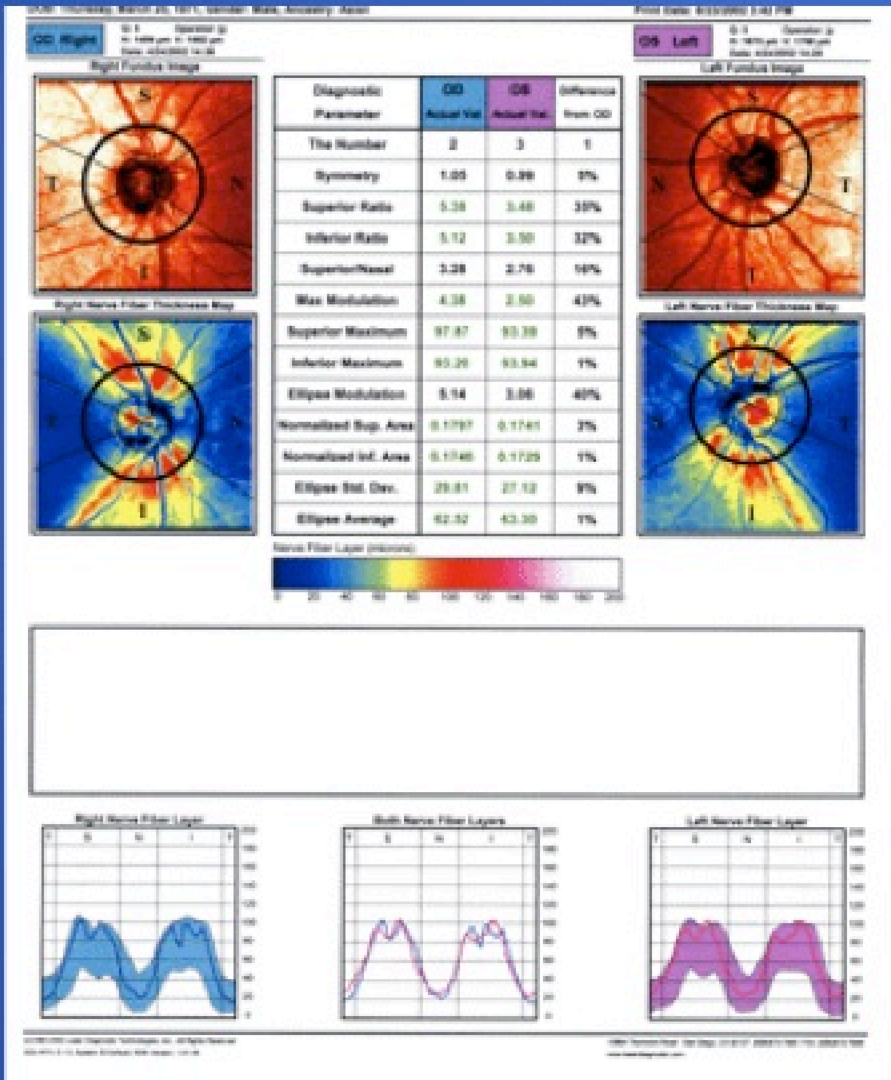
Nerve Fiber Layer Defect

Nerve Fiber Layer Defect
with overlying GDX-VCC Scan



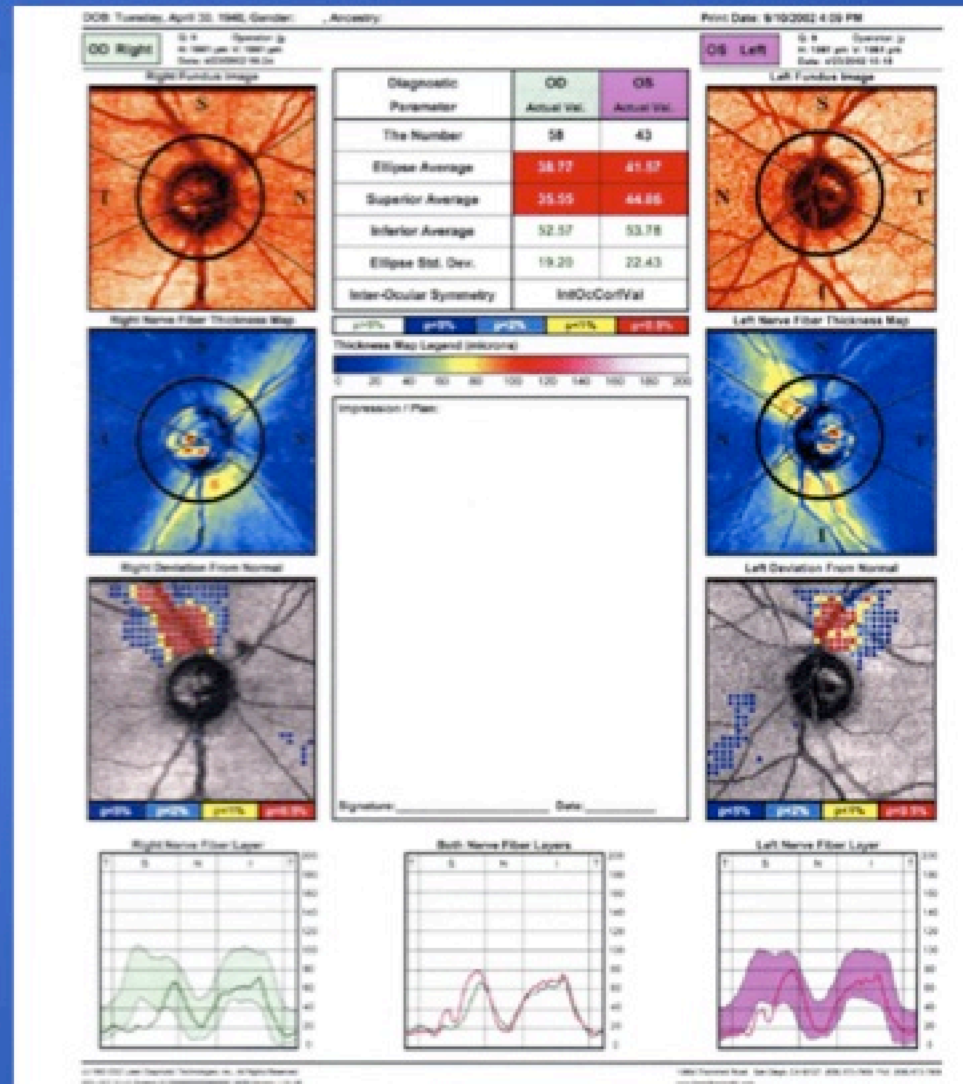
GDx RNFL Analysis

Normal



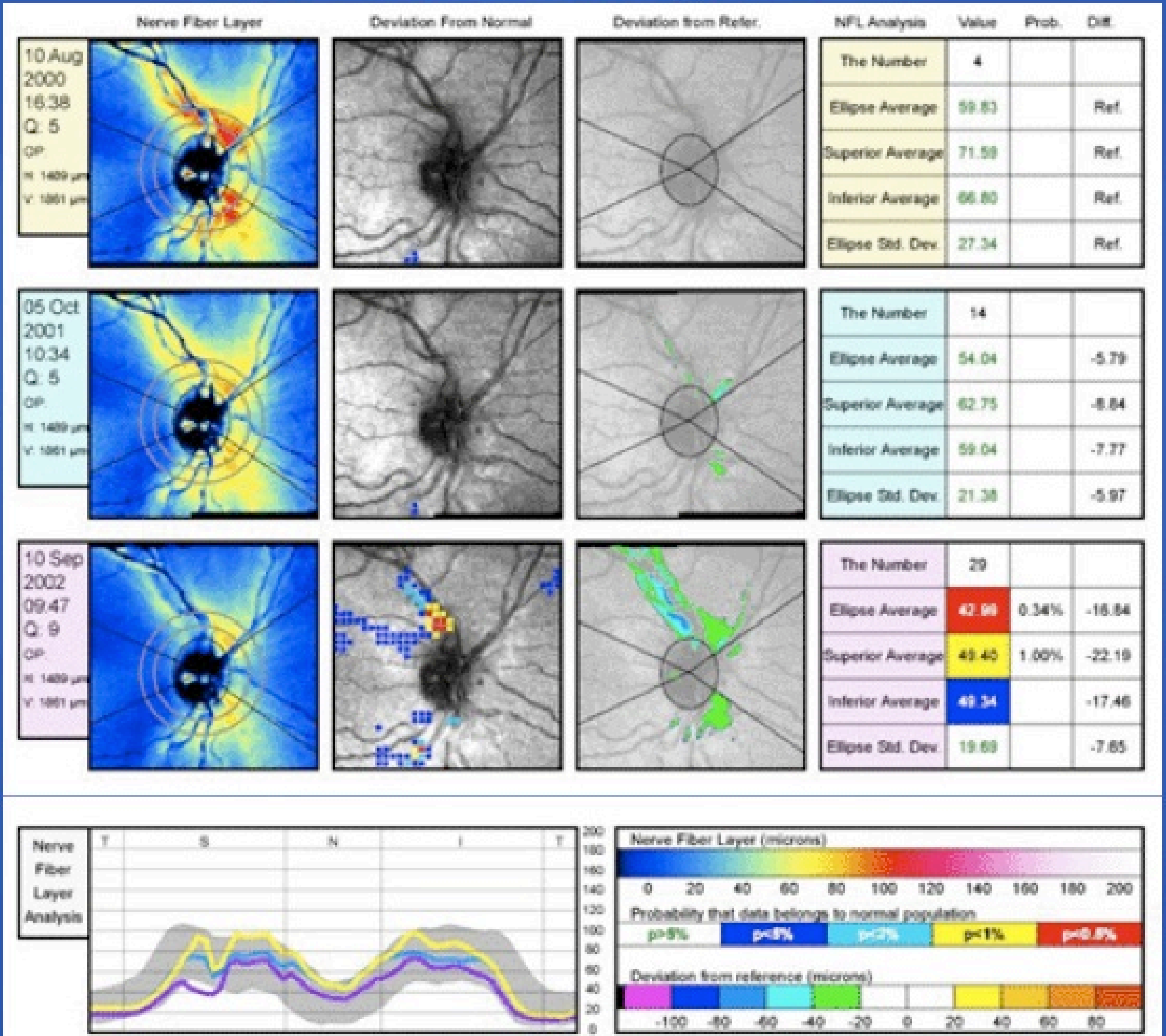
Diagnostic Parameter	OD Actual Val.	OS Actual Val.	Difference from OD
The Number	2	3	1
Symmetry	1.05	0.99	5%
Superior Ratio	5.38	3.48	35%
Inferior Ratio	5.12	3.50	32%
Superior/Nasal	3.28	2.76	16%
Max Modulation	4.38	2.50	43%
Superior Maximum	97.87	93.39	5%
Inferior Maximum	93.20	93.94	1%
Ellipse Modulation	5.14	3.06	40%
Normalized Sup. Area	0.1797	0.1741	3%
Normalized Inf. Area	0.1746	0.1729	1%
Ellipse Std. Dev.	29.81	27.12	9%
Ellipse Average	62.32	63.30	1%

