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Imaging the Anterior Segment of the Eye:

Optical Coherence Tomography

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Financial Interests:
Optovue, Inc.: stock options, patent royalty, travel, grant
Carl Zeiss Meditec, Inc.: patent royalty

Anterior Segment Optical Coherence Tomography Systems

- Time Domain
  - Zeiss Visante
  - Heidelberg SL-OCT (slitlamp-mounted)
- Fourier Domain
  - Optovue RTVue (retina+cornea)
  - Tomey SS-1000 CASIA
  - Zeiss Cirrus (retina+cornea)



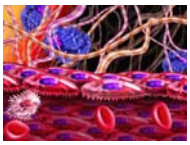


Fourier v. Time Domain OCT

Technology	Time domain (Zeiss Visante)	Fourier domain (Optovue RTVue)
Speed	2000 A-scan/sec	26,000 A-scan/sec

Long v. Short Wavelength Infrared

- Shorter wavelength gives finer resolution
- Longer wavelength gives deeper penetration for angle and scleral imaging

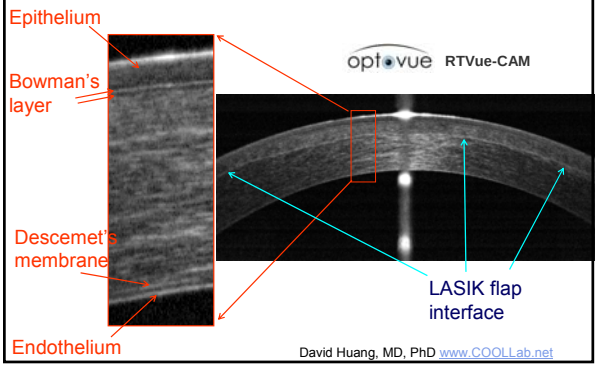


Technology	Visante	RTVue
Axial resolution (FWHM cornea)	17 μm	5 μm
Wavelength	1310 nm	830 nm

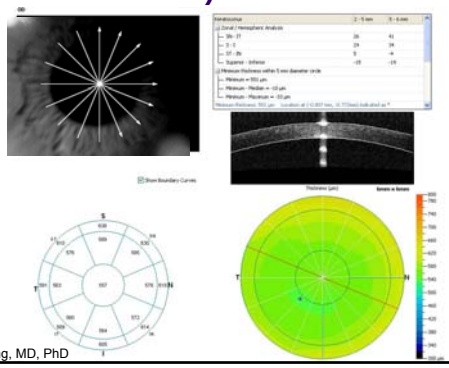
RTVue-CAM: an FD-OCT System for Both Retinal and Corneal Imaging

RTVue with corneal adaptor module

Higher resolution allows better visualization of corneal structure



Corneal mapping over 8 meridians (8 x 1019 a-scans) in 0.31 second



David Huang, MD, PhD

Higher speed means greater precision

Technology	Visante (2 kHz)	RTVue (26 kHz)
Corneal power (D)	0.8	0.19
Pachymetry map (μm)	3.5	1.2
Anterior topography (μm)	14.9	3.4

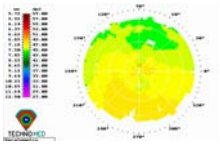
Pooled standard deviation of repeat measurements in normal eyes

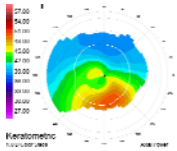
Yan Li, PhD

Keratoconus Screening

Forme Fruste Keratoconus is the Most Important Risk Factor for Post-LASIK Corneal Ectasia

Binder P, Analysis of ectasia after LASIK: risk factors, *J Cat Refract Surg* 33:1530, 2007





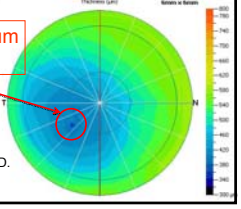
But Topography Does Not Screen Out All Eyes at Risk

Topography	Normal	Suspicious	Abnormal	Total
# Ectasia Cases	25	27	33	93
Percent	27%	29%	41%	100%

Randleman JB et al. Risk assessment for ectasia after corneal refractive surgery. *Ophthalmol* 2007; 115:37-50

Detecting Keratoconic Thinning with OCT Pachymetric Indices

- General thinning
  - Min
- Focal thinning
  - Minimum - median
- Inferotemporal thinning
  - I-S
  - IT-SN
  - Y location of the Min

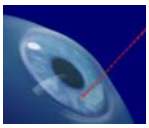
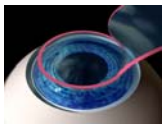
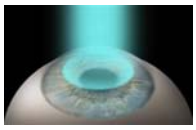


Li Y, Meisler M, Tang M, Lu A, Thakrar V, Reiser B, Huang D. Keratoconus diagnosis with optical coherence tomography pachymetry mapping. *Ophthalmology* 2008;115:2159-2166.

