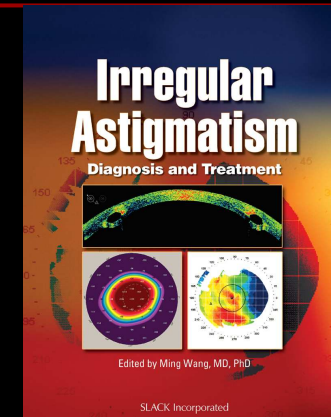
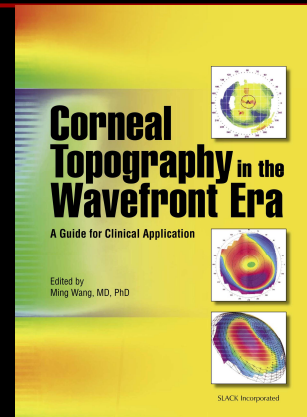


Irregular astigmatism: definition, classification, topographic and clinical presentation

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Clinical Associate Professor of
Ophthalmology of University of
Tennessee

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Nashville, TN, USA



Coworkers

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- Helen Boerman, O.D.;
- Lav Panchal, M.D.;
- Yangzi Jiang, M.D., O.D.;
- No financial interest.

Irregular astigmatism

- Definition and classification;
- Statistical indices and KC risk indices;
- Clinical causes;
- Other visually significant corneal changes;
- Topo-WF correlates of irregular astigmatism;
- Treatment.

Definition and classification

Irregular astigmatism, defined as astigmatism where the principle meridians are **not 90 degrees apart** and associated with **loss of vision**, represents one of the most serious and frequent complications of corneal refractive surgery.

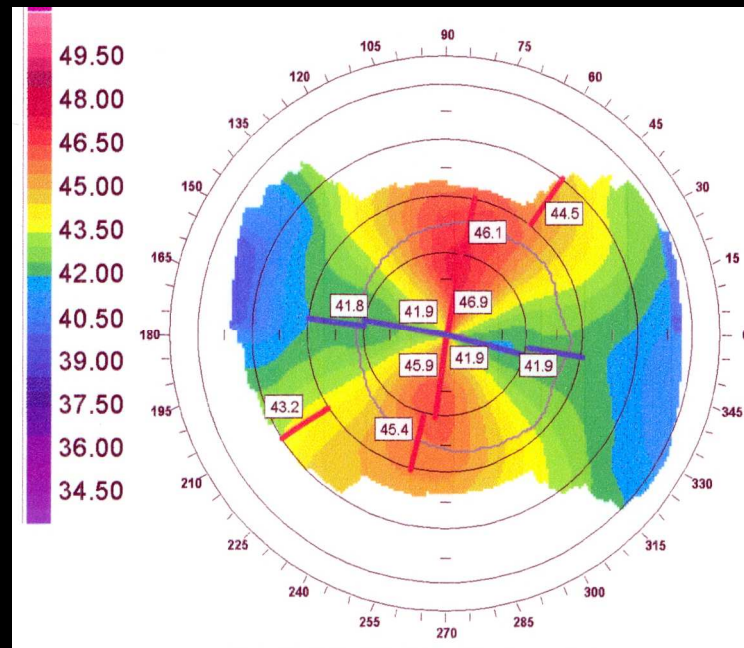
Regular vs irregular astigmatism

- Regular astigmatism is correctable using a cylindrical spectacle lens;
- Irregular astigmatism occurs when the **orientation** of the principal meridians changes *from one point to another across the pupil*, or when the **amount** of astigmatism changes from one point to another;
- The further distinction of irregular astigmatism includes *regularly or irregularly* irregular astigmatism and relates to the presence of **pattern** recognition on computerized topography. Irregularly irregular astigmatism is rough or uneven, and shows no recognizable pattern on topography.

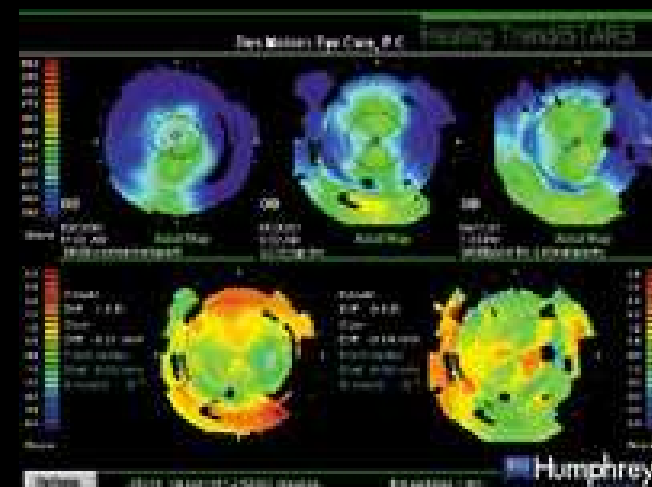
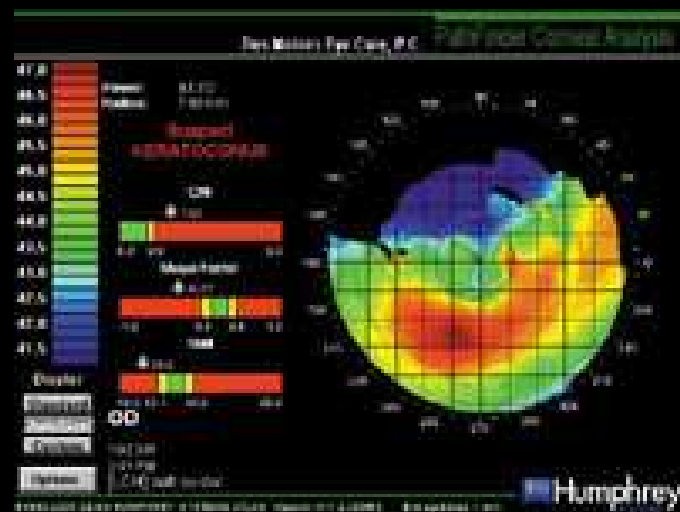
Classification

- Irregular astigmatism with defined pattern (Macroirregular, or **regularly irregular astigmatism**): There is a steep or flat area of at least 2 mm of diameter, which is the primary cause of the astigmatism.
- Irregular astigmatism with undefined **pattern** (Microirregular, or **irregularly irregular astigmatism**): Multiple irregularities; big and small, steep and flat, and profile maps are almost impossible to calculate.

Regular astigmatism



Irregular astigmatism: Astigmatism in which different parts of the same meridian have different degrees of curvature



Irregular astigmatism

- Definition and classification;
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- Clinical causes;
- Other visually significant corneal changes;
- Topo-WF correlates of irregular astigmatism;
- Treatment.

Statistical indices and KC risk indices

- SimK, SAI, SRI;
- SF, CIM, MTK,
- KC risk index panel.

Sim K, SAI, SRI.

- **Simulated keratometry (SimK)** provides the power and axis of the steepest and flattest meridian similar to values provided by the keratometer. They are calculated from rings 7 to 9 corresponding to the position on the cornea at which keratometry measurements are obtained.
- **The surface asymmetry index (SAI)** is a centrally weighted summation of differences in corneal power between corresponding points 180° apart on 128 equally spaced meridians. The SAI approaches zero for a perfectly radially symmetrical surface and increases as the corneal shape becomes more asymmetrical.
- **The surface regularity index (SRI)** is calculated from a summation of local power fluctuations along 256 equally spaced meridians. The SRI rises with increasing irregular astigmatism and approaches zero for a smooth corneal surface.
- Numerous other indices have been developed such as potential visual acuity, average corneal power, coefficient of variation of corneal power, and algorithms for the detection of keratoconus.

SF

- *Shape Factor (SF)* is the measurement of corneal **asphericity**. A negative SF usually indicates a post-refractive surgery eye with the center flatter than the periphery (oblate).
- Normal 0.13 to 0.35
- Borderline 0.02 to 0.12
- Abnormal -1.0 to 0.01 .

CIM

- *Corneal Irregularity Measurement (CIM)* is an index which represents the **irregularity** of the corneal surface. Higher the value of CIM predicts more irregularity
- Normal 0.03μm to 0.68μm
- Borderline 0.69μm to 1.0μm
- Abnormal 1.1μm to 5.0μm

CIM

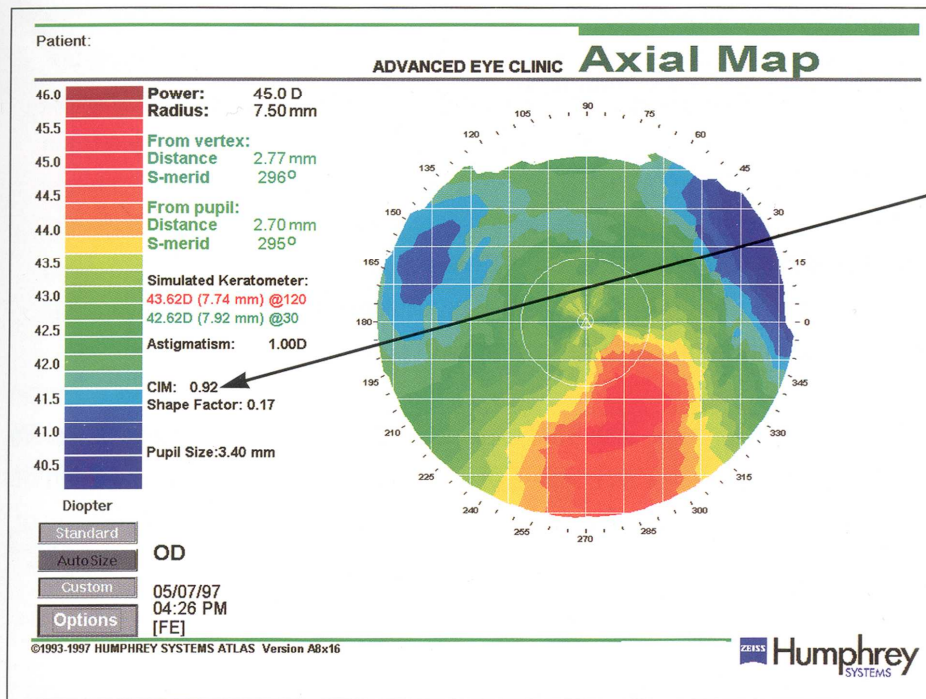


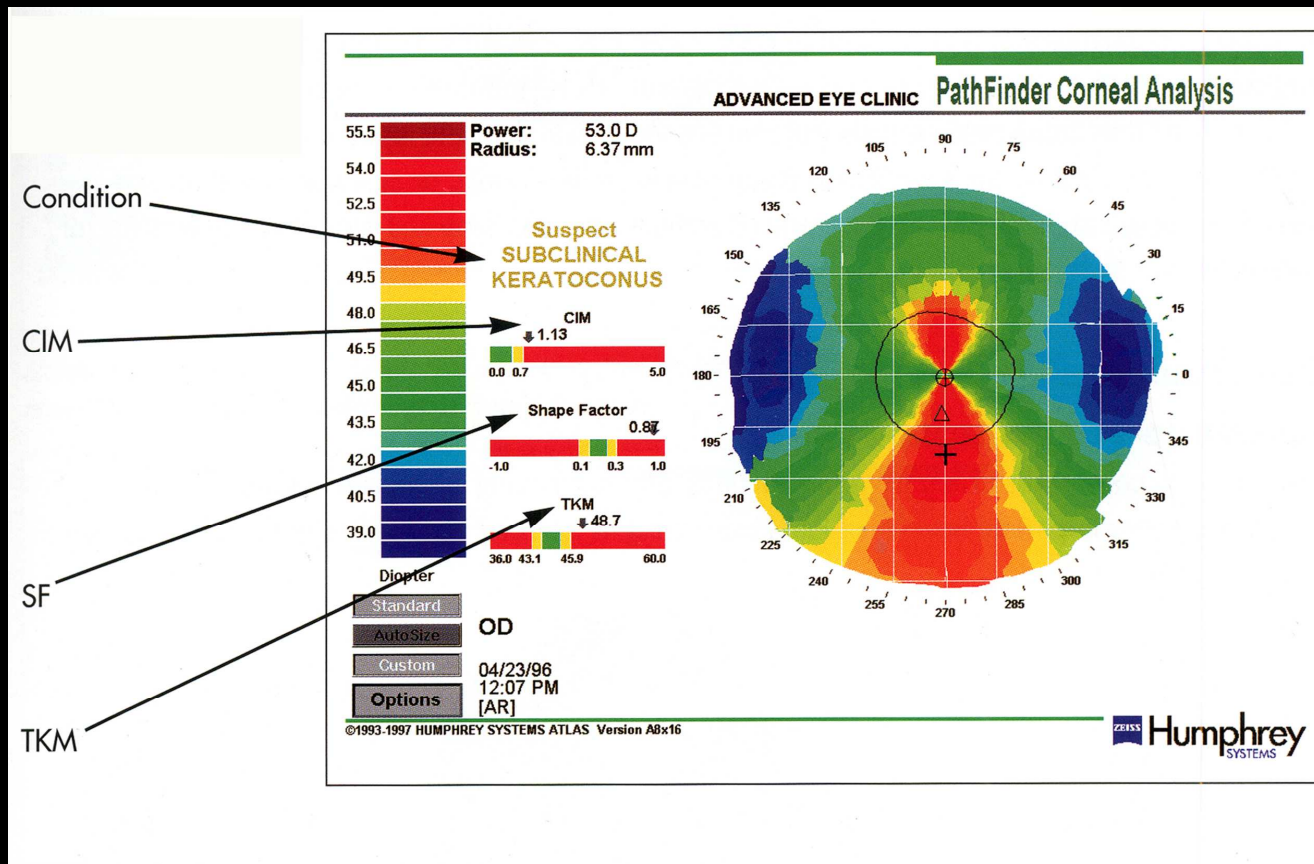
FIGURE 3-3 CIM AND CONTACT LENS DISTORTION.

A high CIM suggests some corneal irregularity, which could be an indication of contact lens distortion.

MTK

- *Mean Toric Keratometry (MTK)* indices use elevation data to compare the toric reference to the actual cornea. The mean apical curvature value helps select the **best toric fit** using a spherocylinder design. This provides the most accurate toric representation of a patient's cornea.
- Normal 43.10 diopters to 45.90 diopters
- Borderline 41.80 diopters to 43.00 diopters and 46.00 diopters to 47.20 diopters
- Abnormal 36.00 diopters to 41.70 diopters and 47.3 diopters to 60.0 diopters