RNFL Thinning



Diagnostic Parameter	OD Actual Val.	OS Actual Val.
The Number	58	43
Ellipse Average	38.77	41.57
Superior Average	35.55	44.66
Inferior Average	52.57	53.78
Ellipse Std. Dev.	19.20	22.43
Inter-Ocular Symmetry	IntOcCorlVal	

GDx Serial Analysis



GDx-VCC

Strengths

- RNFL well-assessed in
- BOTH transverse and axial resolution
- Early defects
  - Helpful in suspect screening
- Ease of use
- Large and varied
- database
- Well-designed printout and interpretation data
- Early serial analysis software

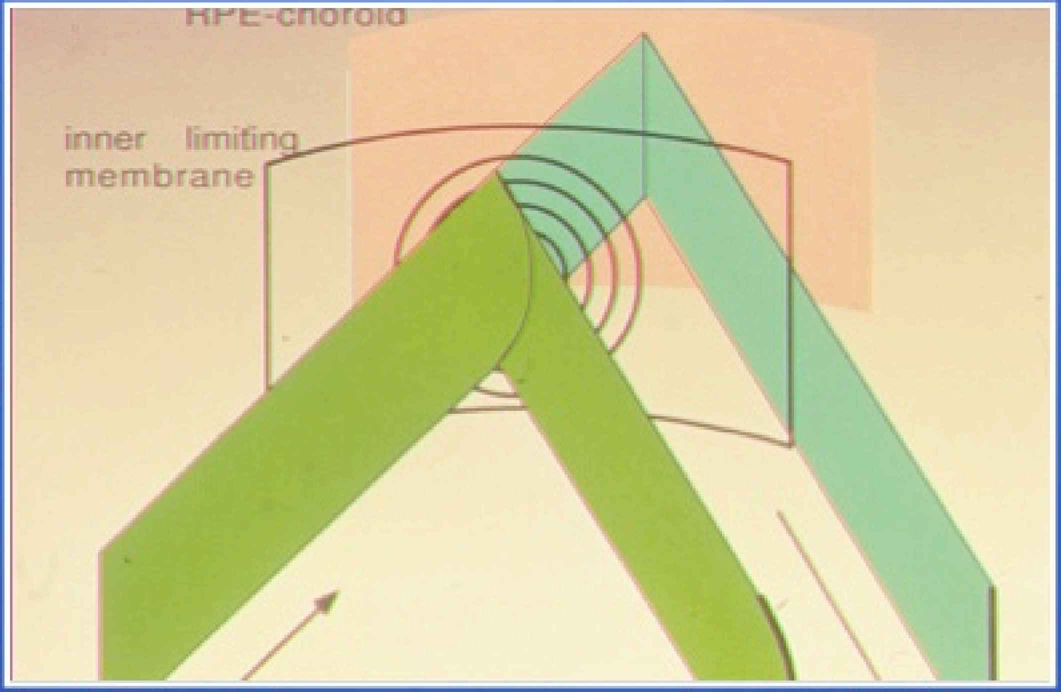
Weakness

- Indirect measure of RNFL
- Birefringence assumptions
- Other ocular structures
- ?non-homogenous
- birefringence of RNFL
- Lack of progression software analysis
- PPA

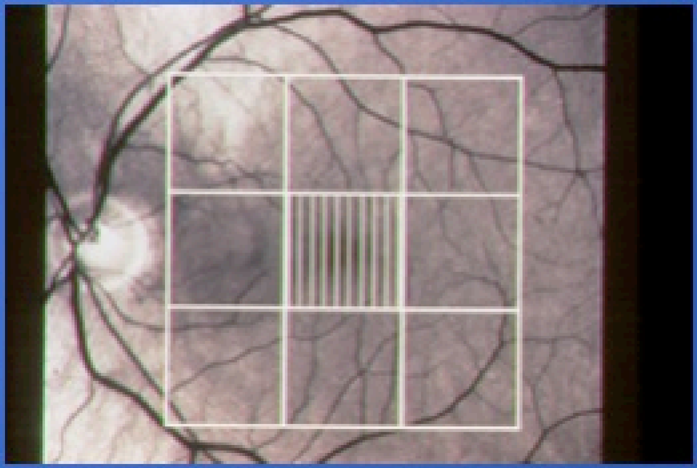
Retinal Thickness Analysis

Principle:

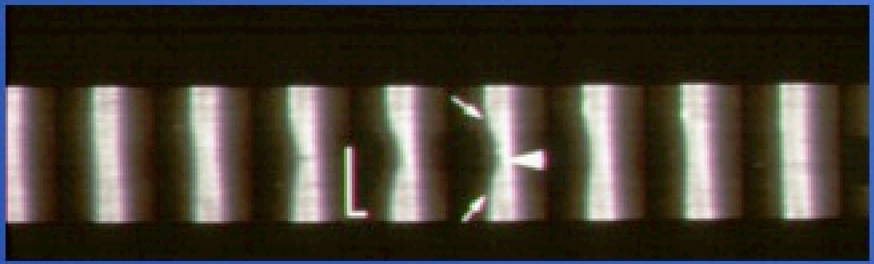
- A narrow laser beam illuminates the retina, similar to slit lamp biomicroscopy.
- Its intersections with the retina are viewed at an angle



- The laser beam is scanned across the fundus and 10 optical cross sections are obtained in 200 msec
- 9 locations are scanned in a 6 X 6 mm area at the posterior pole centered on the fovea in a total time of 1 minute per eye

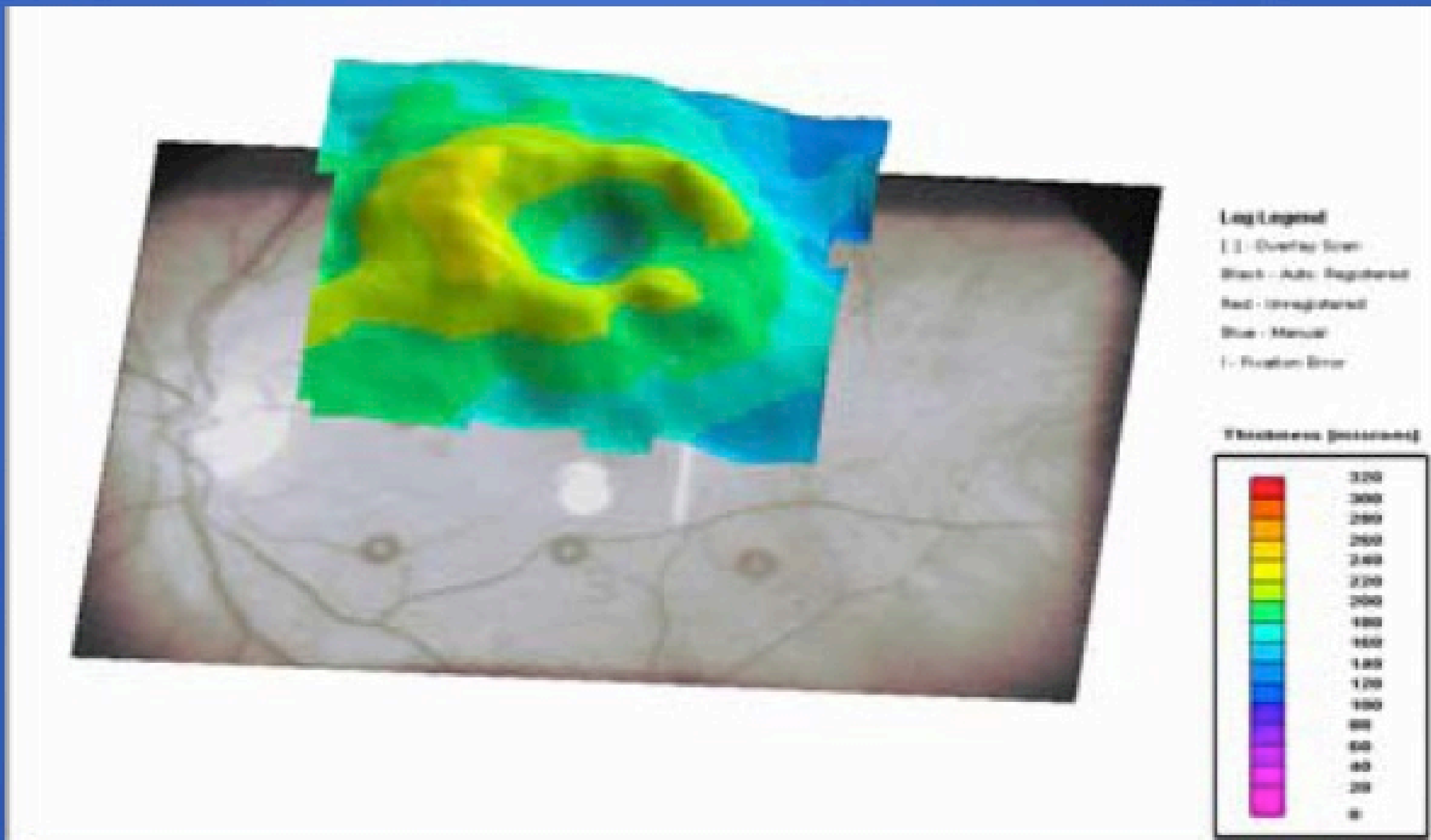


Optical cross section, fovea

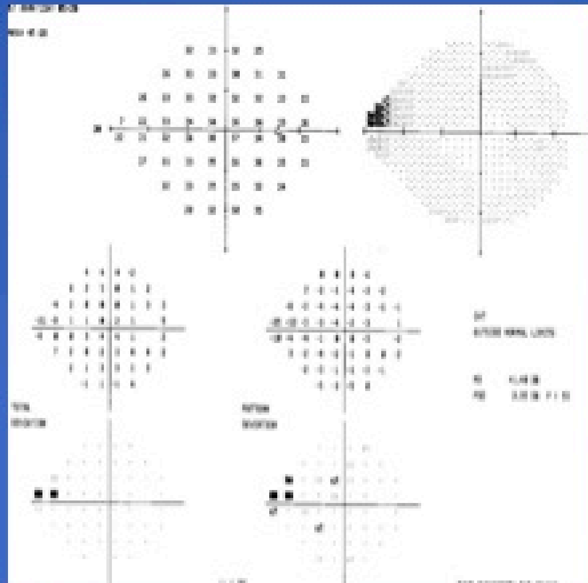


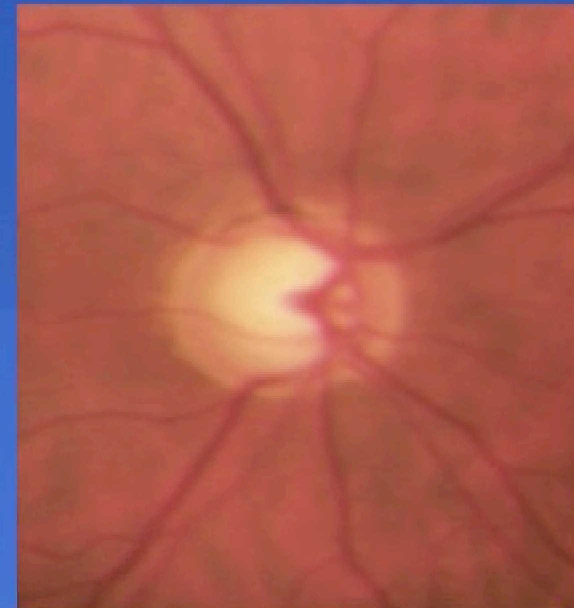
Normal Retinal Thickness Map

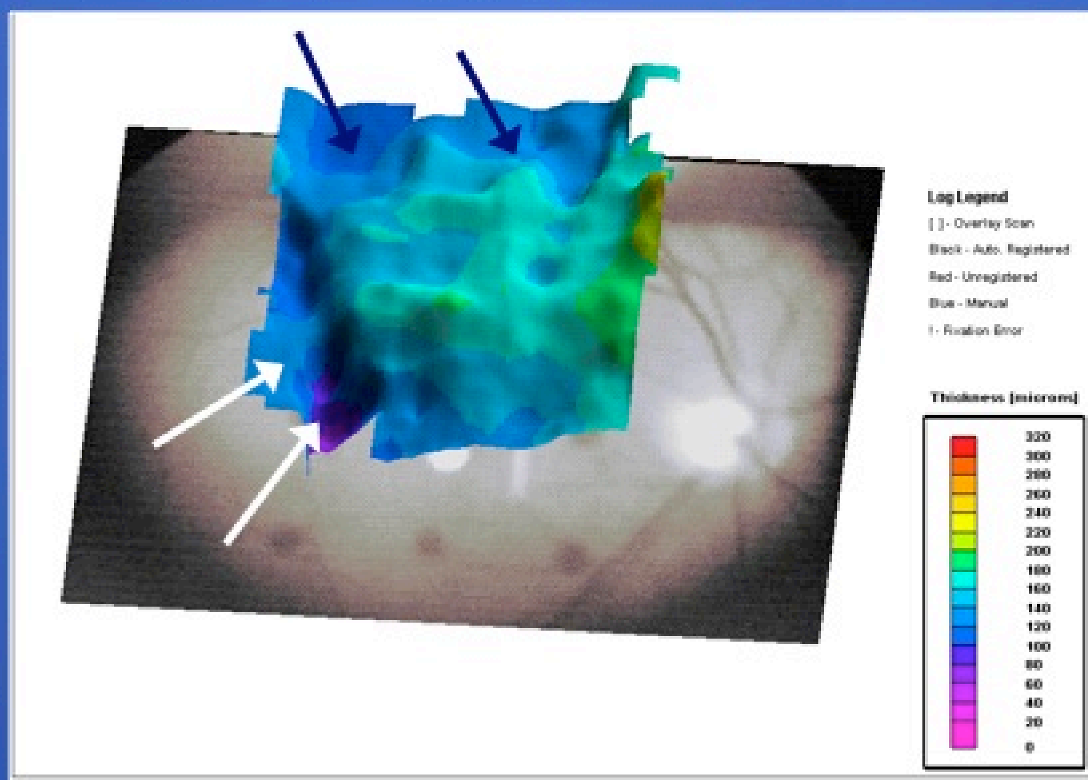
- Doughnut shaped thickening seen in the parafoveal region



