# Wavefront-guided LASIK Lessons from a 2 and 1/2 year experience ESCRS Munich 2003


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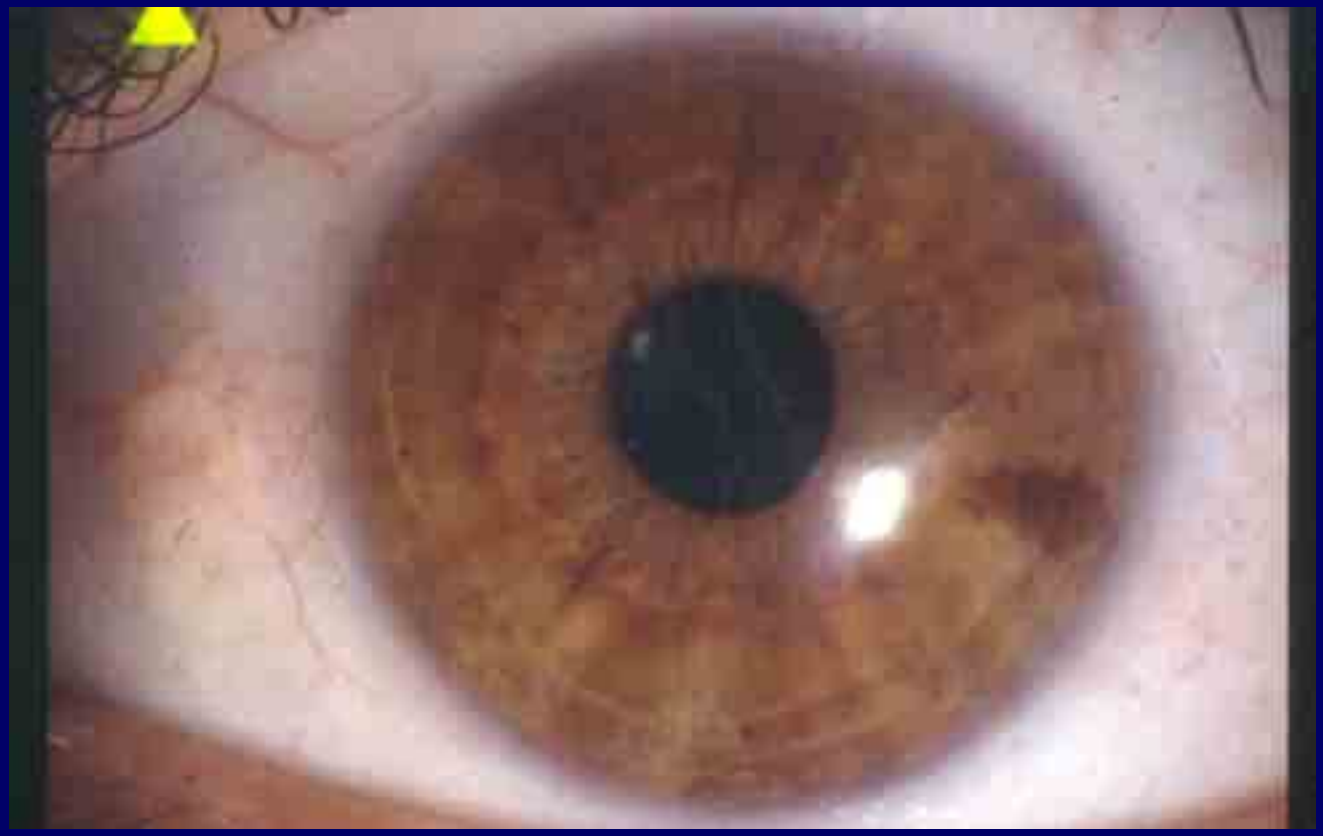
# My Background

- Harvard Medical School-Cornea Fellow
- Cornell University-Cornea Fellow
- Medical Director- TLC Laser Eye Centers
- Director of Refractive Surgery, NYU Medical School, NY
- Laservision.gr Eye Institute, Athens, Greece
- Over 11000 Lasik procedures

# Experience-Excimer Lasers

- Summit- Apex plus
- VISX-S2 and S3
- Lasersight
- Nidek
- Alcon-Ladarvision
- B&L: Technolas 217
- Wavelight: Allegretto-Wave

# One of the initial LASIK cases, 1993



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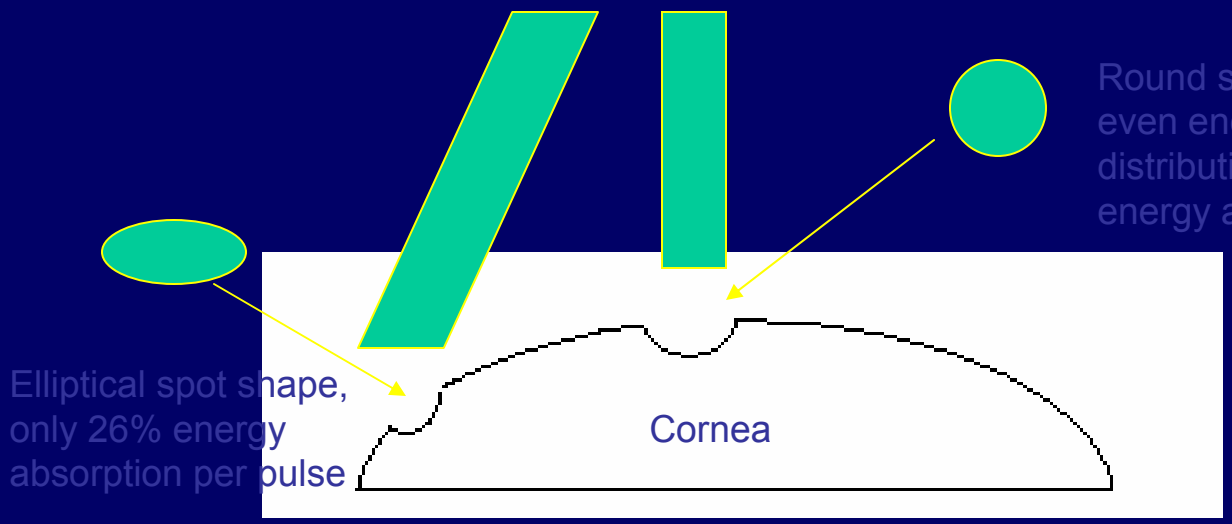
# Common problem with standard LASIK: "goasting"