Combining CIM, SF and MTK, to determine KC risk



CL Distortion

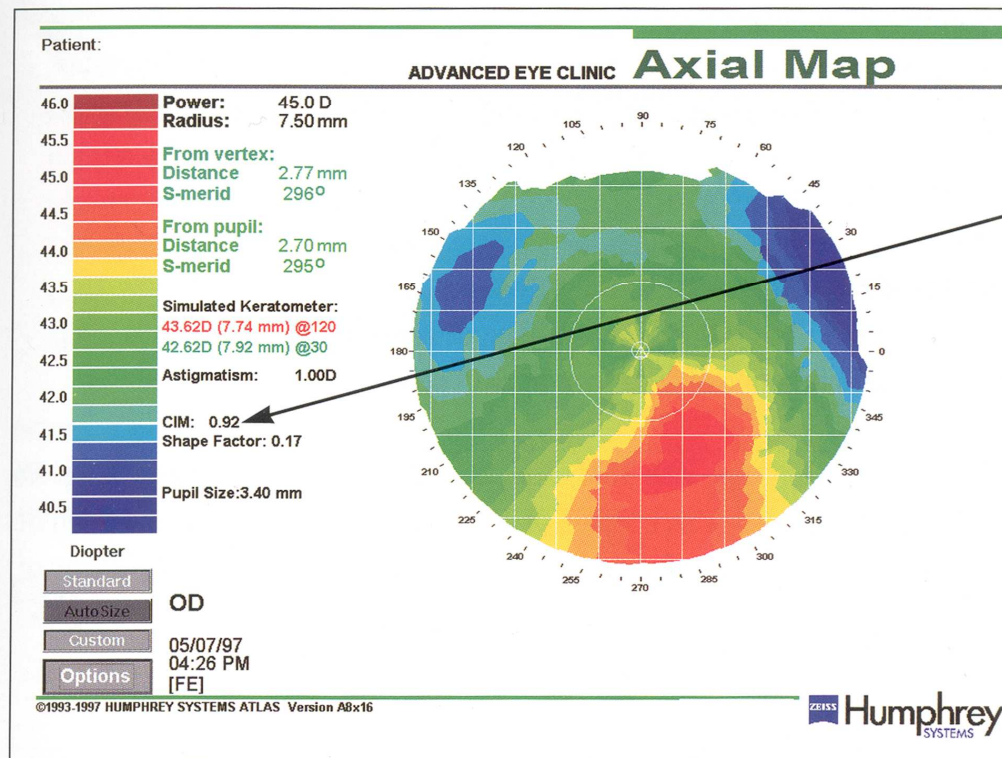
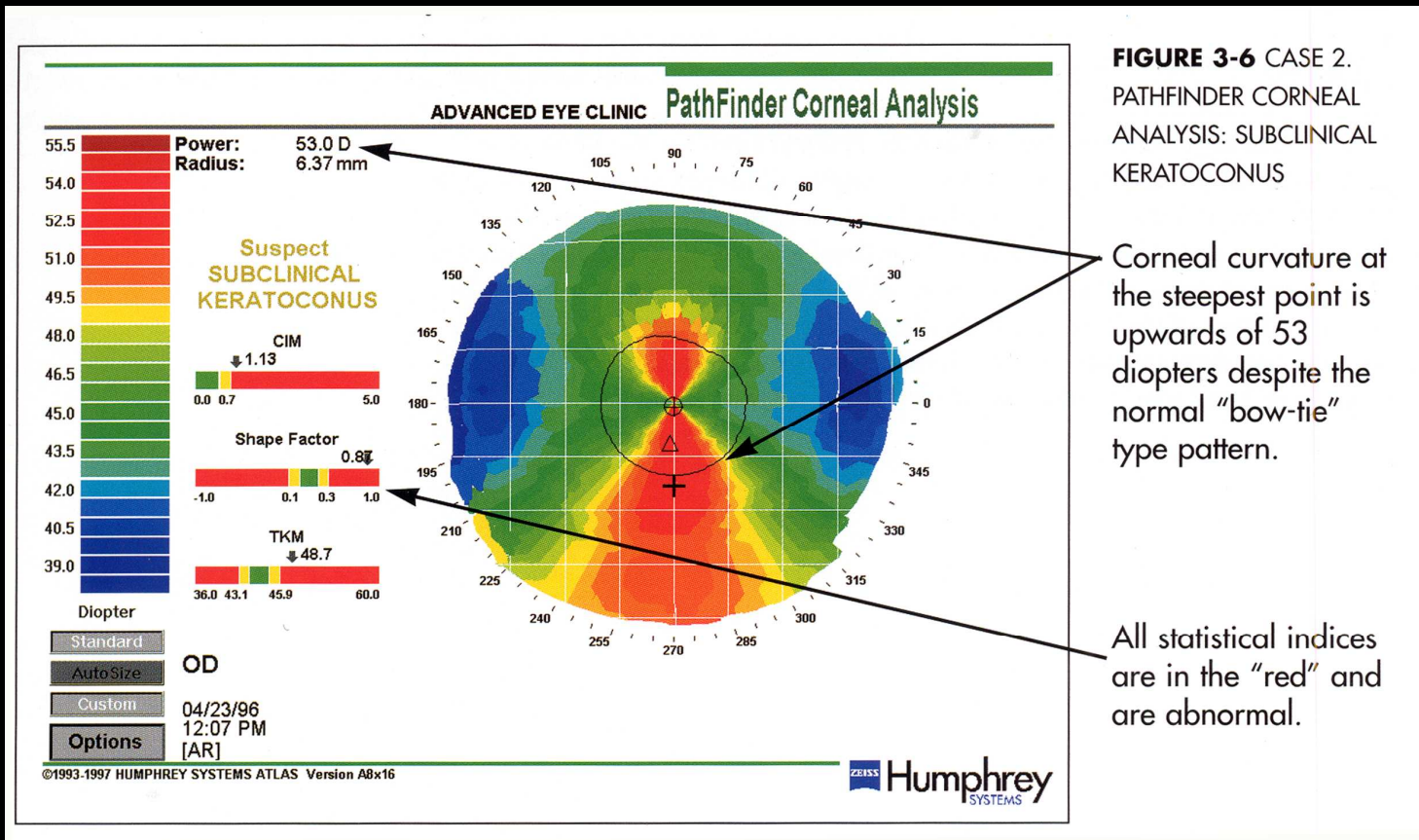


FIGURE 3-3 CIM AND CONTACT LENS DISTORTION.

A high CIM suggests some corneal irregularity, which could be an indication of contact lens distortion.

Subclinical keratoconus



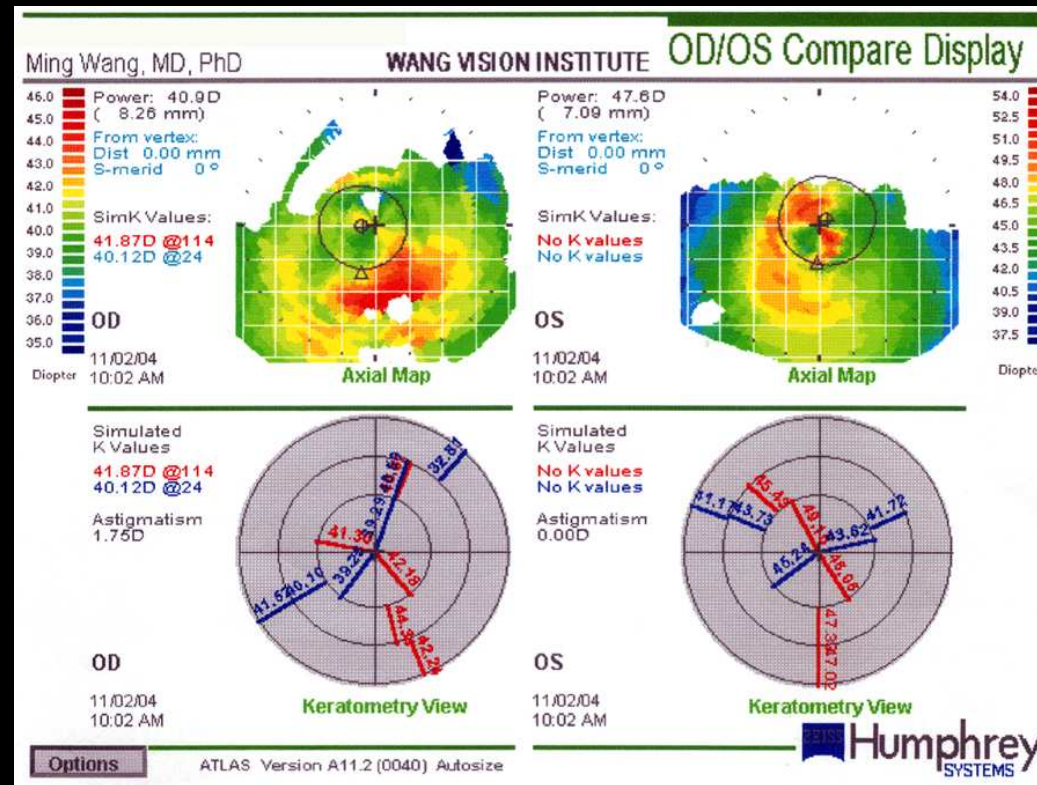
Irregular astigmatism

- Definition and classification;
- Statistical indices and KC risk indices;
- **Clinical causes;**
- Other corneal visually significant changes;
- Topo-WF of irregular astigmatism;
- Treatment.

Clinical causes of irregular astigmatism

- Irregular but **stable** cornea (e.g., irregular scar surface): cornea is irregular because of **LOCAL** geography;
- Irregular but **unstable** cornea (biomechanical decompensation): cornea is irregular because of **GLOBAL** corneal weakness;
- Clinical causes:
 - CL warpage/overwear
 - FFKC/KC/Pellucid
 - Chalazion
 - Pterygium
 - Trauma
 - Limbal/corneal dystrophies
 - Keratorefractive surgery (LASIK, PRK, CK, ectasia)
 - Others

CL warpage

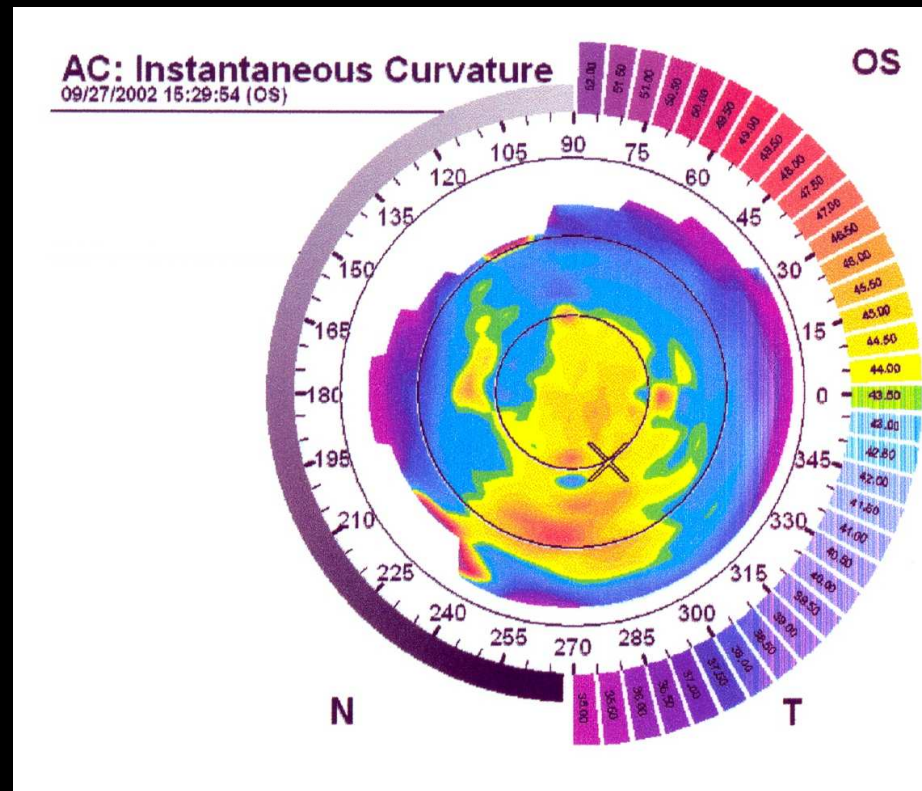


Irregular astigmatism (dry eyes)

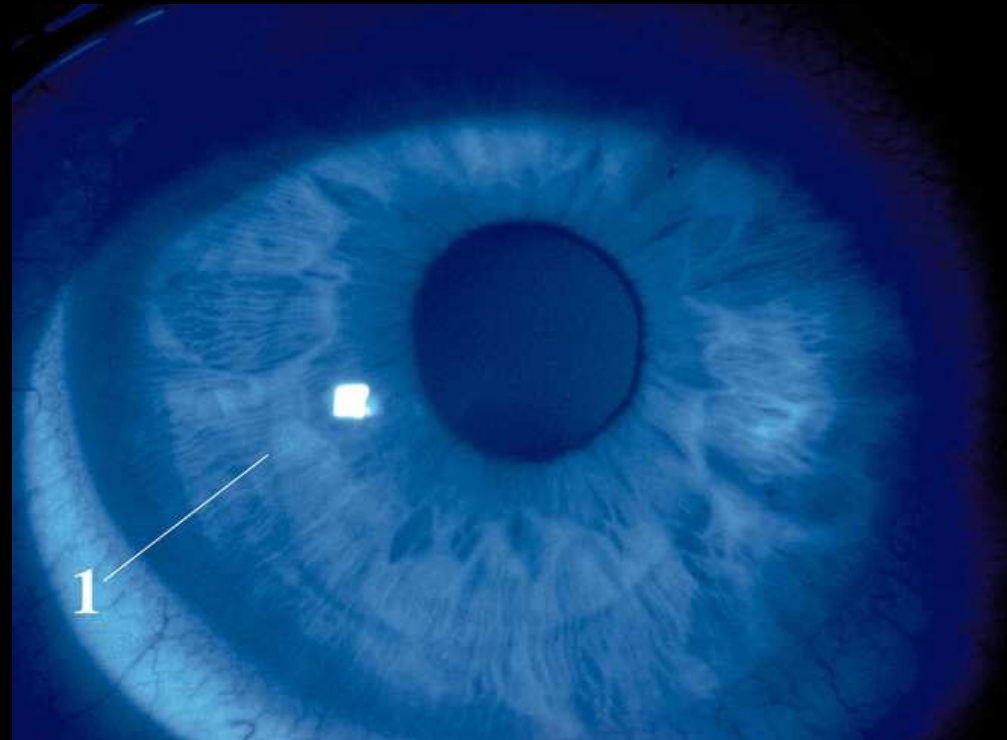
Our most
common
irregularity
without defined
pattern post
LASIK is *dry eye*
(**47%** of HOA in
on study)



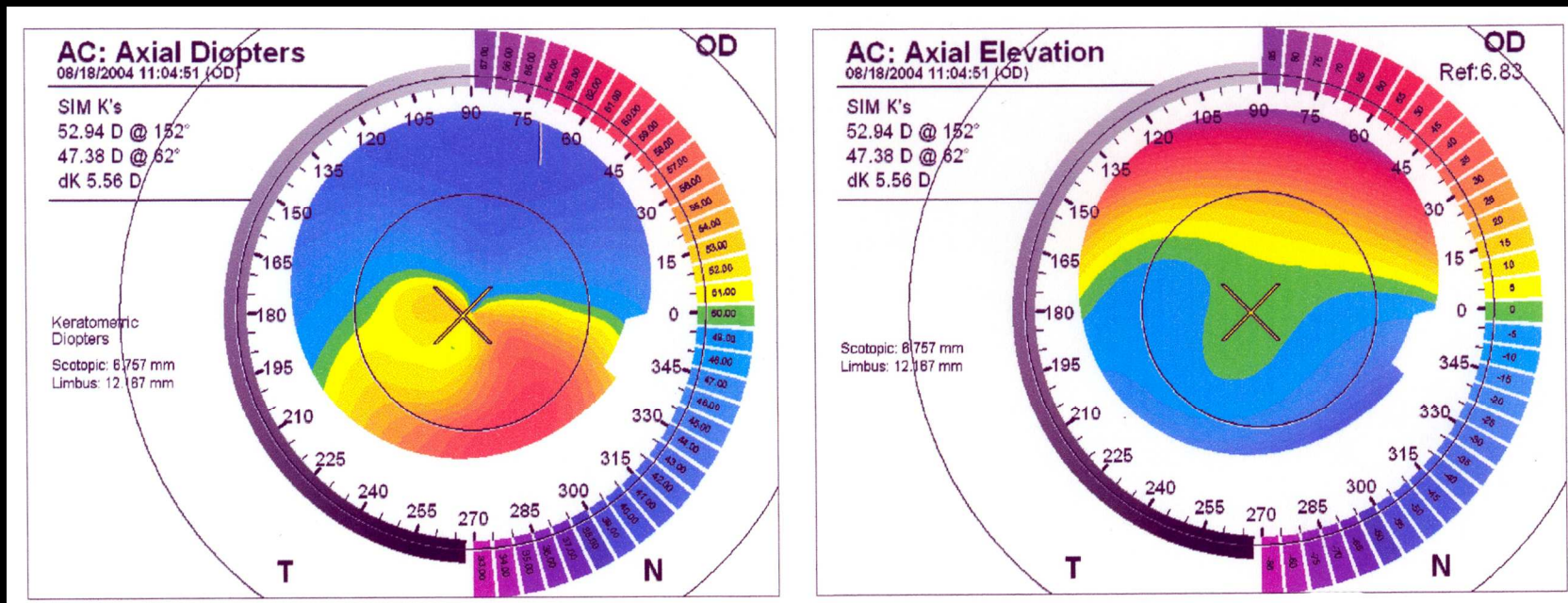
Irregular astigmatism (dry eyes con't)