Photos courtesty of S. Asrani






Log Legend
[ ] - Overlay Scan
Black - Auto. Registered
Red - Unregistered
Blue - Manual
! - Fixation Error
Thickness (microns)
320
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0

RTA

Strengths

- Both transverse AND some axial resolution
- Similar to HRT disc assessment and regression analysis
- Macular assessment in glaucoma

Weakness

- Axial resolution poorer compared to OCT, GDx
- No exceptional ability
- Least developed of imaging devices
- Questionable validity at this time, especially in early glaucoma
- No independent, customized database

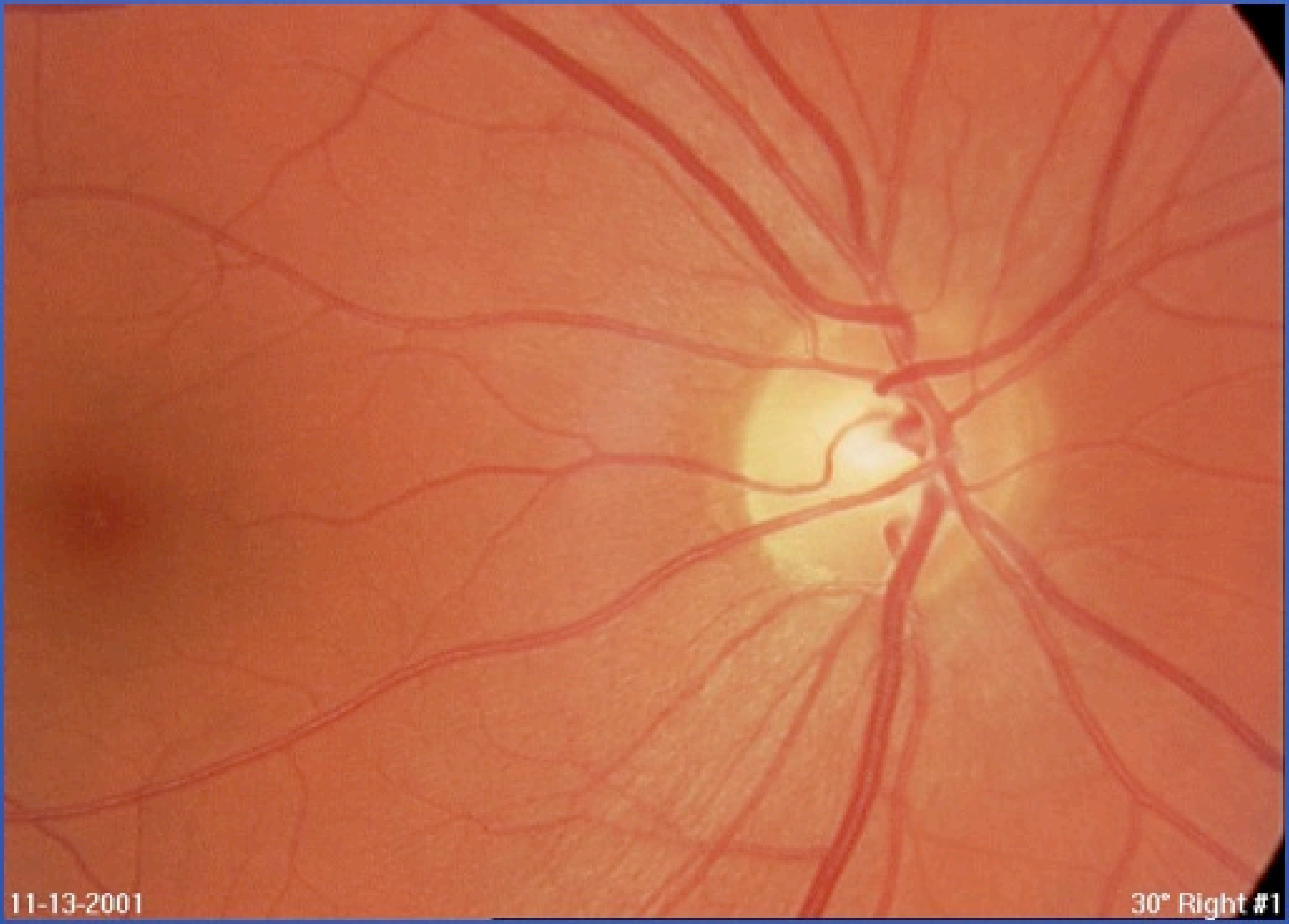
When should imaging be done?

- Imaging can be performed for any patient in which:
  - glaucoma is suspected or present,
  - when the number of risk factors is elevated,
  - and baseline measurements of the retinal nerve fibre layer and optic nerve head status are needed for documentation and later follow-up.