Combining OCT pachymetry indices improves keratoconus diagnosis

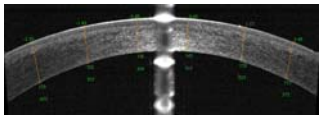
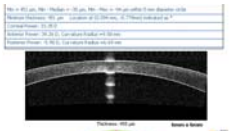
Parameter	1% Cutoff	Sensitivity	Specificity
IT - SN	< -52 μm	0.673	0.993
I - S	< -54 μm	0561	0.986
Min	< 464 μm	0.649	1.000
Min-median	< -33 μm	0.839	0.986
Min location	Y < -1.1 mm	0.415	0.979
1 Abnormal		0.907	0. 958
2 Abnormal		0.824	0.986

* Optovue RTVue database based on 143 normal and 205 keratoconus eyes from David Huang, MD, PhD; Robert Brass, MD; Yaron Rabinowicz, MD

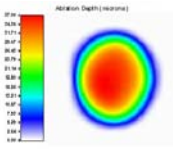




Planning Laser Vision Correction

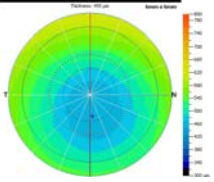
Planning LASIK Retreatment

Central flap thickness = 150 microns



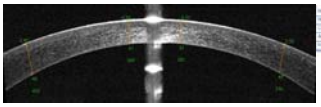
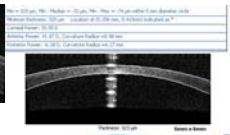
Ablation depth
= 29 microns



Residual stromal bed thickness =
451 – 150 – 29 = 272 (microns) OK

Minimum pachymetry =
451 microns

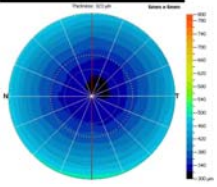
Planning PRK Retreatment

Central epithelial thickness = 61 microns

MR = -2.50 sph, 6.0 mm OZ
Ablation depth = 30 microns

Residual stromal bed thickness =
320 – 150 – 30 = 240 (microns)
NOT SAFE!

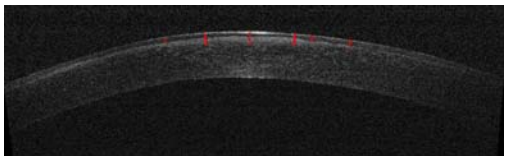


Minimum pachymetry =
320 microns

Yan Li, PhD

Guiding Phototherapeutic Keratectomy

Epithelial Thickness and Opacity Depth Measurements on OCT



	1	2	3	4	5	6	7	8
Red measurement bar (micron)	61	143	162	148	73	75		
Corneal thickness at the red measurement bar (micron)	576	577	583	590	594	603		
Distance to the vertex (mm)	-1.1	-0.6	0.0	0.6	0.8	1.3		

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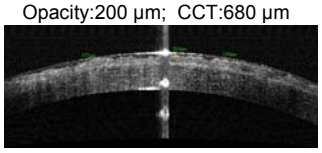
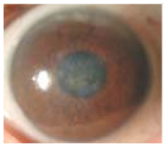
OCT Is Useful in The Planning of PTK Example: Reis Buckler Dystrophy

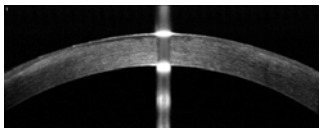
Opacity:200 µm; CCT:680 µm



Pre-
PTK

BSCVA
20/100





Post-
PTK

BSCVA
20/40

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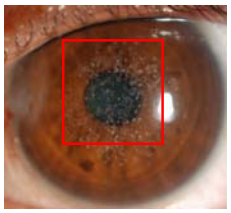
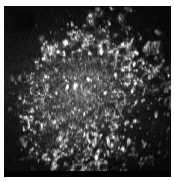
Granular Corneal Dystrophy