KC



Elevation and curvature flipped with KC



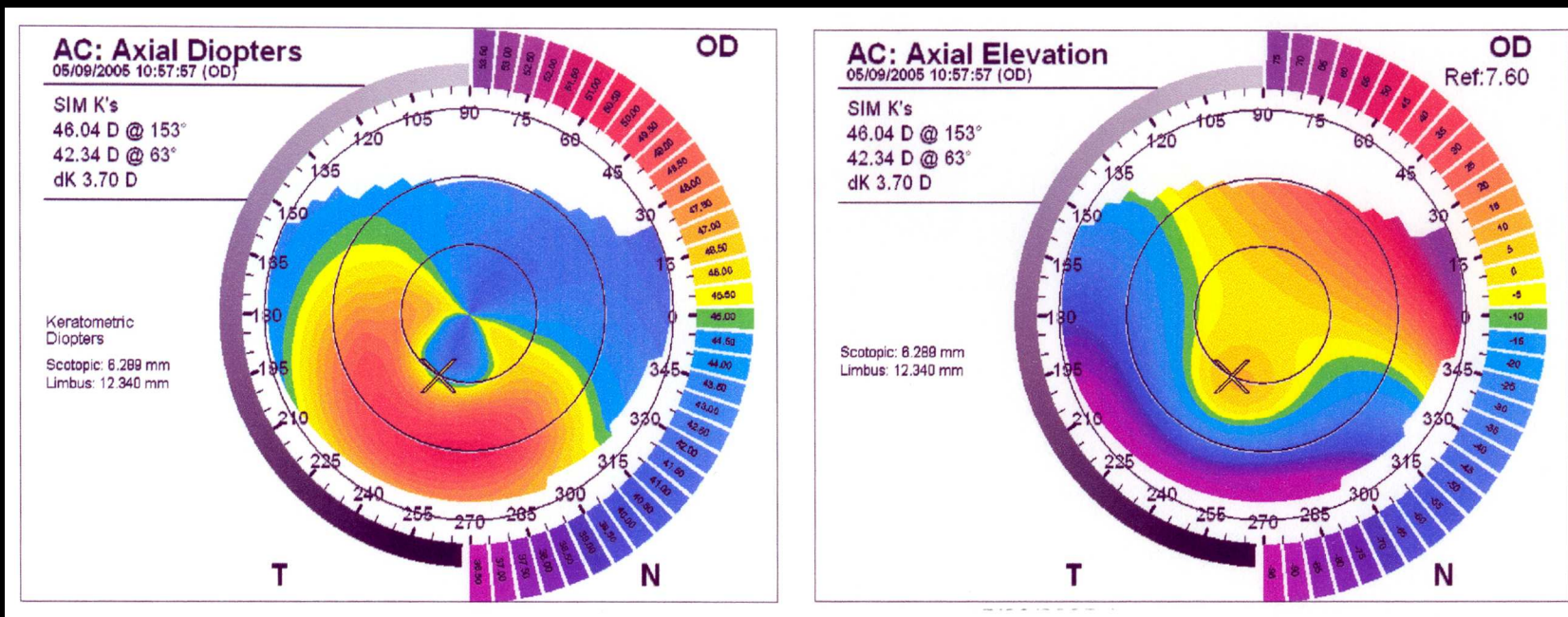
KC



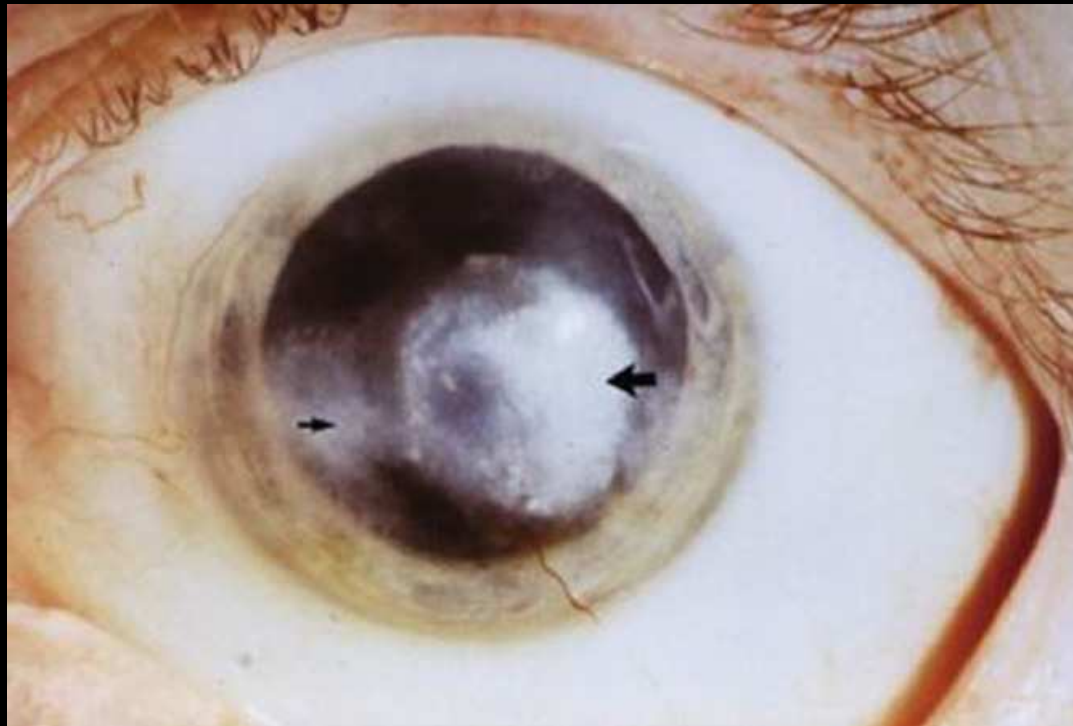
KC



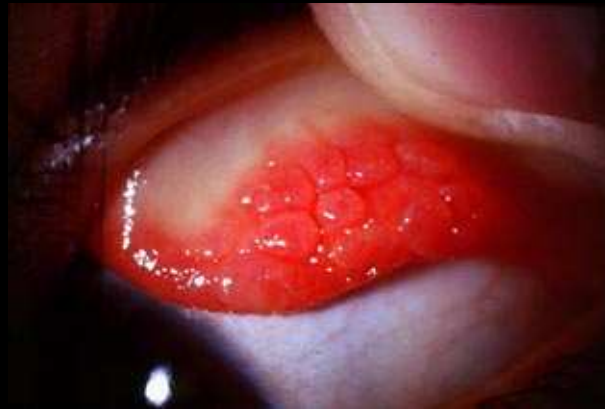
Pellucid curvature and elevation maps



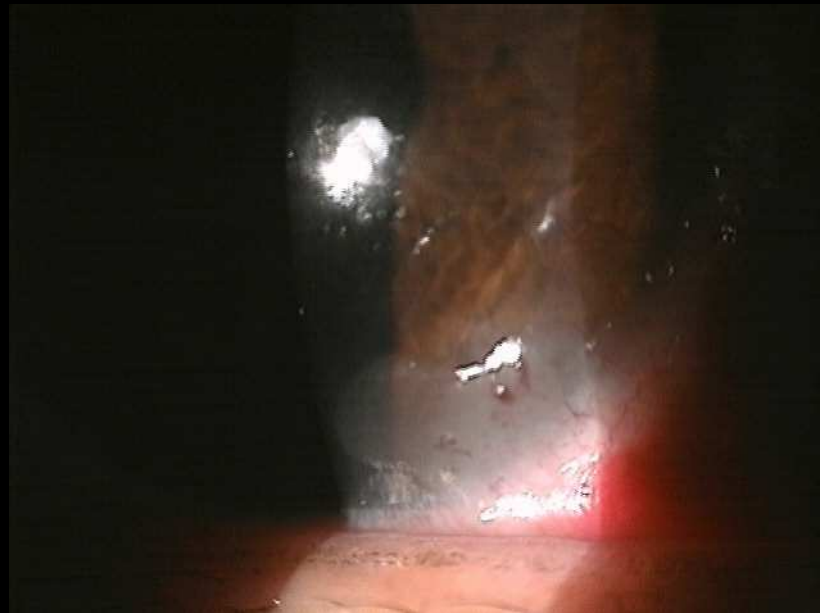
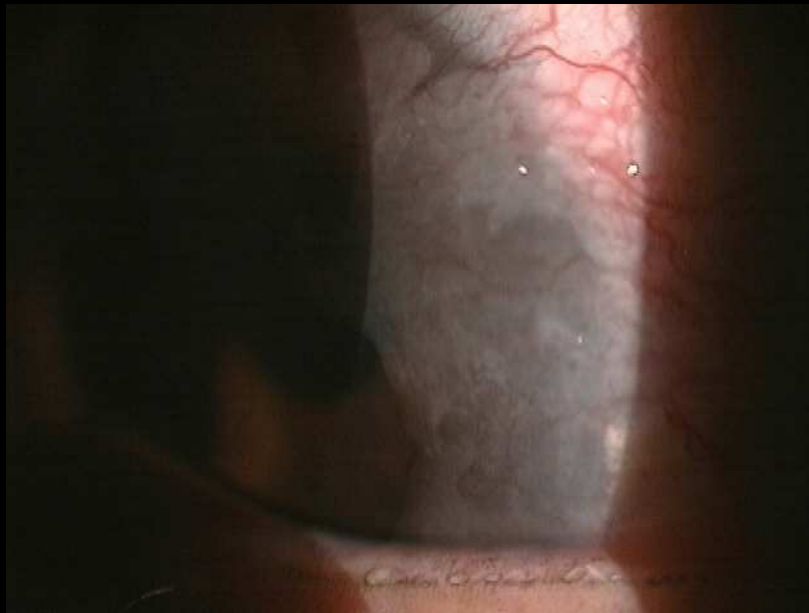
Corneal scarring



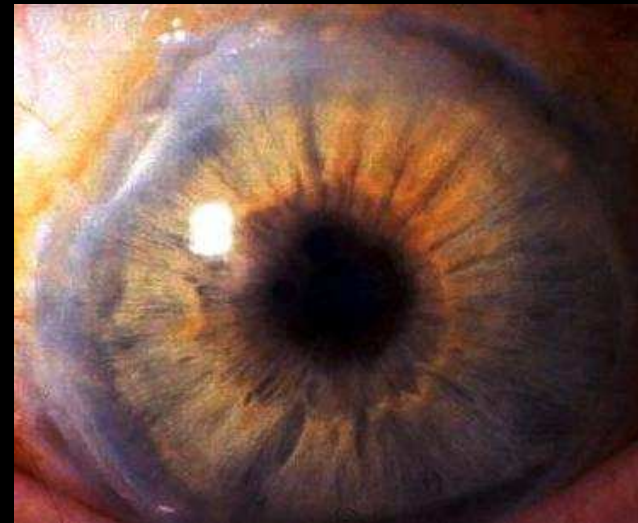
Extreme GPC or other lid disorders
may affect corneal shape



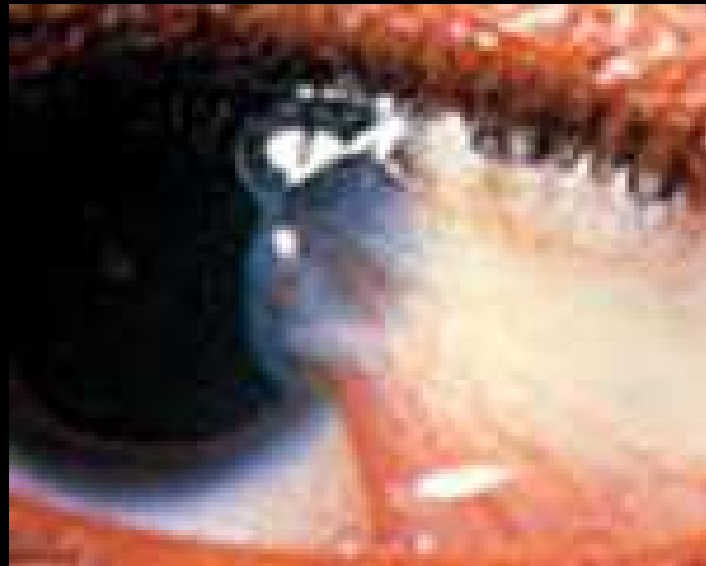
HPV CIN causing changes



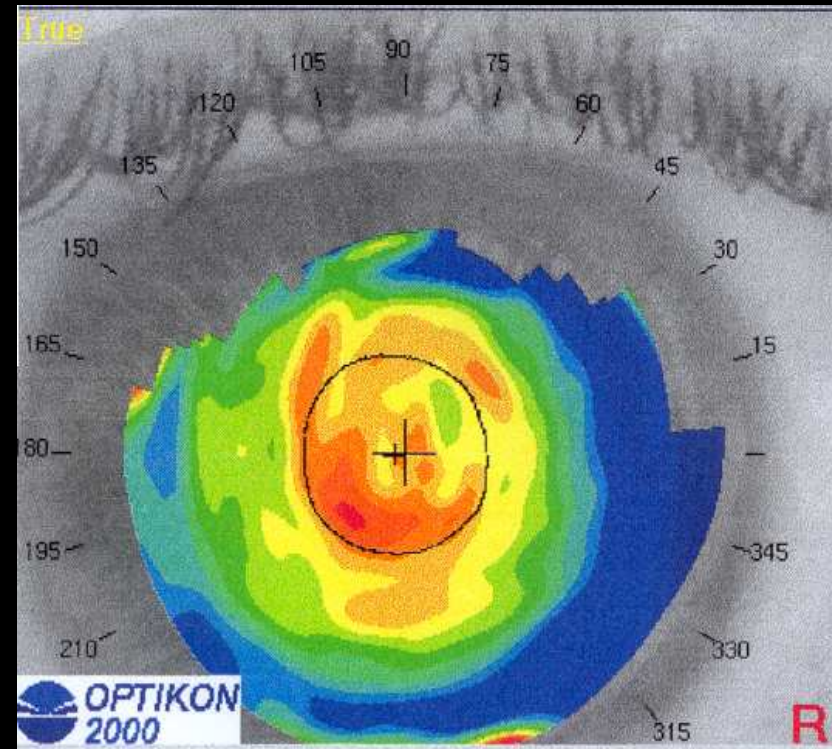
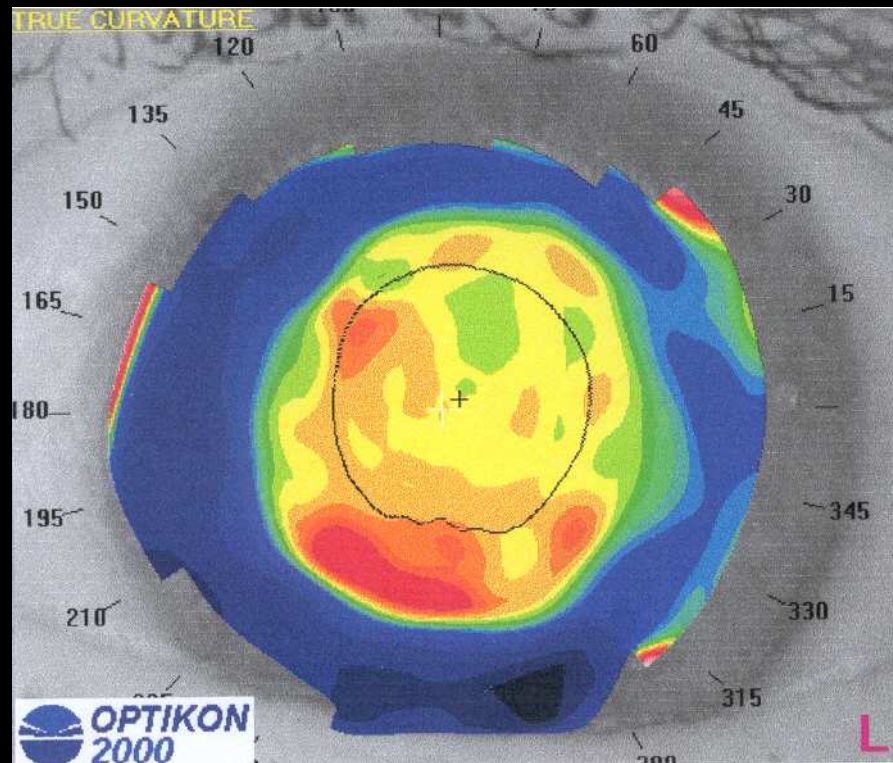
Peripheral melt/Mooren's



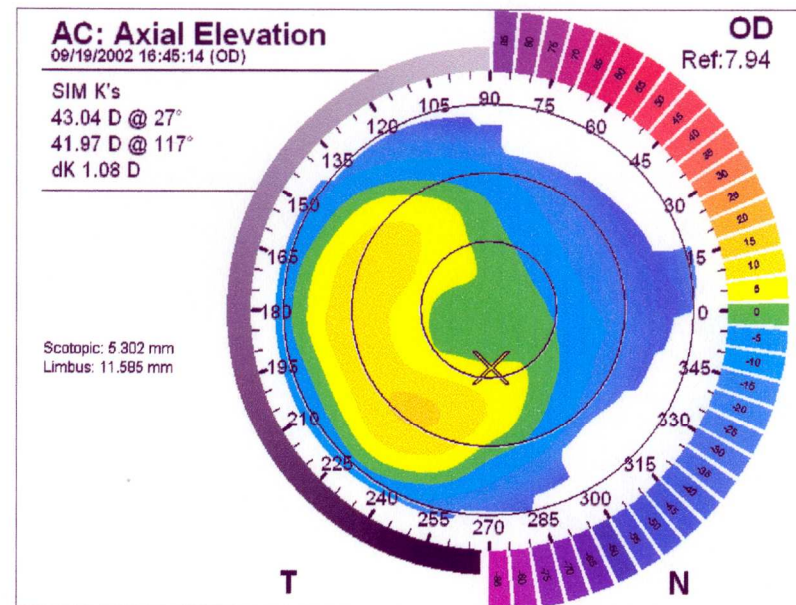
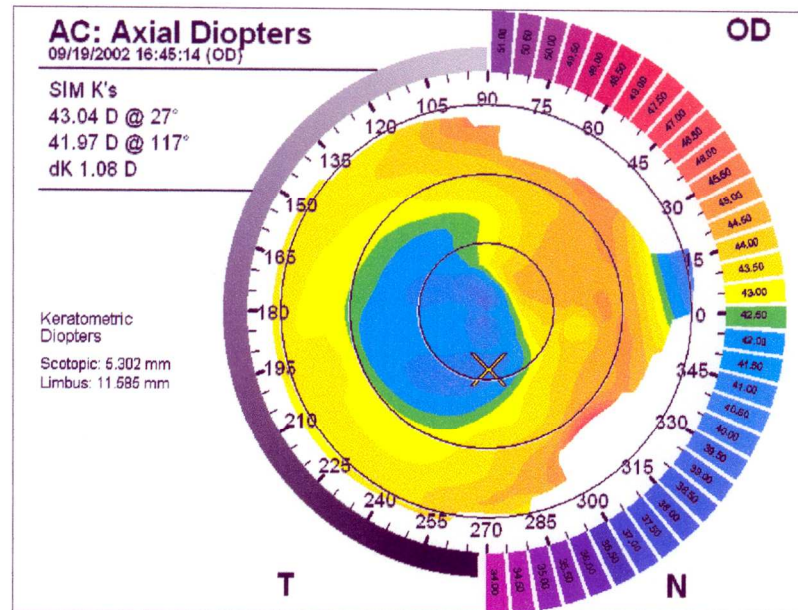
Pterygium



CK (left) vs. LASIK (right) for presbyopia (optical zone issues)



Decentered treatment



The power of 3 – 3-D stereo corneal topographer



astramax™
3 - D S T E R E O T O P O G R A P H E R

3-D stereo corneal topography:



Initial Images (3-camera, checker board)

Exam Edit View Utilities Window Help

New Exam New Patient Find

Patient Exam:

LECROY, DOROTHY

08/28/2002 11:05 - S
08/28/2002 11:13 - S
08/28/2002 11:05 - D

OS OD All

New Info Open

Patient Information:

Last (*): **LECROY**
First (*): **DOROTHY**
Middle:
Acct (*): **31371**
Birth (*): **01/11/1947**
Sex (*): **Female**
Phys: **Ming Wang**
Ref Phys:
Ref Group:
Diagnosis:

Notes:

Raw Eye Images Wang Vision Institute

08/28/2002 11:05: OD

Placido Images

Scotopic Pupil Images, Size: 5.454 mm

Photopic Pupil Images, Size: 3.968 mm

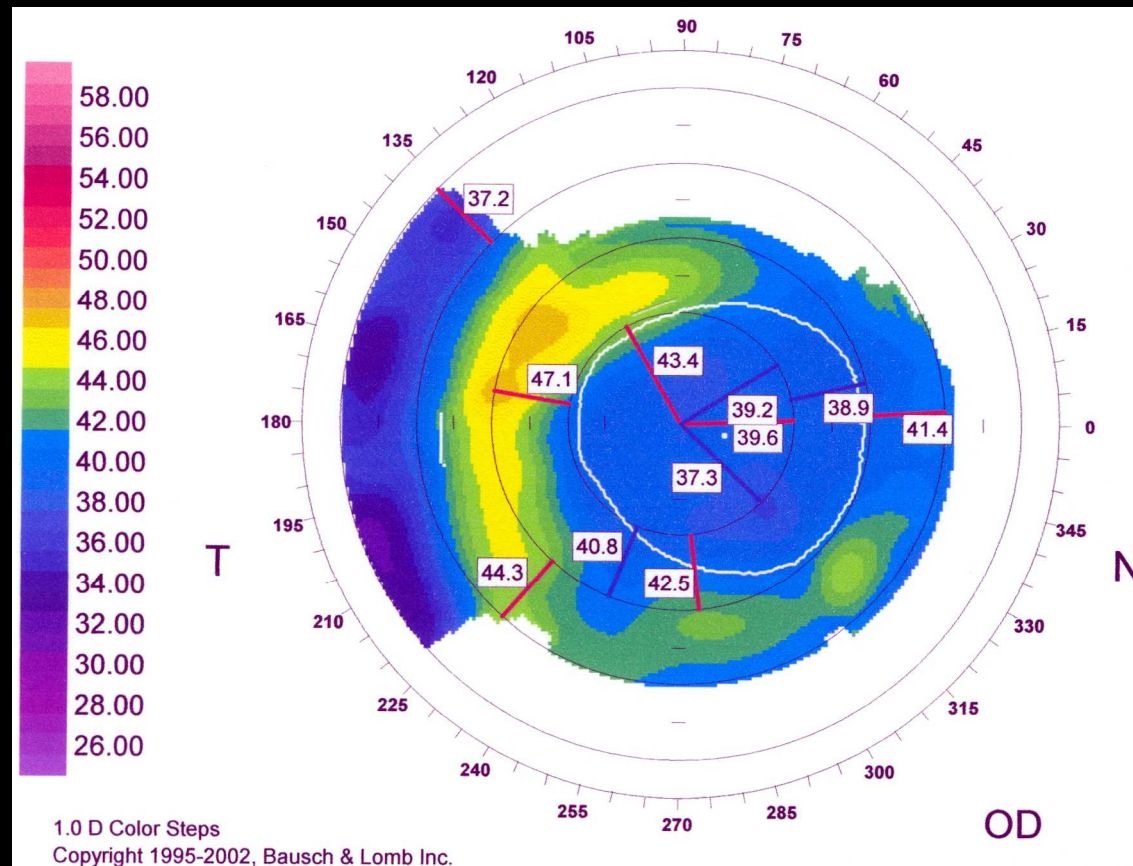
Cross/Pachymetry Images

LASERSIGHT

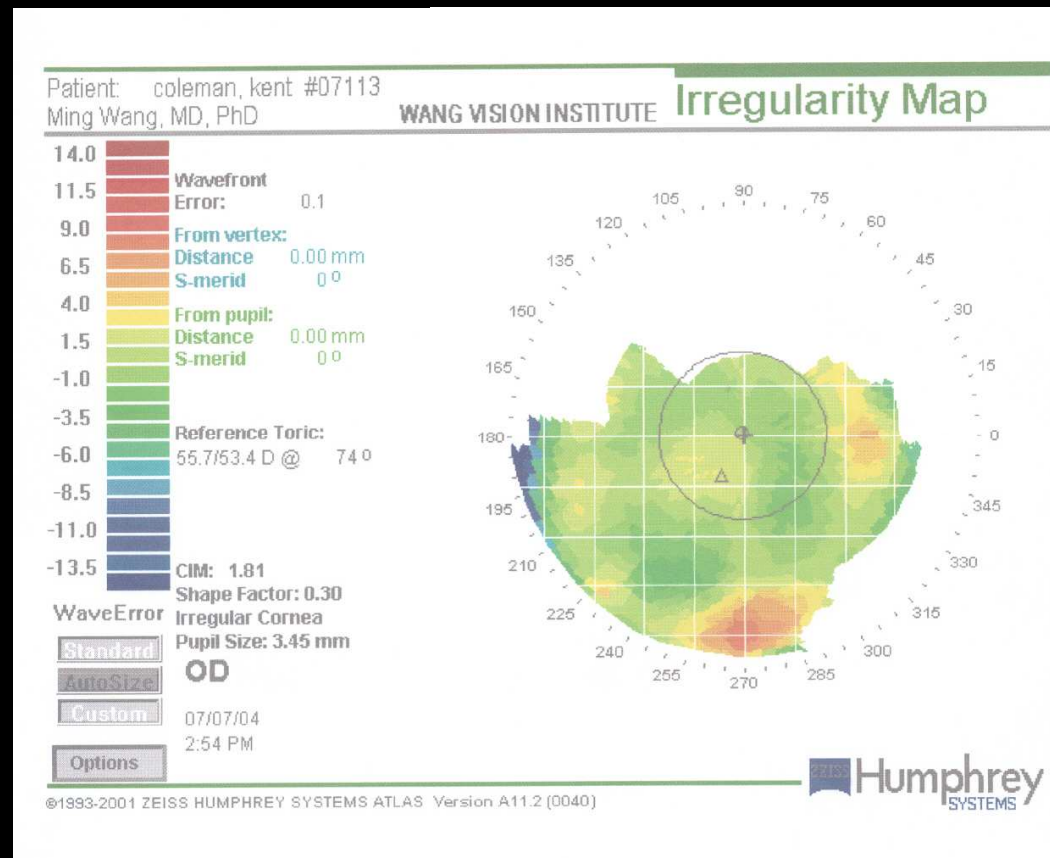
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Save Process Print Help

S/P myopic LASIK with ridge



S/p LASIK (irregularity map)



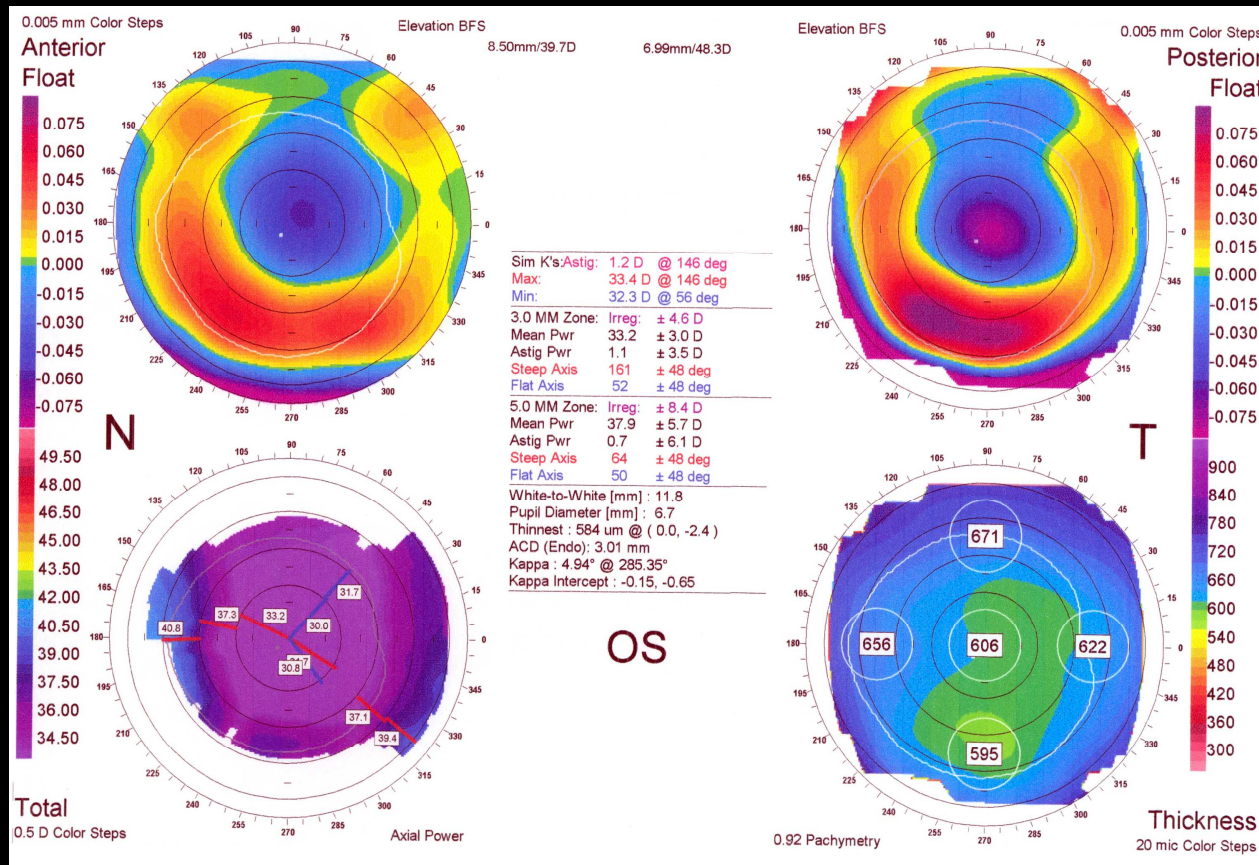
Irregular astigmatism

- Definition and classification;
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- Clinical causes;
- Other visually significant corneal changes;
- Topo-WF correlates of irregular astigmatism;
- Treatment.

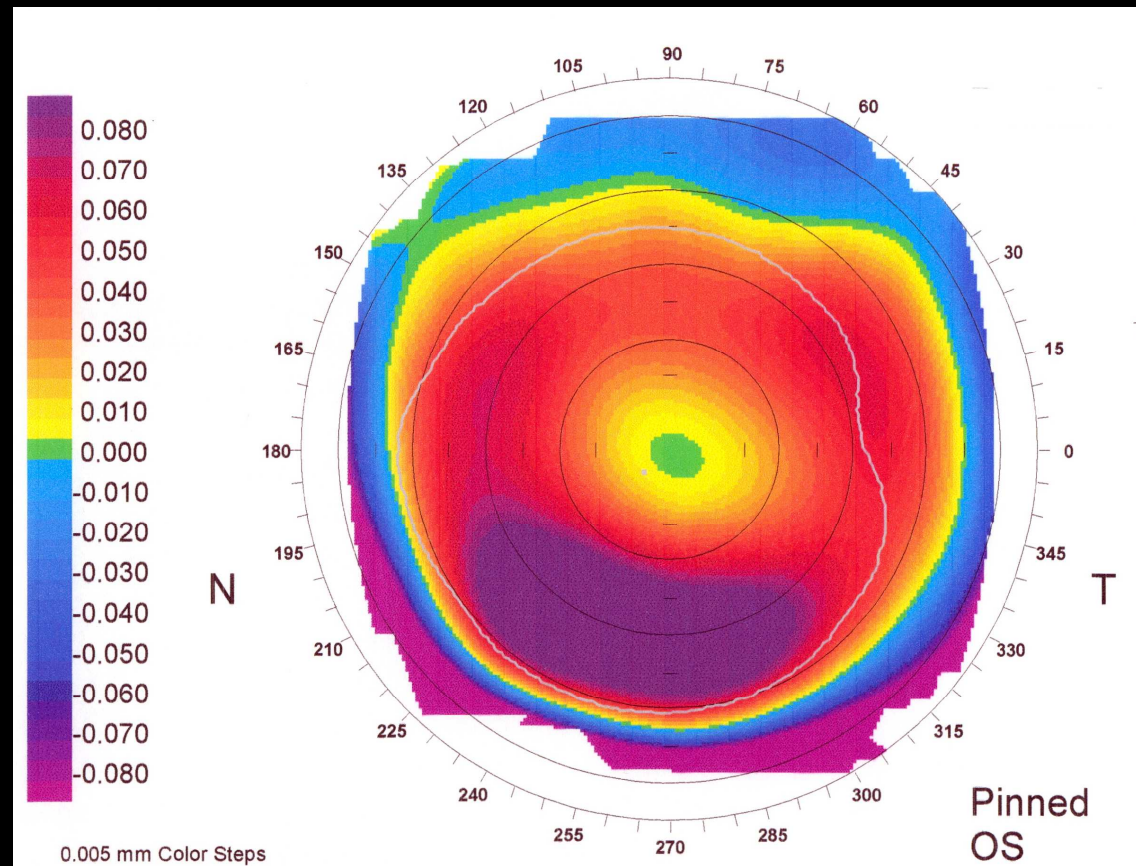
Other visual significantly corneal changes

- Extremely flat (or steep) corneas;
- Small optical zones;
- Posterior corneal changes (anterior and posterior corneal surface become *decoupled after anterior ablative procedure*).

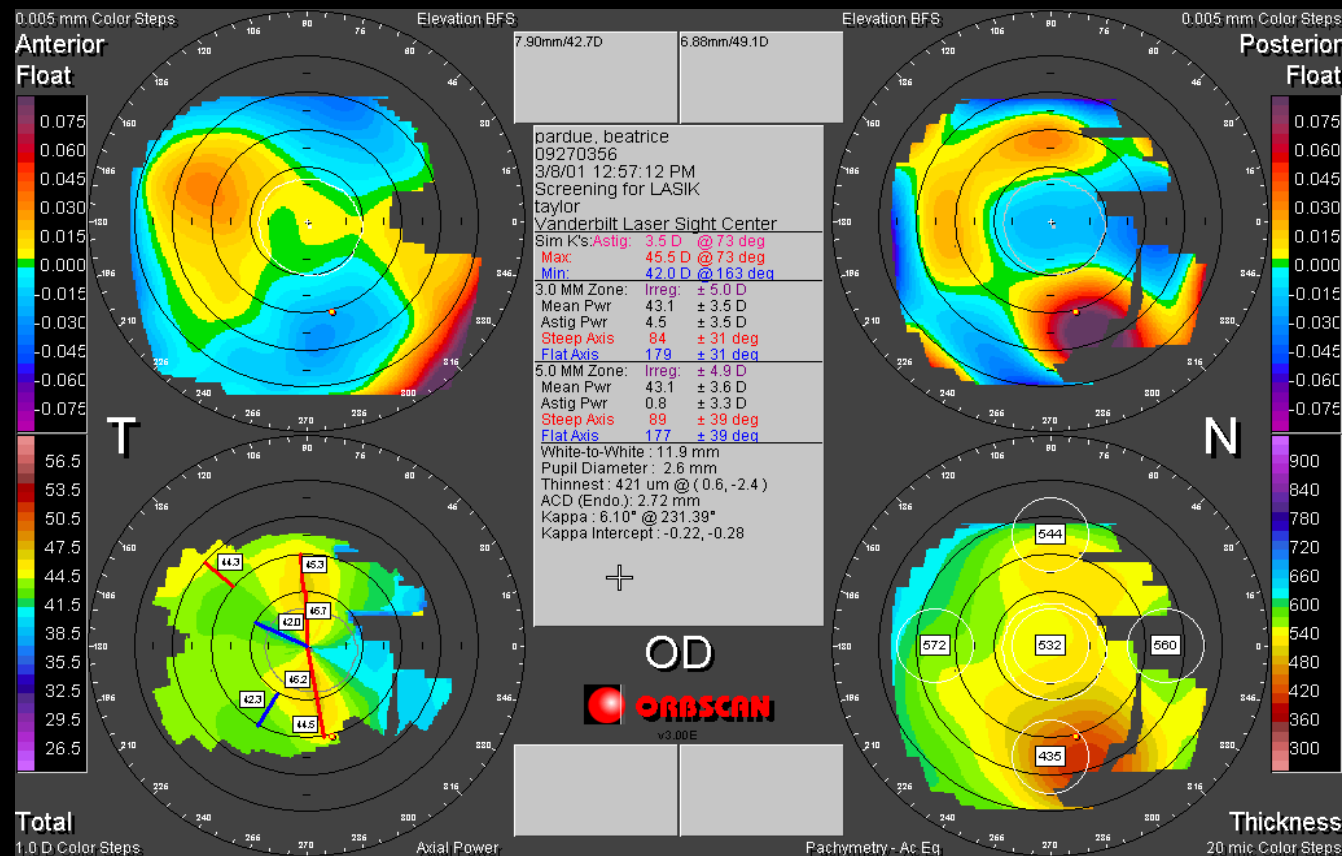
Flat cornea s/p LASIK (visual quality issues)



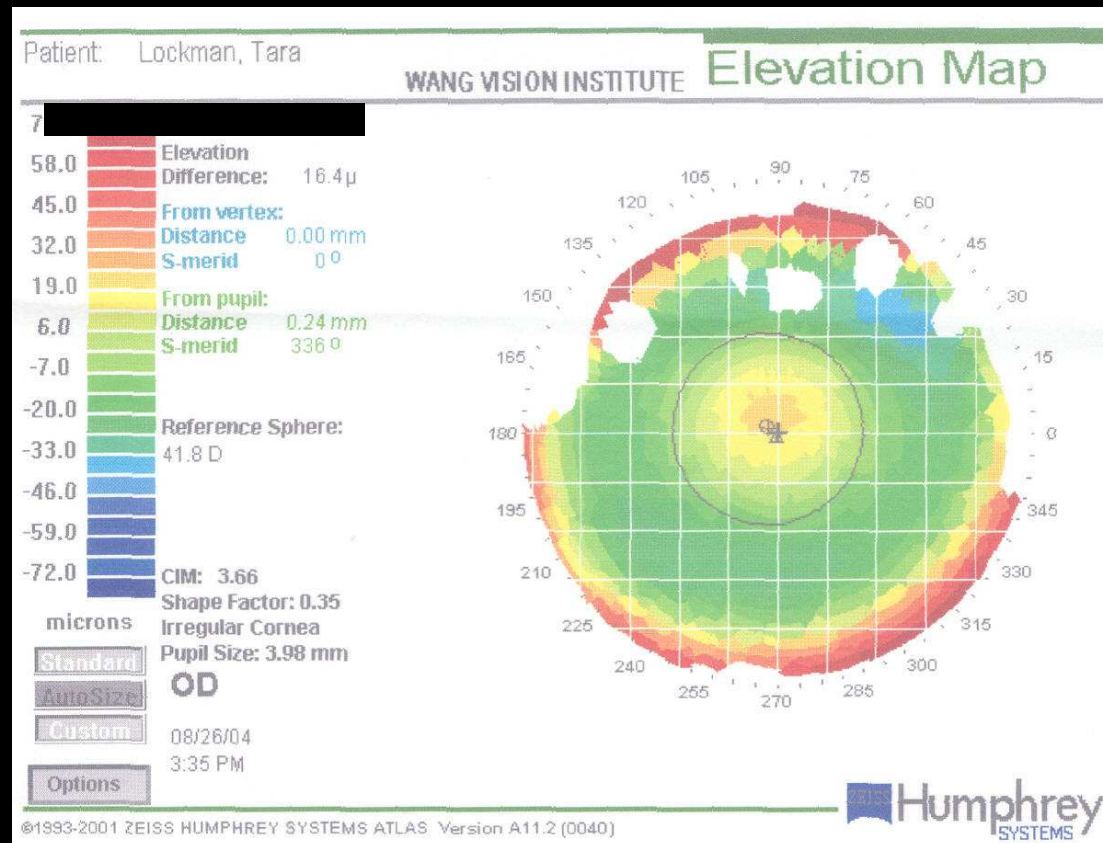
Posterior Surface changes after LASIK



Posterior changes with normal anterior corneal surface (visual **quality** issue)



S/P H-LASIK, small optical zone (night vision problems)



Irregular astigmatism

- Definition and classification;
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- Clinical causes;
- Other corneal visually significant changes;
- **Topo-WF correlates of irregular astigmatism;**
- Treatment.