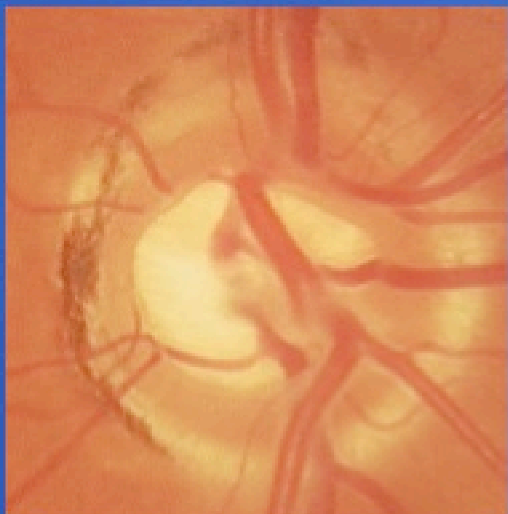
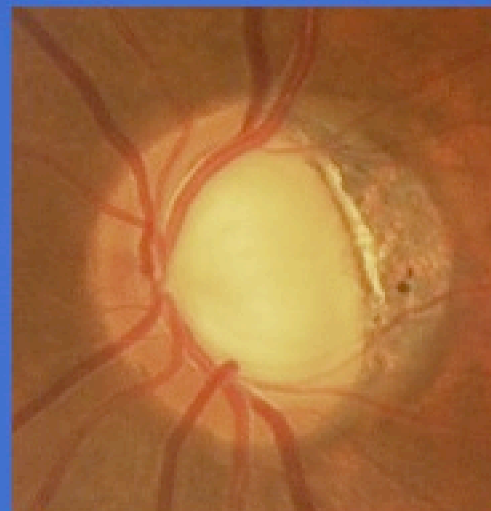
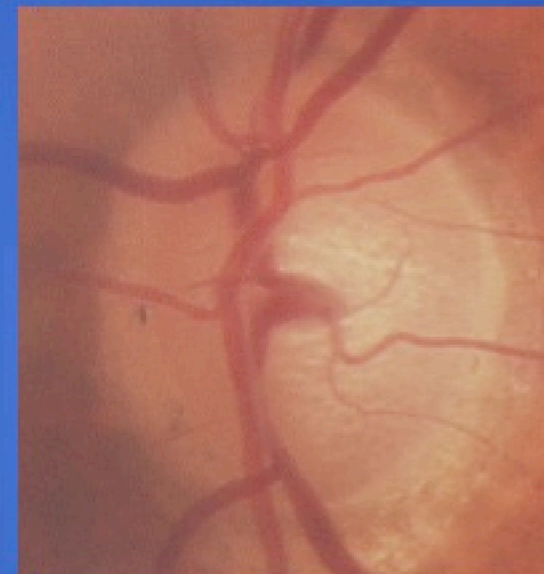
Value of Imaging as a Screening Device

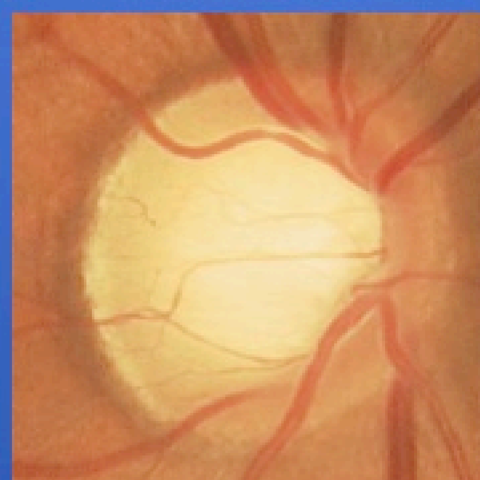
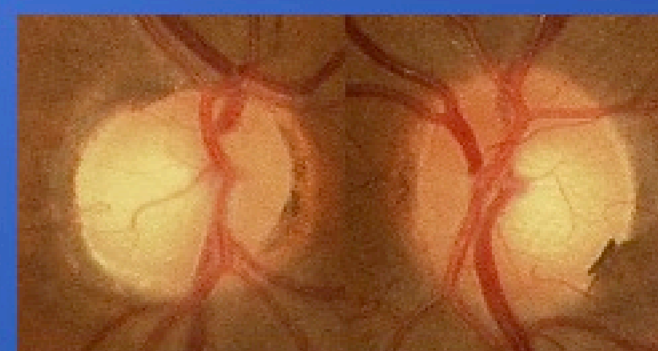
- The value of imaging devices in screening for glaucomatous damage is not yet well established.
- Factors one needs to consider when using imaging for screening purposes:
  - Portability
  - Ability to perform in an undilated patient
  - Cost-effectiveness
  - Overall validity
- These tests should be repeated according to usual routine visits