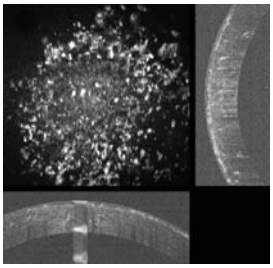
Slit-lamp photo



OCT projection



PTK + PRK Simulation



- Transepithelial PTK
  - 6.5/0.5 mm AZ/TZ circle, 76μm
- PRK
  - -2.00 D, 6mm, 24μm

Maolong Tang, PhD

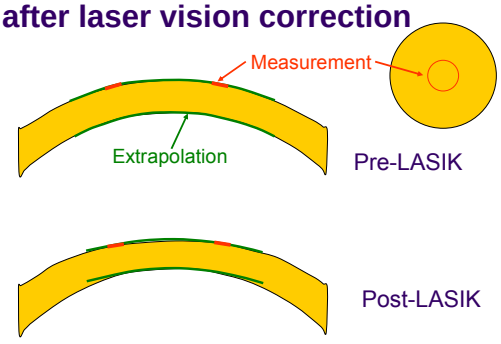
Corneal Power Measurement and Intraocular Lens Power Calculation

IOL calculation after laser vision correction is less accurate.

Group	Post-LASIK	Control
Within 1 D of emmetropia	30%	90%
Mean absolute deviation	1.3 D	0.6 D

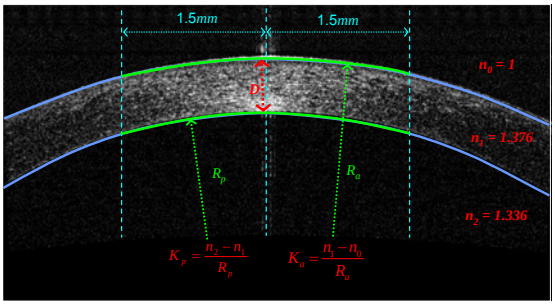
Cataract surgery results using the clincial history method. Randleman JB et al. *Cornea.* 2002; 21:751

The problem with keratometry after laser vision correction

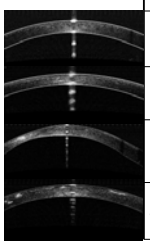


The extrapolation no longer works!

Net corneal power combines anterior & posterior curvature measurements from OCT sections of corneal meridians



Corneal power can be repeatably measured with OCT



Category	Number of eyes	Pooled STDEV (D)
Normal	38	0.19
Post-LASIK	16	0.26
Keratoconus	16	0.30
Scar	6	0.57

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OCT corneal power outperformed other methods in IOL power calculation

Method	# Eyes	Single-K SRK/T		Single-K Hoffer Q		Double-K Holladay II	
		MAE (D)	Range (D)	MAE (D)	Range (D)	MAE (D)	Range (D)
IOL-Master K	13	2.24	(-4.6, 1.4)	1.50	(-3.5, 0.8)	1.20	(-2.9, 0.89)
RGP K	11	2.20	(-5.1, 3.0)	1.86	(-4.1, 3.8)	1.70	(-3.5, 4.1)
Clinical History	11	1.35	(-3.7, 1.5)	1.35	(-2.8, 1.6)	1.44	(-2.3, 2.1)
OCT K	13	1.10	(-3.9, 0.9)	**0.87**	(-2.7, 1.6)	1.02	(-2.1, 1.9)

MAE = mean absolute error
Prediction error = Predicted MRSE – Measured MRSE 1 month after surgery
13 eyes of 11 cataract patient who had myopic LASIK
Unpublished study performed at the Doheny Eye Institute

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Some OCT functions presented are not yet FDA-approved

- RTVue Keratoconus Diagnosis Normative Reference
  - International software release November 2010
  - FDA approval pending
- RTVue Corneal Power
  - International software release November 2010
  - FDA approval pending
- PTK Simulation
  - Experimental software not FDA approved

Acknowledgements

National Eye Institute
NATIONAL INSTITUTES OF HEALTH

R01 EY018184

Guiding The Treatment of Anterior Eye Diseases with Optical Coherence Tomography

COOL Center for Ophthalmic Optics & Lasers

PDF handout is posted on

www.COOLLab.net