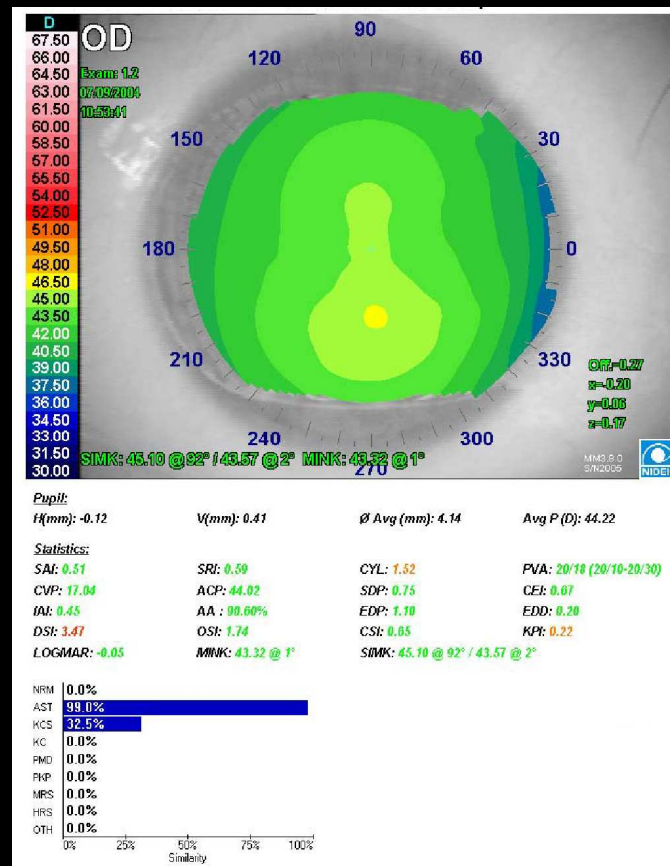
Corneal topographers

- Placido disc: Humphrey, EyeSys, Tomey Optikon, Topcon, Magellan, Orbscan, AstraMax 3-D;
- Scanning/projecting slit: Orbscan, AstraMax 3-D;
- 3-D stereo: AstraMax 3-D;
- Schimpflug rotating camera: Pentacam; Precisio;
- Ultrasound: Artemis.

3-D stereo checkboard AstraMax



Magellan



OCULUS - PENTACAM

Patient Examination Display Settings

Name: Demo, Pre-Post Lask ID: change in post. surface Date of Birth: 07/13/1978

Exam

300
340
380
420
460
500
540
580
620
660
700
740
780
820
860
900
10 μ m
Pachy.
Abs
+1.0
0.0
-1.0
-2.0
-3.0
-4.0
-5.0
-6.0
-7.0
-8.0
-9.0
-10.0
-11.0
-12.0
-13.0
-14.0
0.25 D
Curvature
Rel

A: 10/27/2003 15:32:48 Left (25) post. op.

Corneal Thickness

Sagittal Curvature (Back)

B: 09/30/2003 14:41:52 Left (25) pre. op.

Corneal Thickness

Sagittal Curvature (Back)

Difference A - B

Corneal Thickness

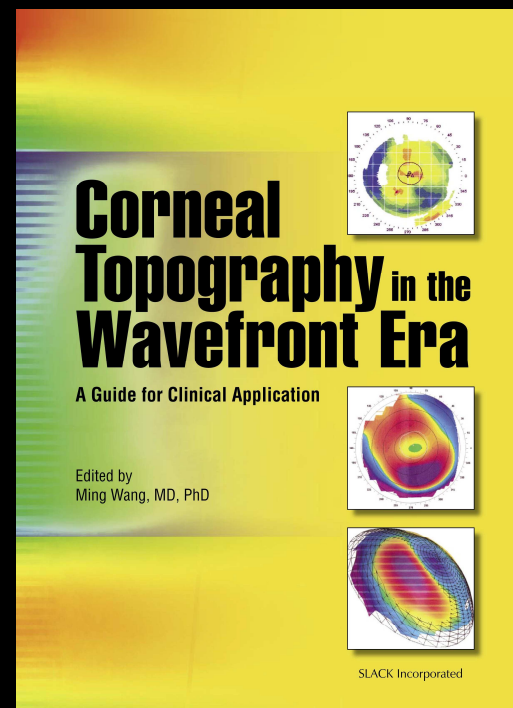
Sagittal Curvature (Back)

Corneal topo and combined systems

- Placido disc: Humphrey, EyeSys, Tomey Optikon, Topcon, Magellan, Orbscan, AstraMax 3-D;
- Scanning/projecting slit: Orbscan, AstraMax 3-D;
- 3-D stereo: AstraMax 3-D;
- Schimplug rotating camera: Pentacam;
- Ultrasound: Artemis;
- Topo-WF combined systems.

New Book: "Irregular Astigmatism"
(SLACK)

New comprehensive textbook



Topo-WF correlates of irregular astigmatism

TOPOGRAPHY

WAVEFRONT ABERROMETRY

Loss of prolate
cornea, small
optical zone

Increase in
spherical
aberration

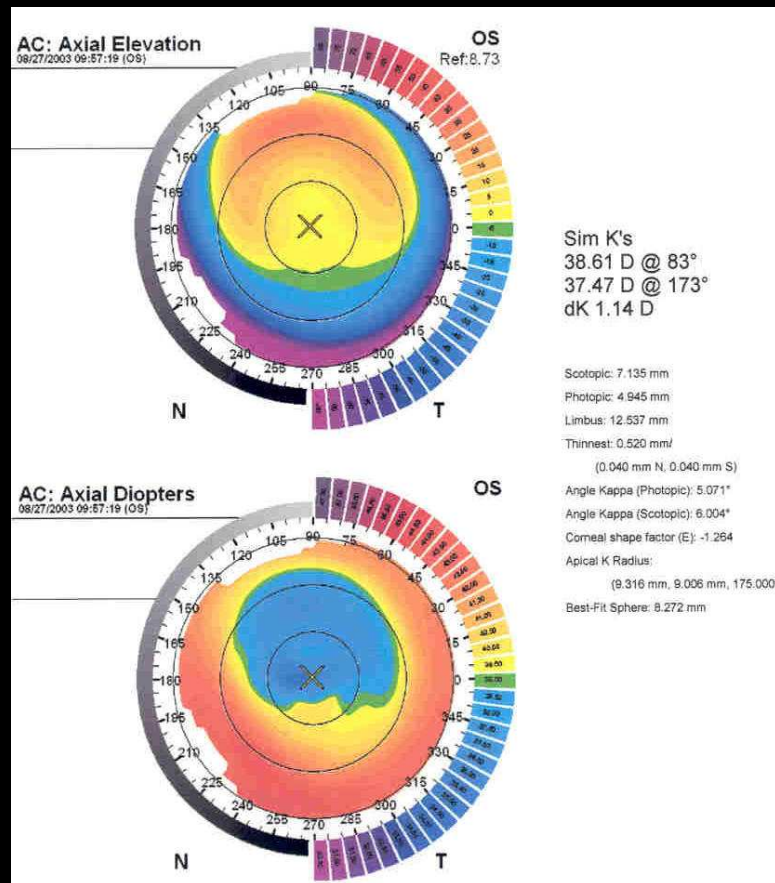
Irregular
astigmatism

Increase in coma
and trefoil

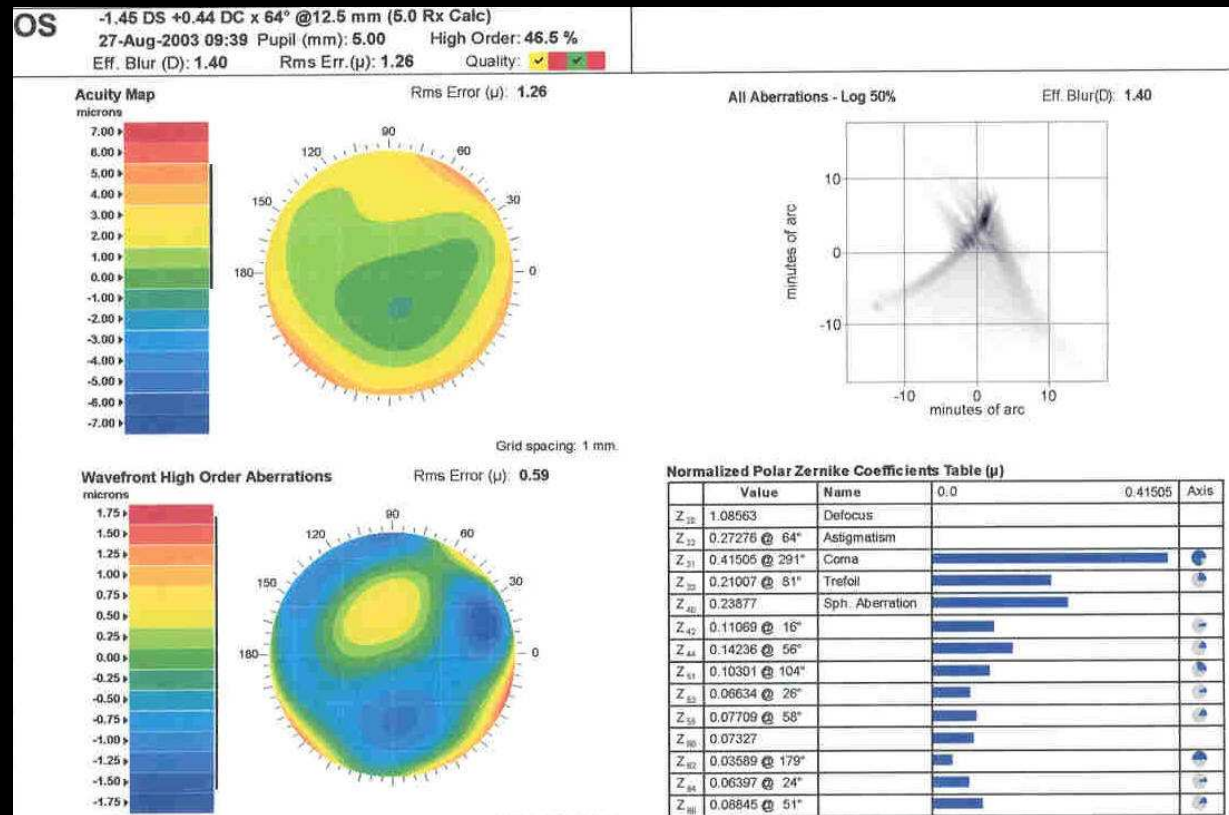
Decentered
ablations

Coma

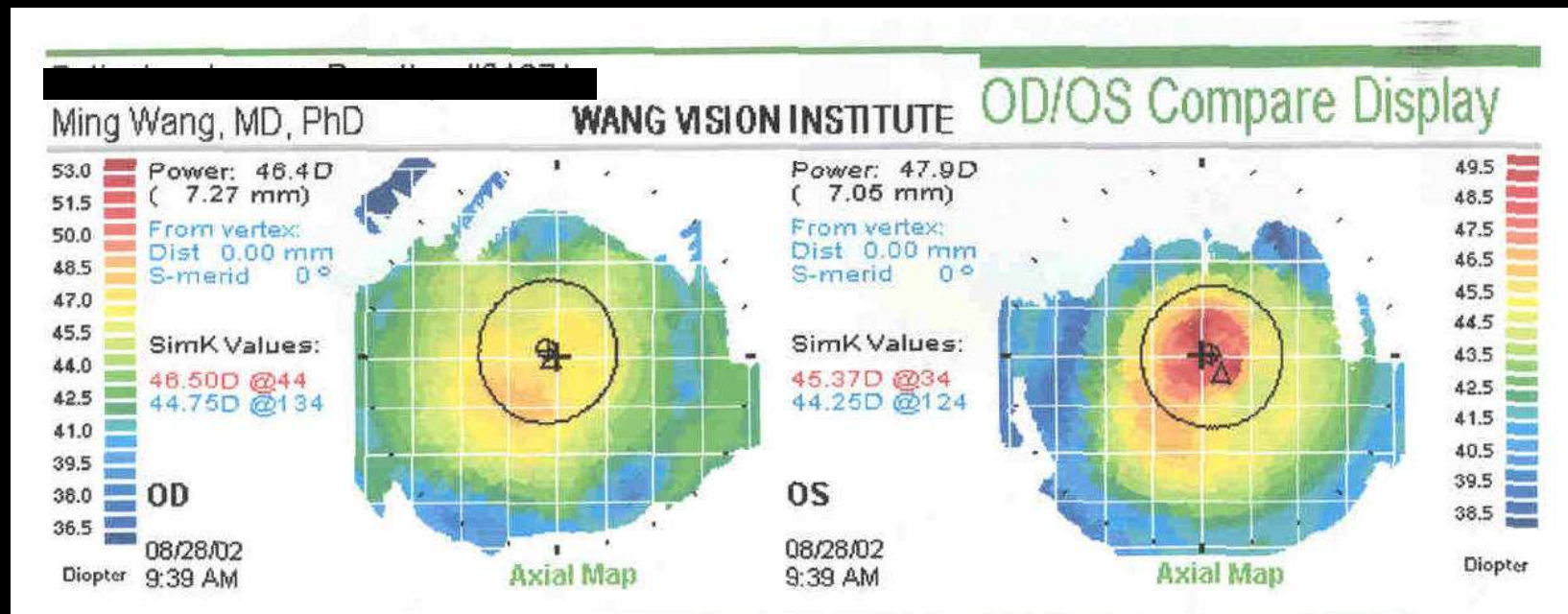
Decentered ablation (topo)



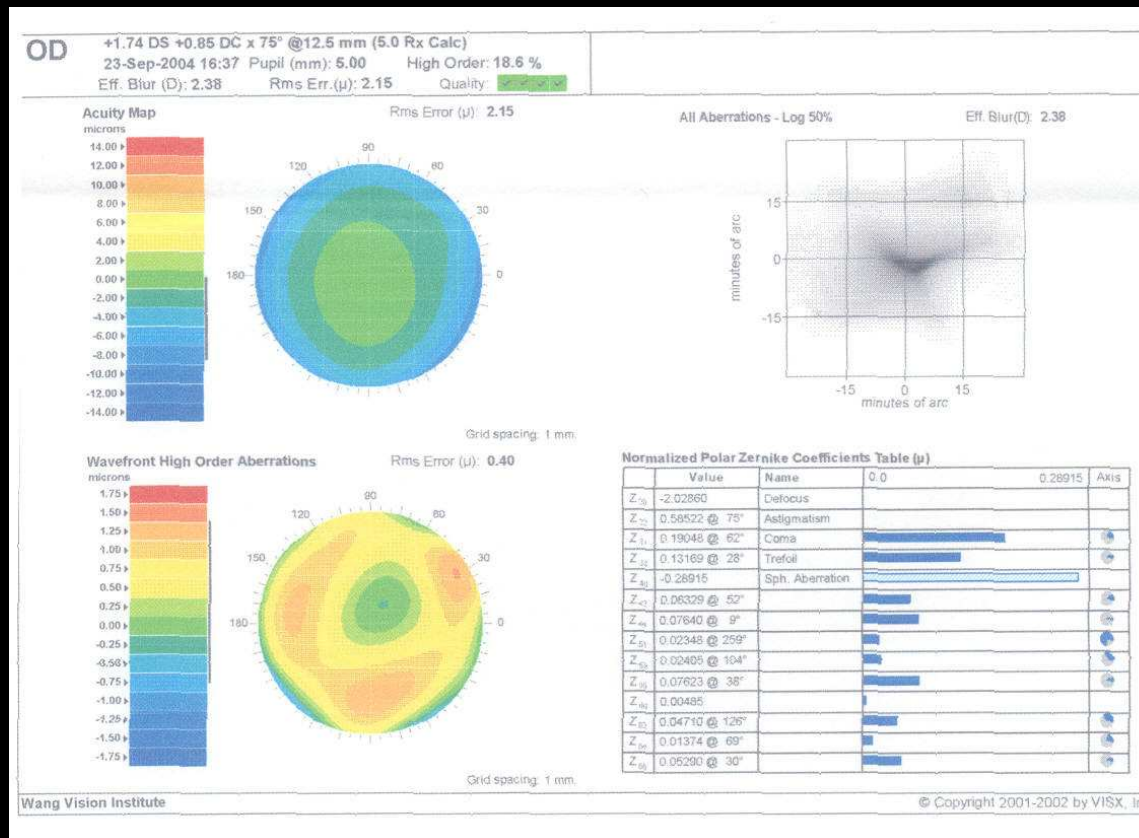
Decentered ablation (WF: coma)