The Normal Optic Nerve Head

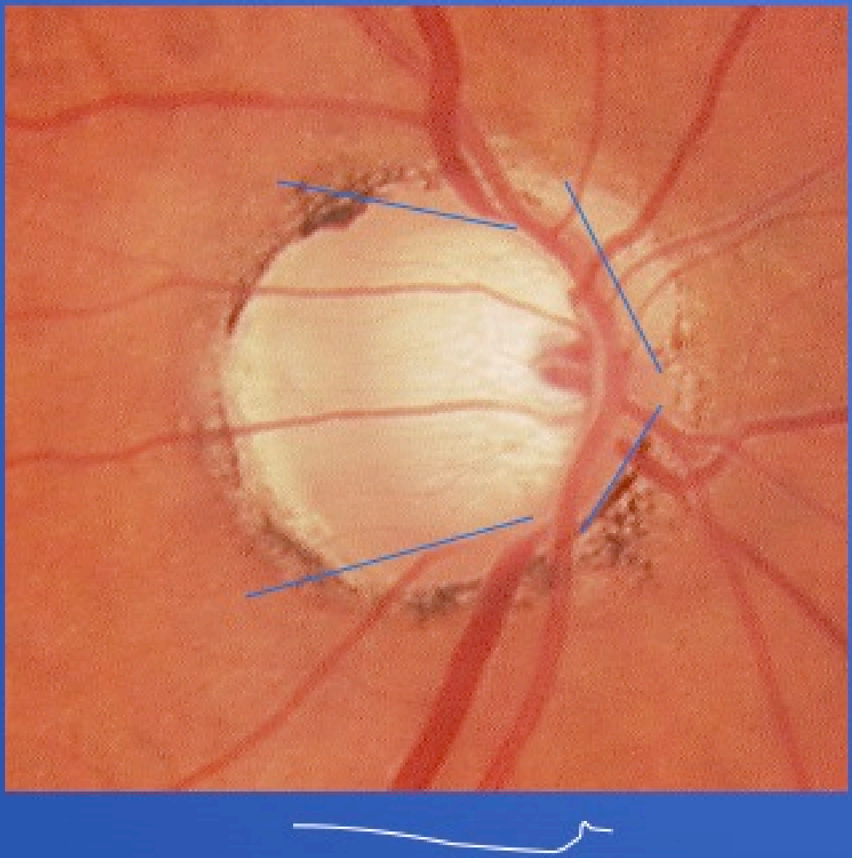


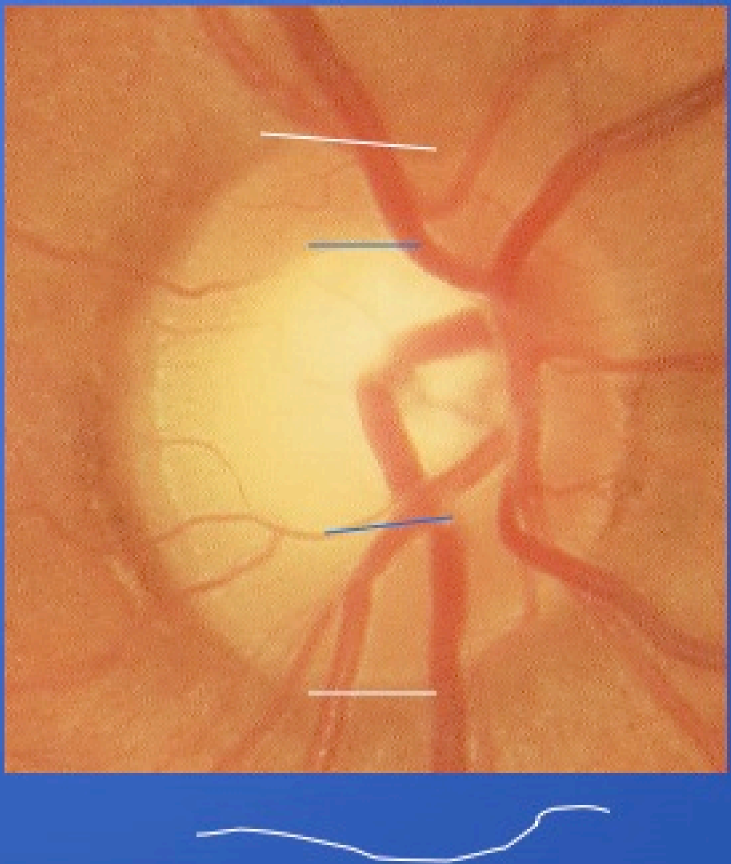
Patterns of Glaucomatous Damage

Draw the Nerve Diagrams





Comparison

Table 2. Comparison of Imaging Techniques to Detect Glaucomatous Optic Nerve Damage

	Sensitivity (%)	Specificity (%)	Diagnostic Precision (%)	ROC Area (%)
Disc photos	78	83	81	89
HRT	82	87	85	91
NFA II (GDx software)	79	69	74	78
OCT	79	79	79	85

ROC = receiver operator characteristic; HRT = Heidelberg Retina Tomograph; NFA = nerve fiber analyzer with integrated GDx software; OCT = optical coherence tomography.

Source: Nakla M, Nduaguba C, Rozier M, et al. Comparison of imaging techniques to detect glaucomatous optic nerve damage. Invest Ophthalmol Vis Sci 1999; 40 (Suppl):397.

Be Optimistic!