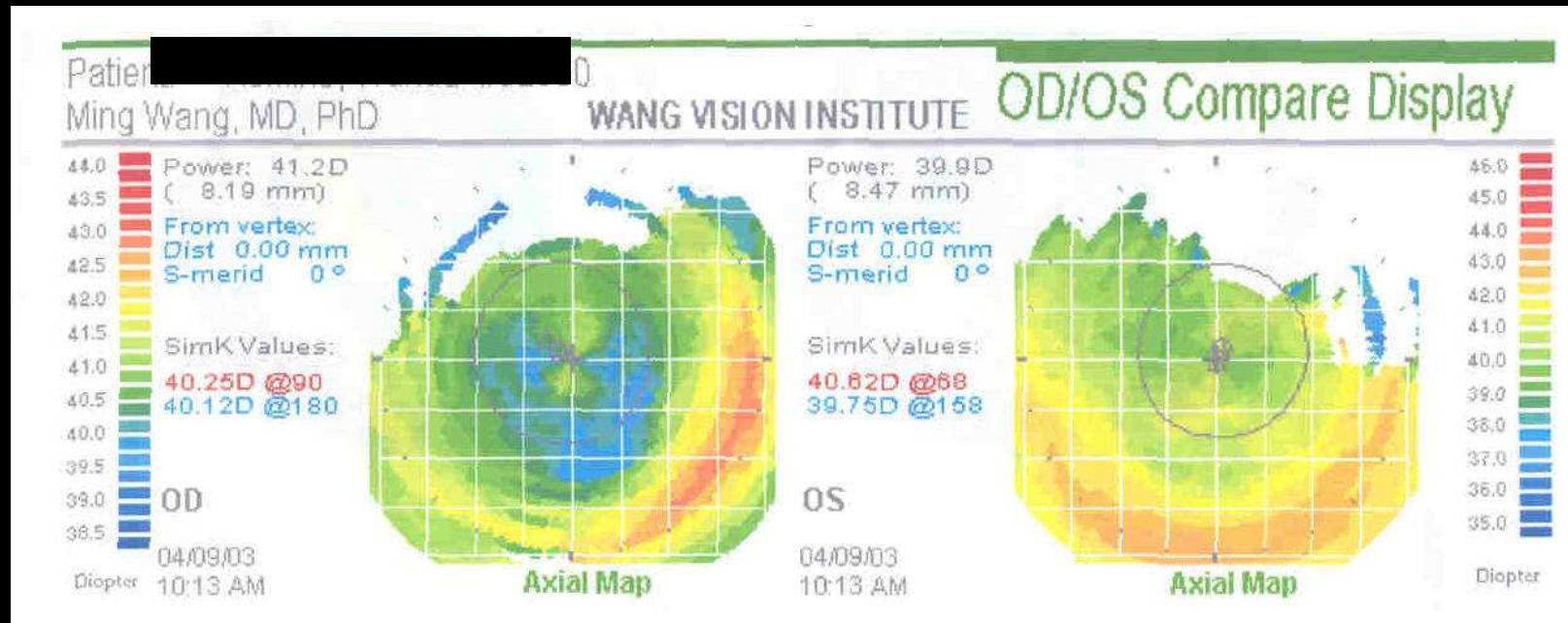
Small optic zone s/p H-L (topo)



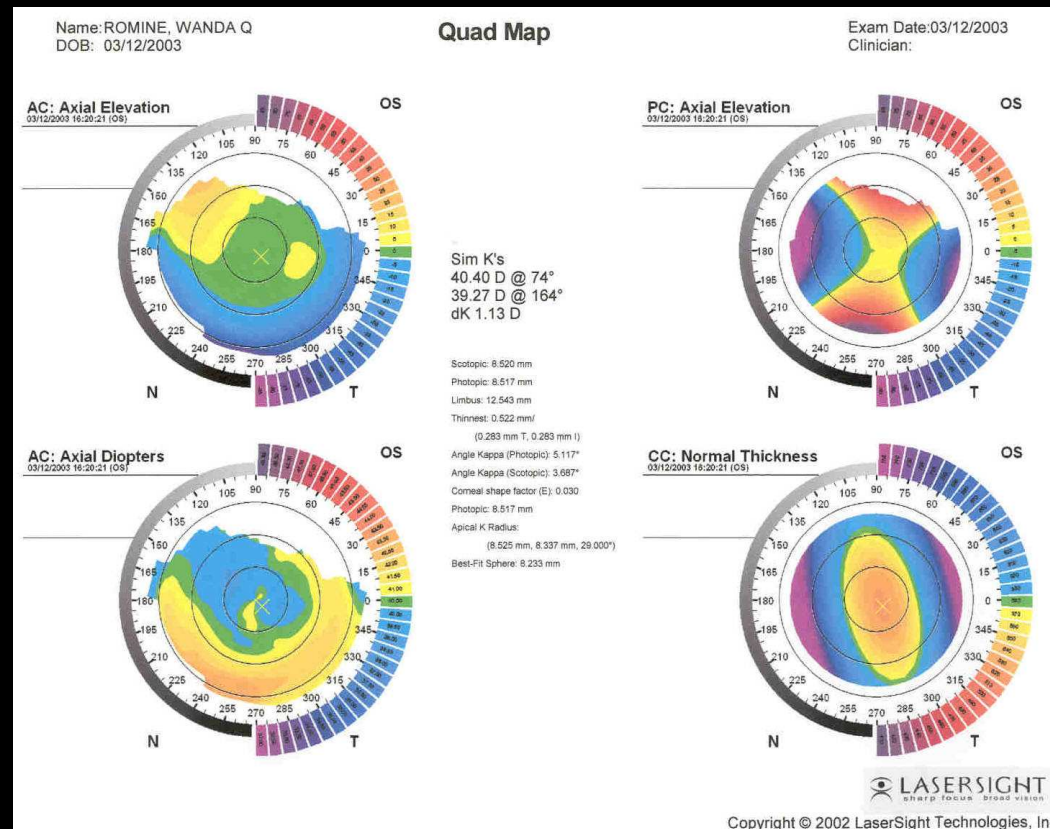
Small optical zone s/p H-L (WF: spherical aberration)



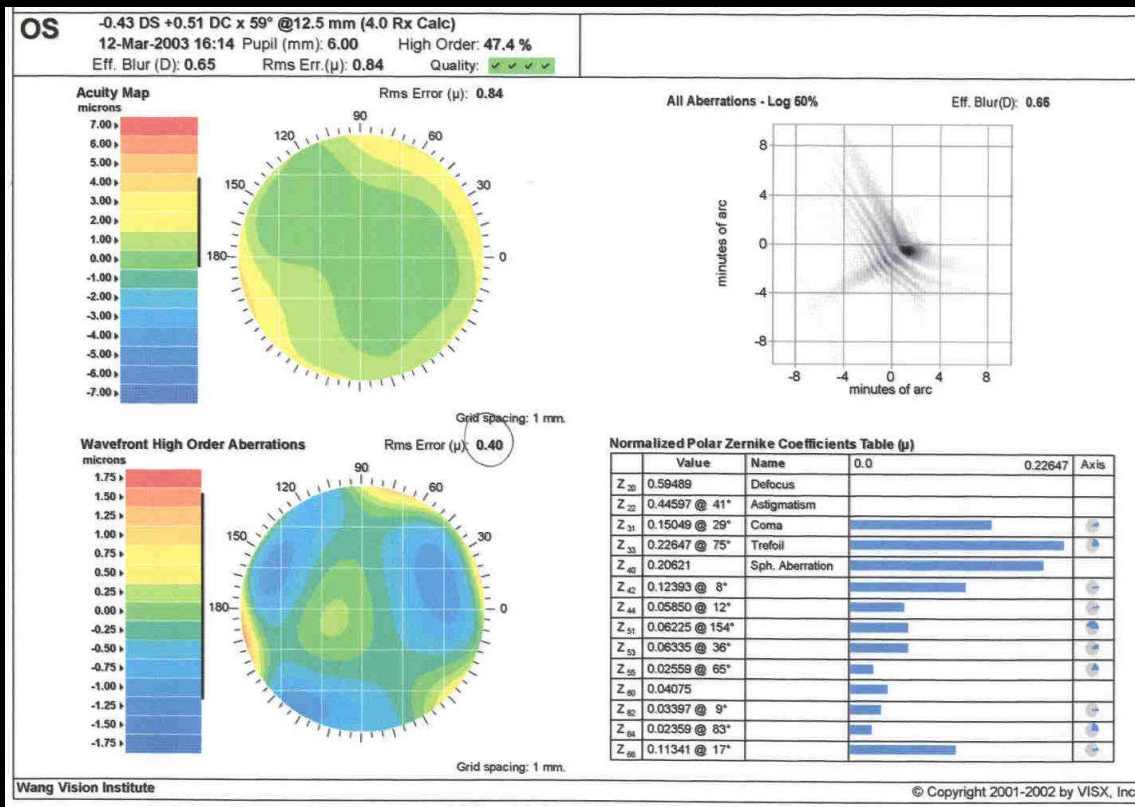
Irregular astigmatism (topo): night glare and decreased BSCVA



Irregular astigmatism (topo, 3-D)



Irregular astigmatism (WF: trefoil, SA, coma)



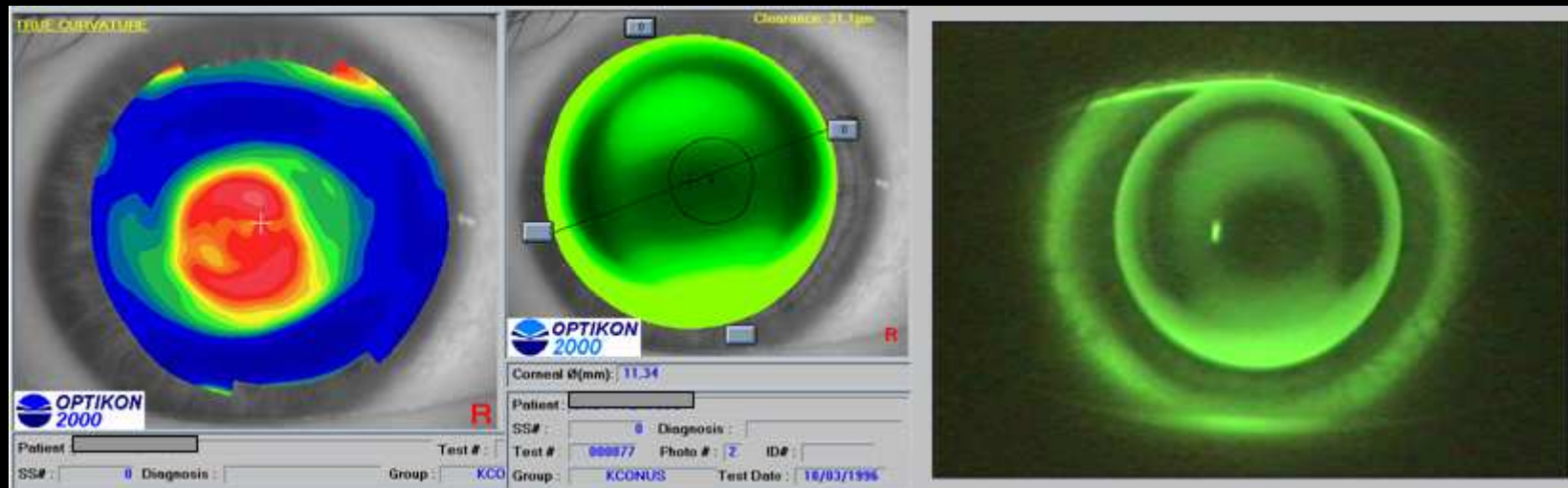
Irregular astigmatism

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- **Treatment.**

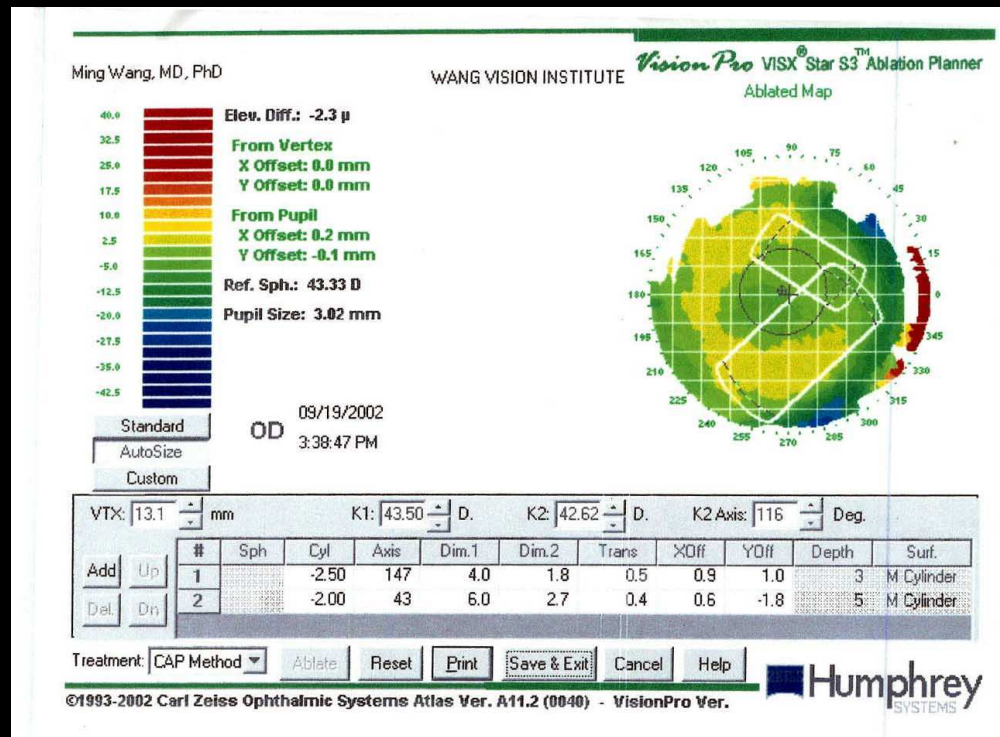
Treatment options for irregular astigmatism

- RGP;
- C-CAP for decentered treatment;
- Wavefront-driven custom;
- Topo-driven custom;
- Intacs for KC;
- Topo-wavefront combined approach (ACAP);
- Others.

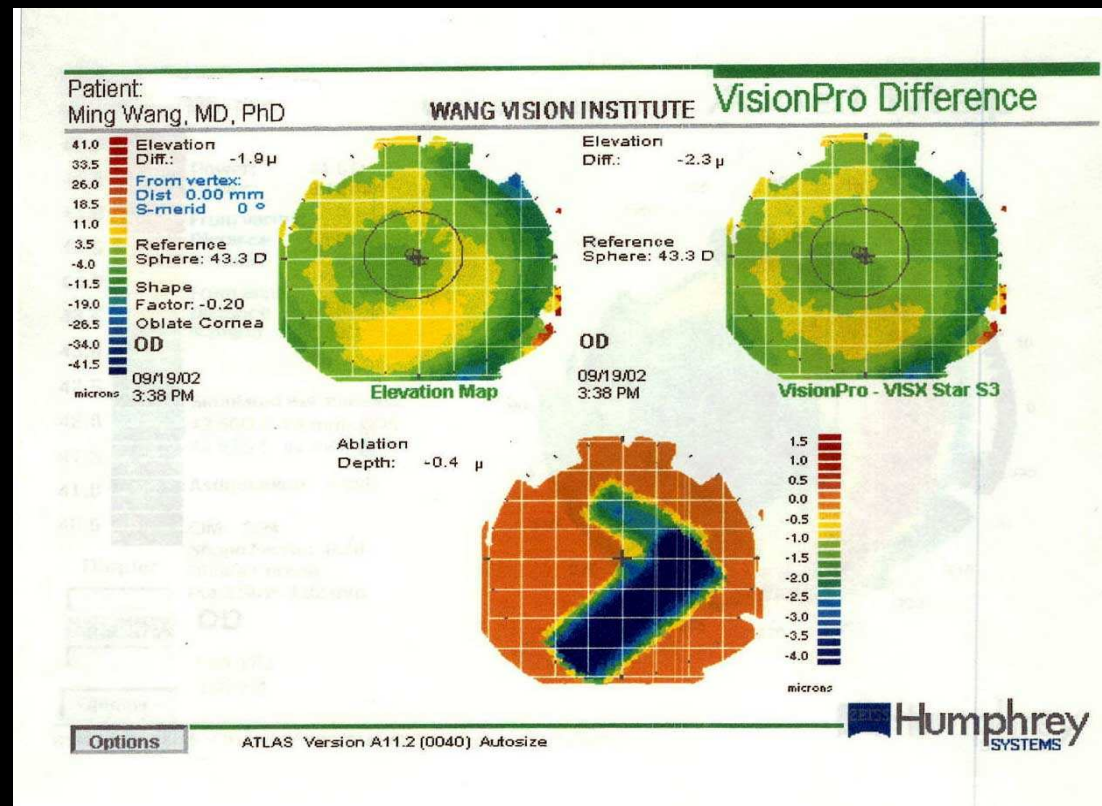
RGP



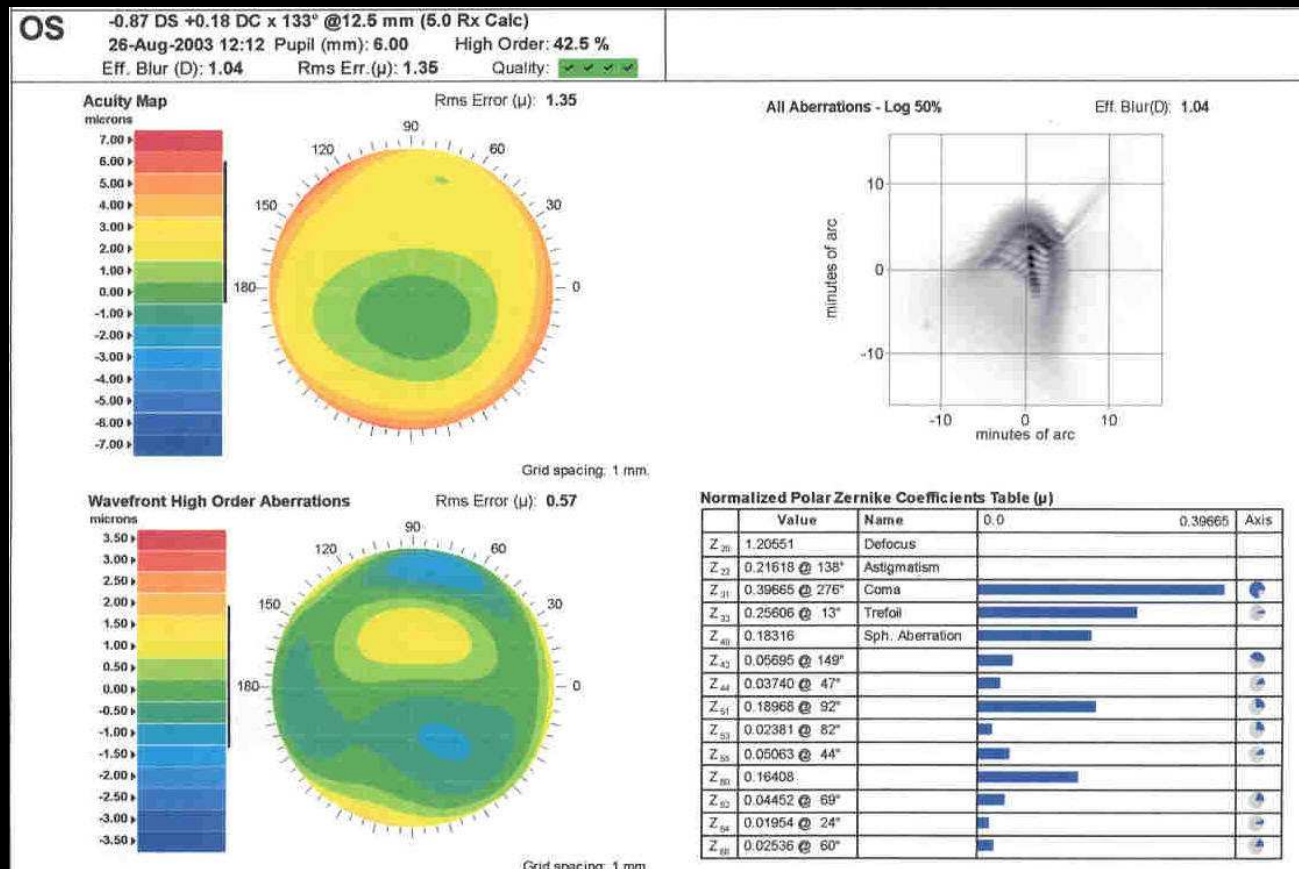
C-CAP for decentered treatment



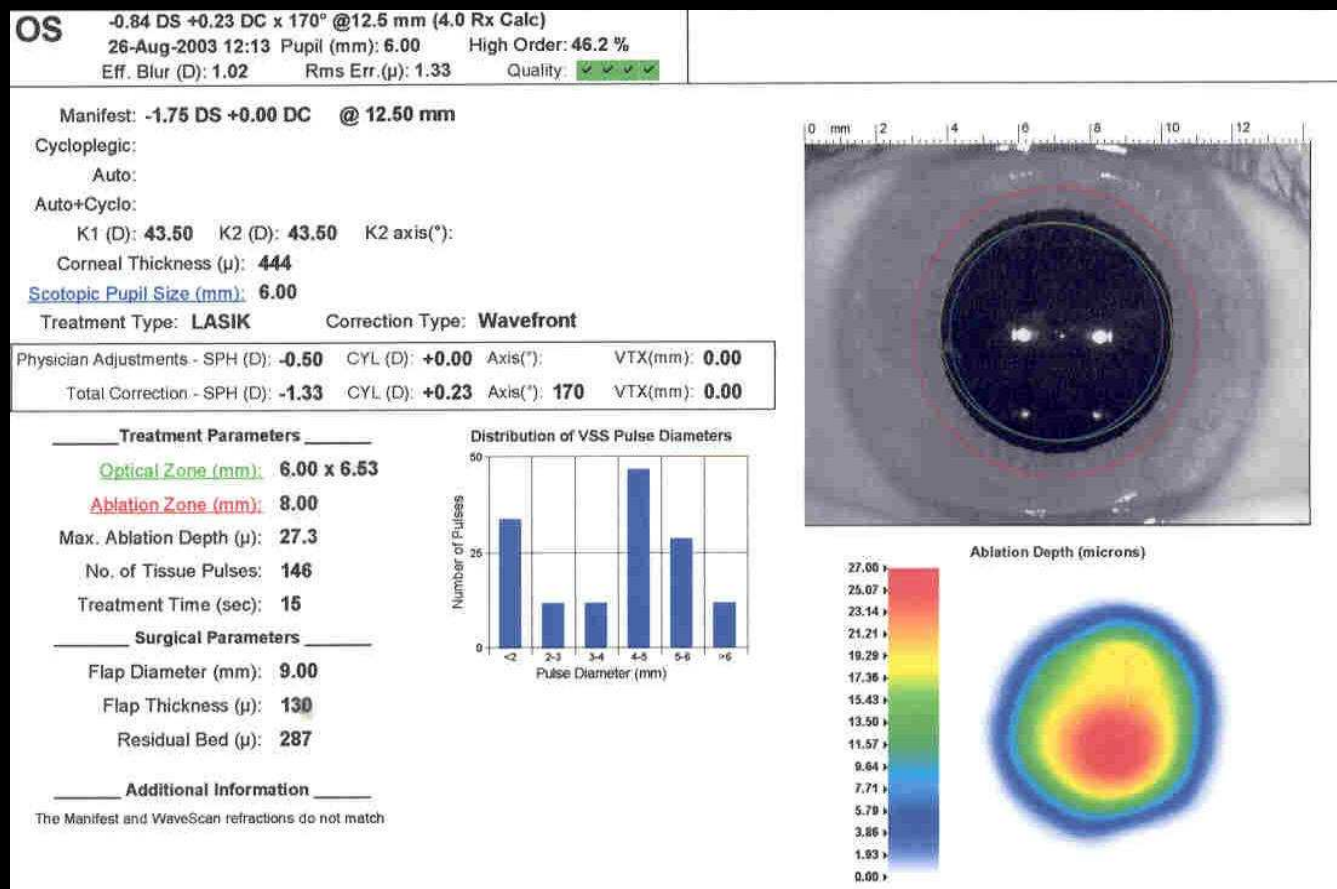
C-CAP: pre and post and difference (volume of corneal tissue removed) map



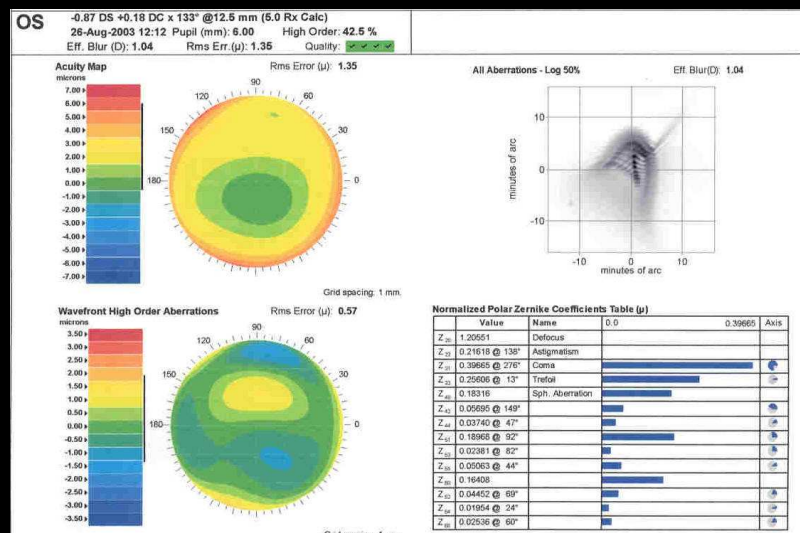
Wavefront-driven custom: Irregular astigmatism (coma, trefoil)



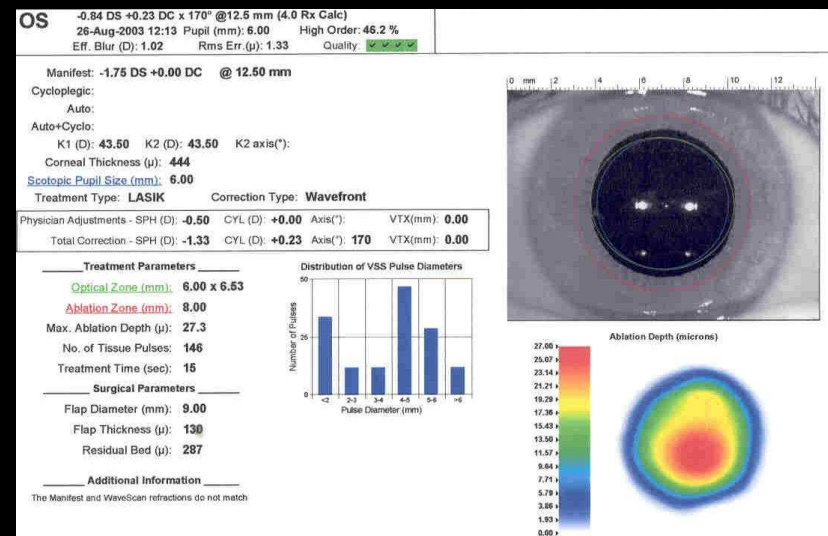
Wavefront-driven custom Rx for irregular astigmatism (coma and trefoil, volume of corneal tissue removed Rx plan)



Wavefront-driven custom for irregular astigmatism: preop WF and corneal removal volume Rx plan

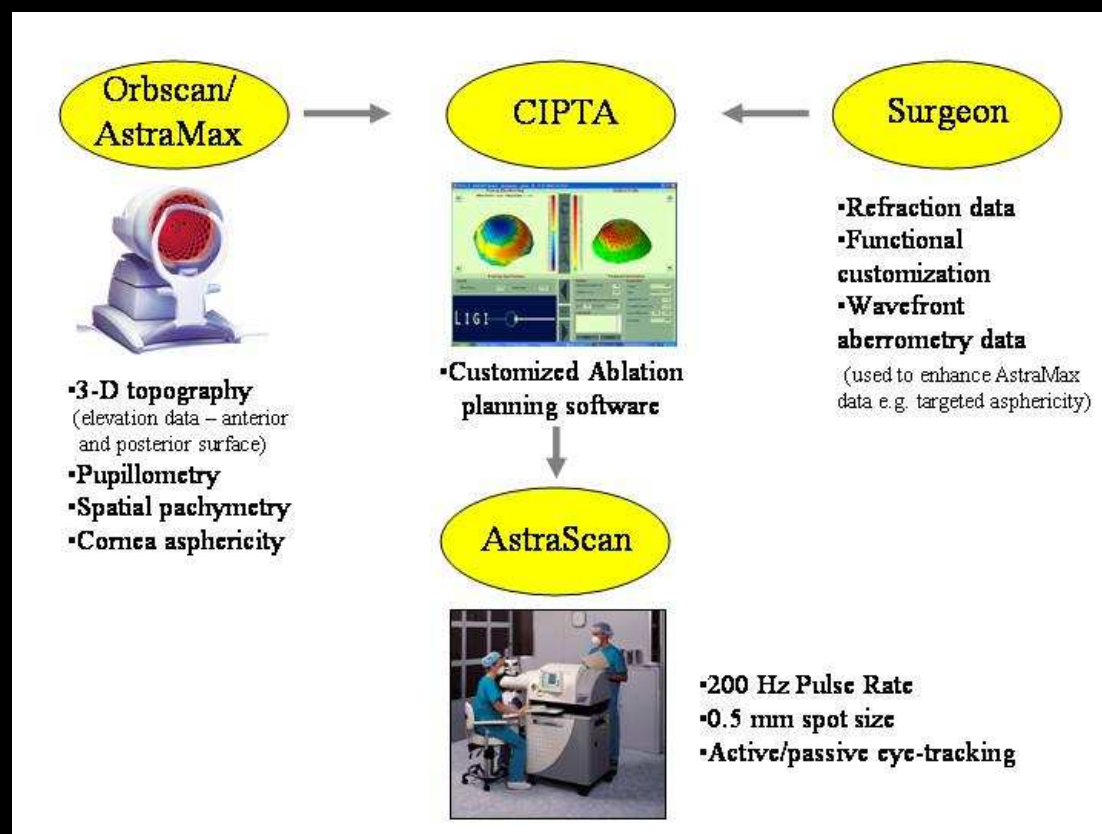


Preop WF



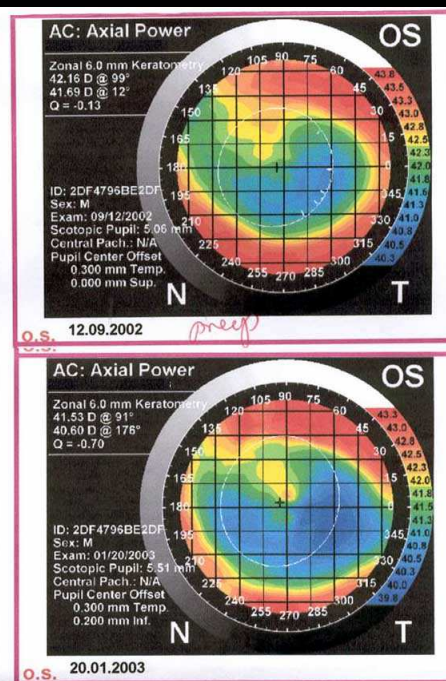
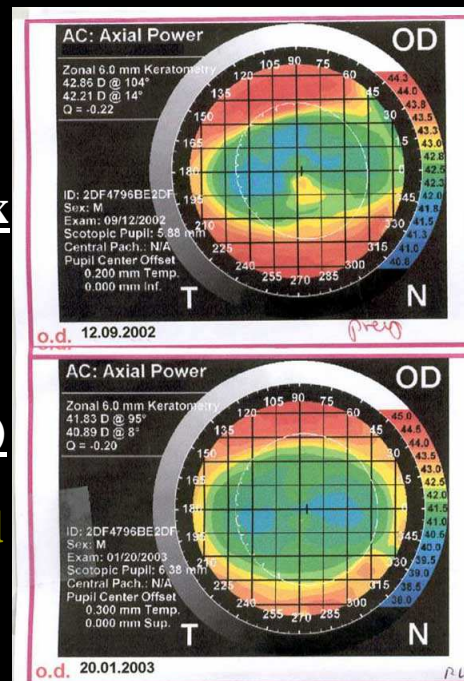
Rx plan (corneal tissue to be removed)

Topography-guided custom LASIK



Topo-driven custom: preop topo (central island) and postop topo, comparing custom (OD) with non-custom (OS) (Stojanovic)

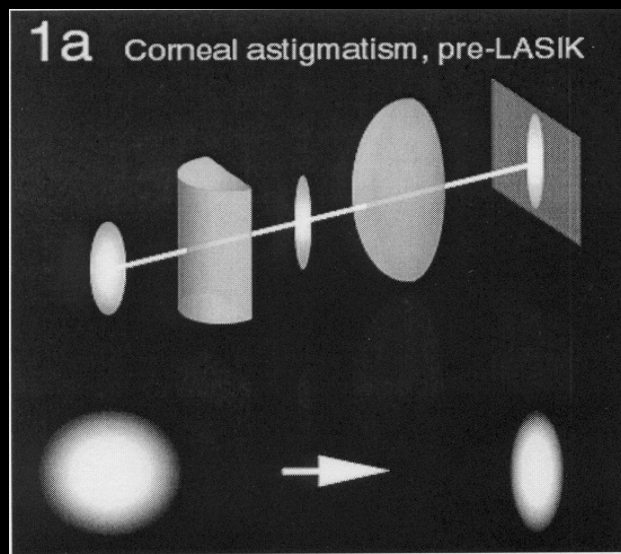
Pre-therapeutic Rx



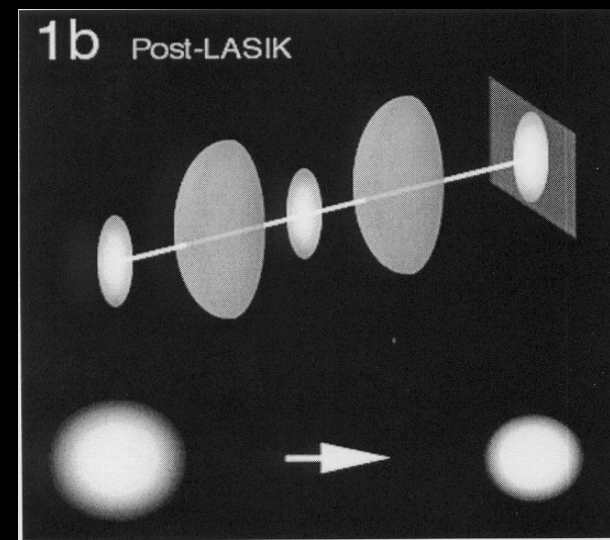
What to base to treat, topo or WF?

- Topo-driven: correct **where** the problem is (s/p keratorefractive surgery). Can create ideal cornea, but can have non-ideal overall WF, and hence may not have as good vision as WF-driven; **Let the cornea bear what is rightfully its burden**;
- WF-driven: Can create ideal overall WF, but can have irregular cornea. Vision can be good (but can be temporally, since cornea is corrected to compensate HOA of lens, and lens HOA changes more sensitively over time). **Let the poor cornea bear the ENTIRE visual axis WF error correction burden (i.e., assuming location of aberration, i.e., lens vs cornea, does not matter)**.
- Topo-WF weighted approach: Alpin's. But, how about the issue of non-simultaneity of optimization of lens and cornea?

Location of aberration along visual axis DOES make a difference: Treating **anterior corneal astigmatism **on cornea** gives good result (lesser untreated cylinder)**

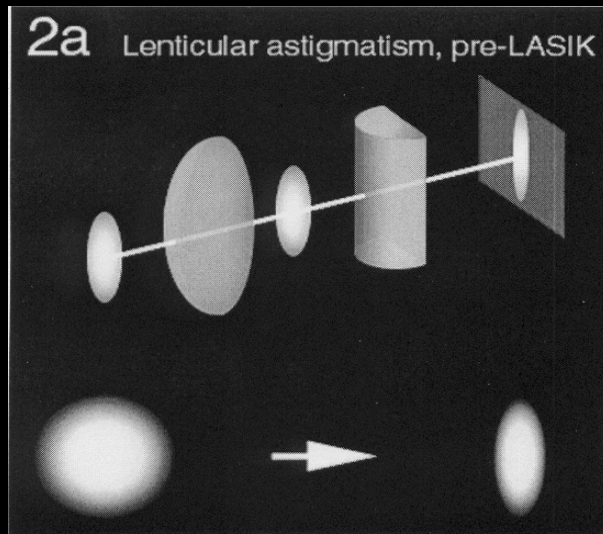


Circular incoming light.

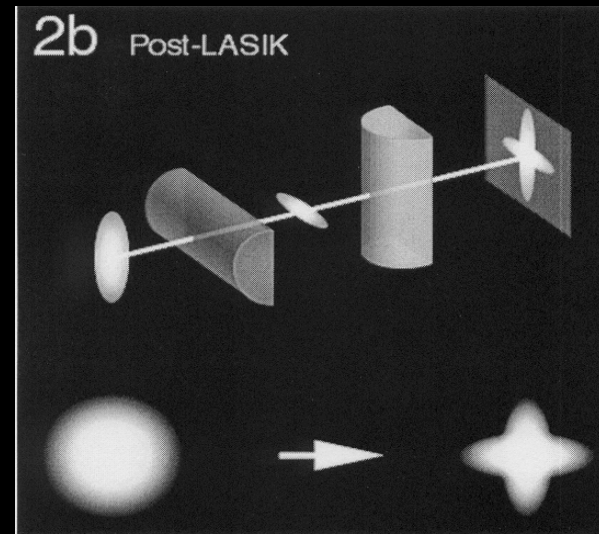


End result: a nice circular image on retina, minimal residual uncorrected cylinder.

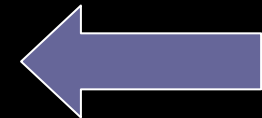
Location of aberration along visual axis DOES make a difference: treating *non-anterior* corneal cyl on cornea gives unsatisfactory result (more cyl left untreated)



Circular incoming light.

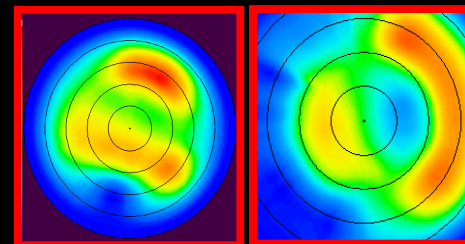
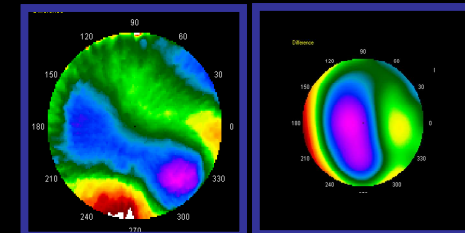
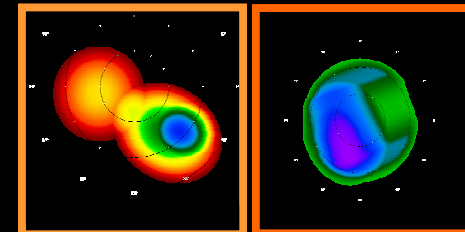
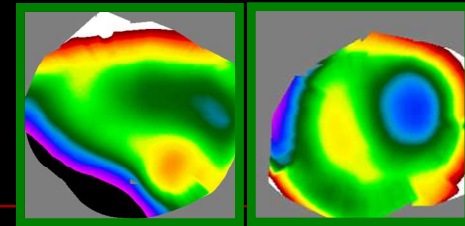


End result: a bizarre imperfect image on retina, due to more residual *uncorrected* cylinder.



Combined topo- WF approach

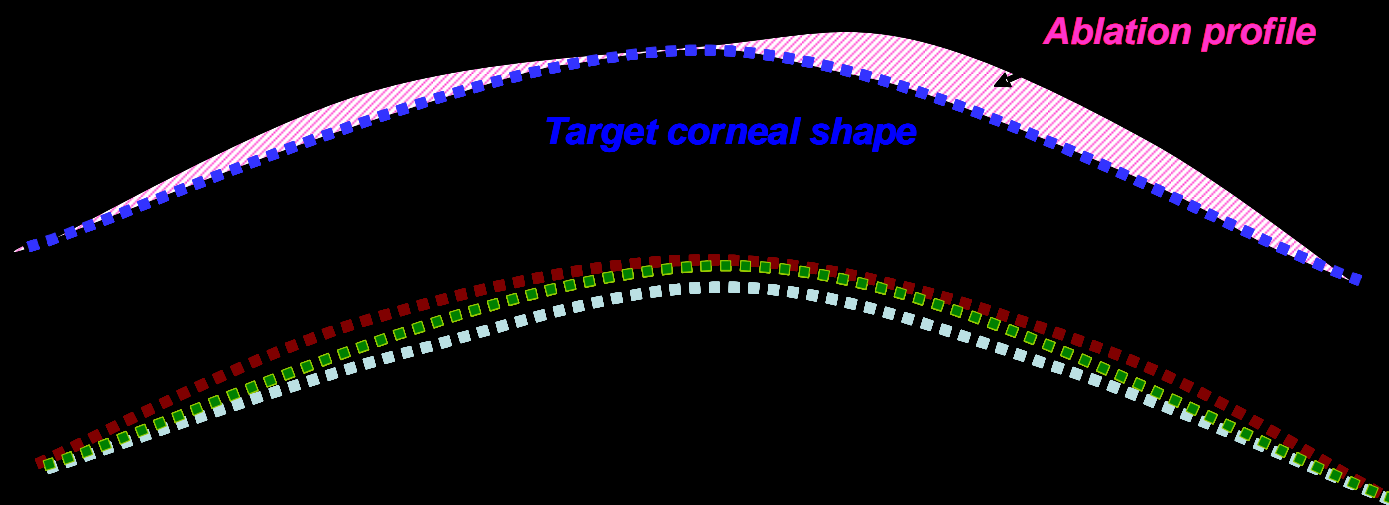
VISX model:
the Advanced
Corneal Ablation
planner (ACAP)



ACAP-topo-WF combined approach

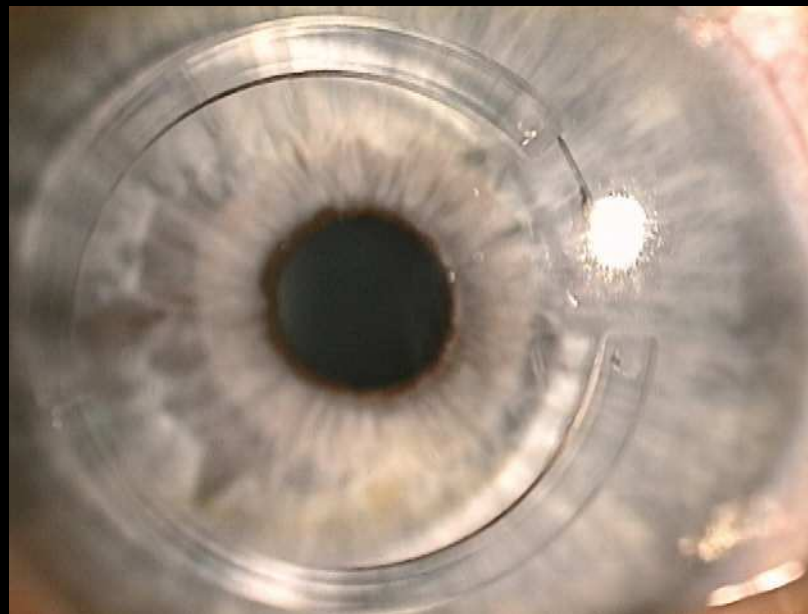
- Integration of wavefront, topography, and VISX laser using WaveStar software;
- Software allows surgeons to build various models representing the “optical target”, defining the desired optical properties of the cornea after surgery based on combinations of wavefront and topographic information.

ACAP-topo-WF combined approach

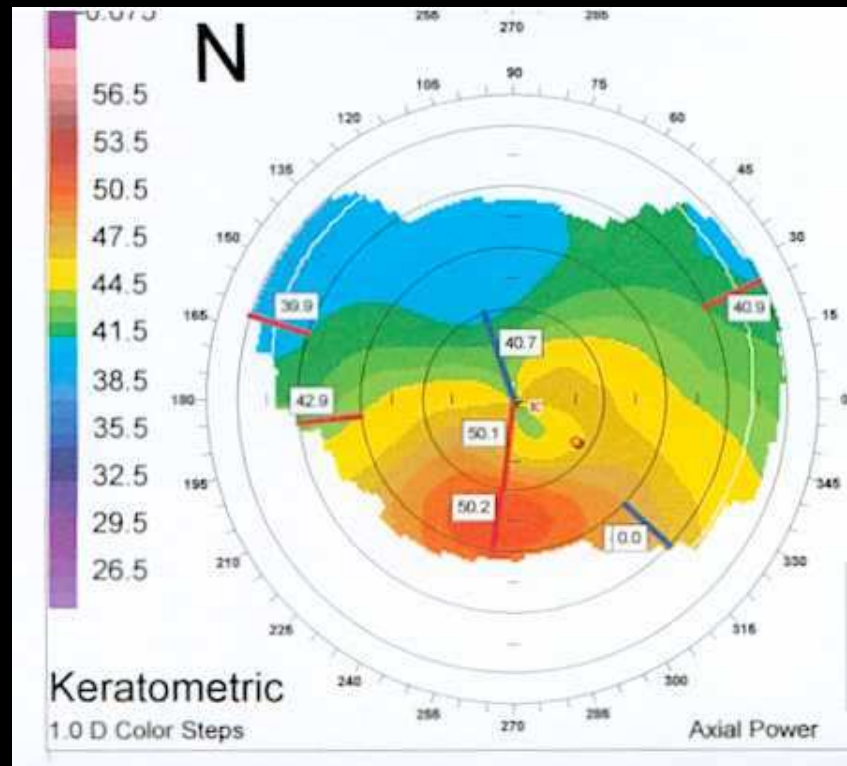


Various models for treatment (corneal tissue removal volume) based on various weighted combinations of wavefront and topography data.

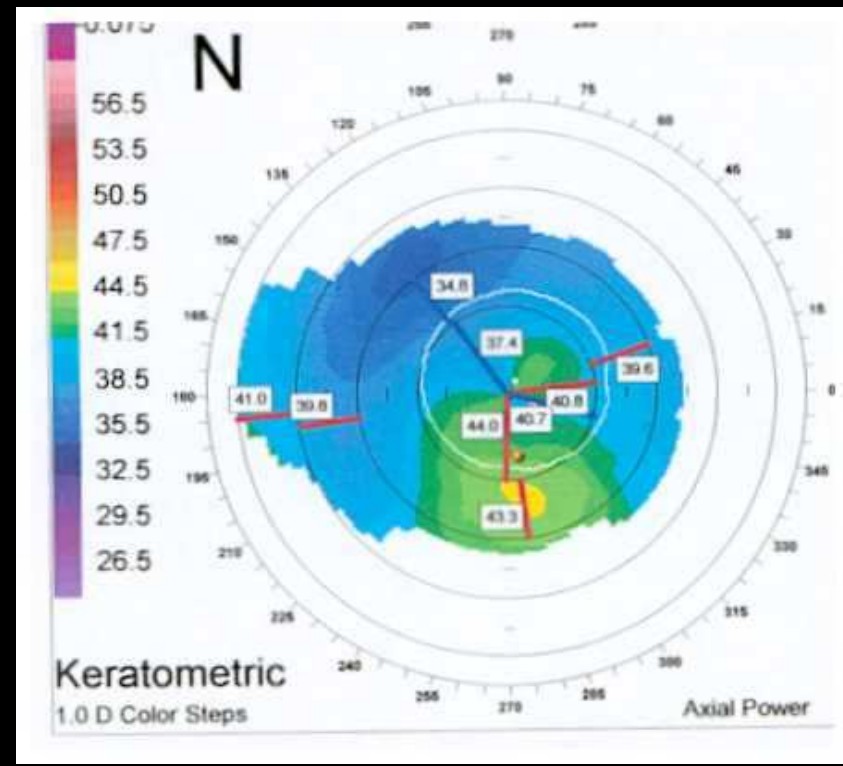
Intacs for KC



Intacs for KC



PRE-OP



POST-OP

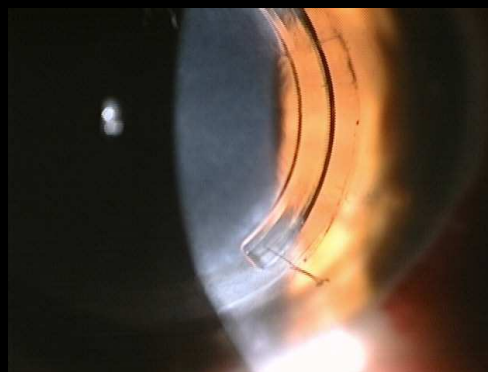
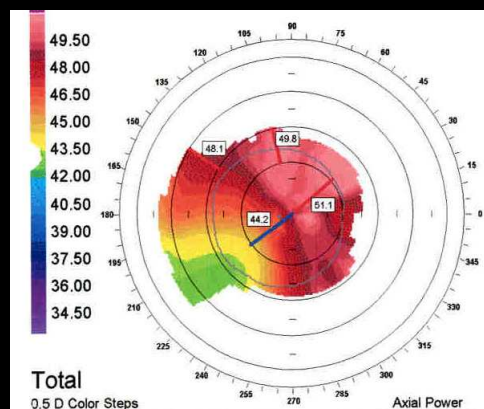
The first case of femtosecond laser- Intacs for recurrent KC on graft

BSCVA=20/200

Diplopia

RGP intolerant

Needs repeat graft

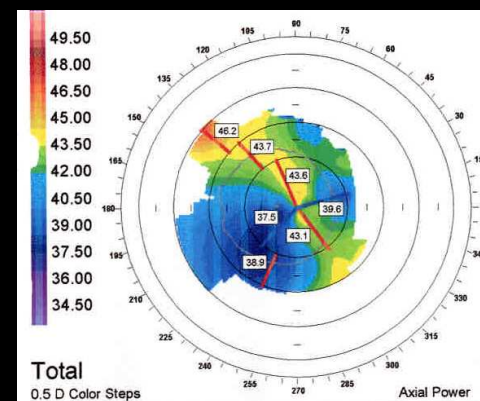


BSCVA=20/20

Happily wearing

SPECTACLES

No diplopia



Irregular astigmatism

- Definition and classification;
- Statistical indices and KC risk indices;
- Clinical causes;
- Other visually significant corneal changes;
- Topo-WF correlates of irregular astigmatism;
- Treatment.