## (large pupils, de-centered/small diameter ablations etc)

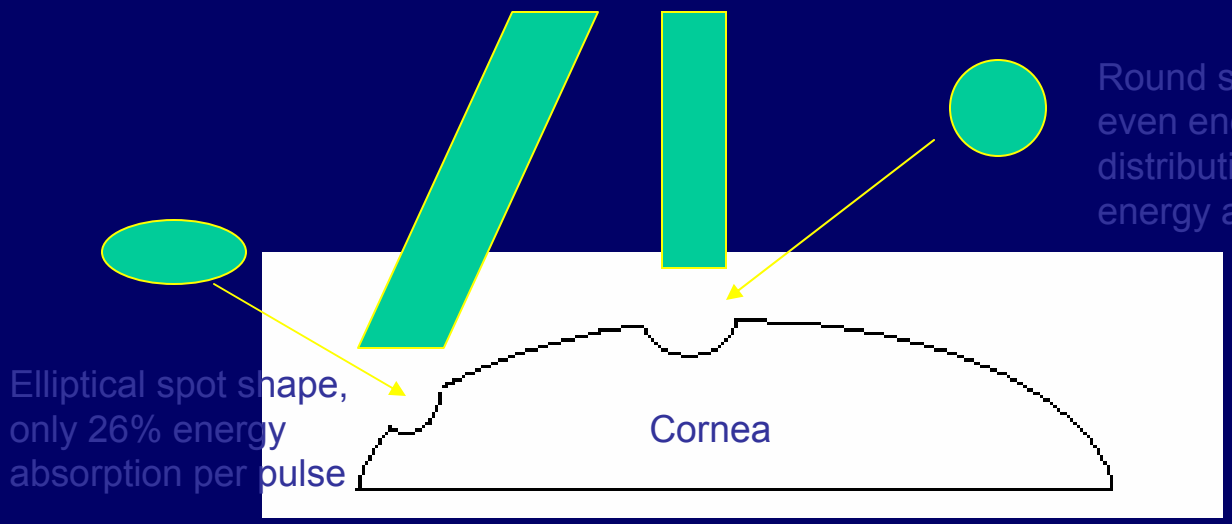
# Effects of Corneal Curvature on Ablation Profile




**The ALLEGRETTO Wave compensates for the reduced energy absorption in the periphery with more spots!**

**Result: True, large optical zone and ability to create prolate cornea shape.**

# Effects of Corneal Curvature on Ablation Profile

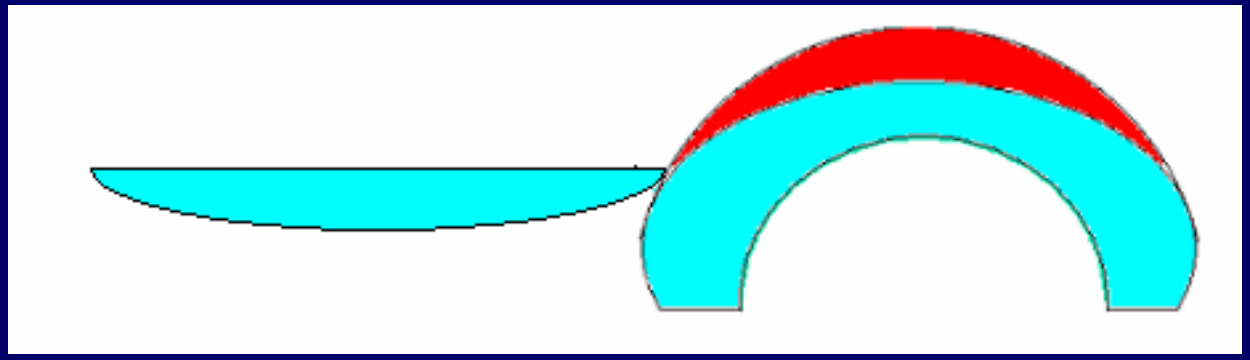



**The ALLEGRETTO Wave compensates for the reduced energy absorption in the periphery with more spots!**

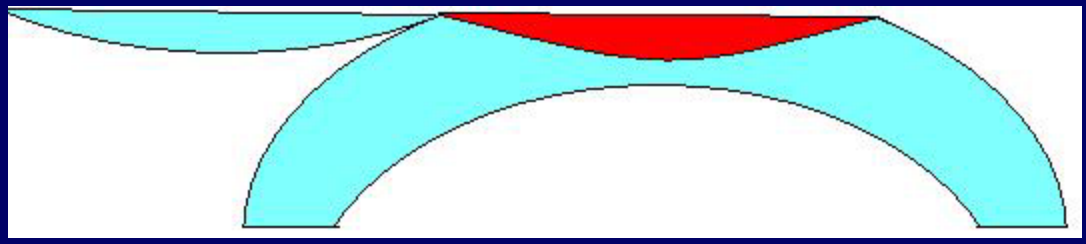
**Result: True, large optical zone and ability to create prolate cornea shape.**

# Prolate Ablation

## Prolate Cornea Shape



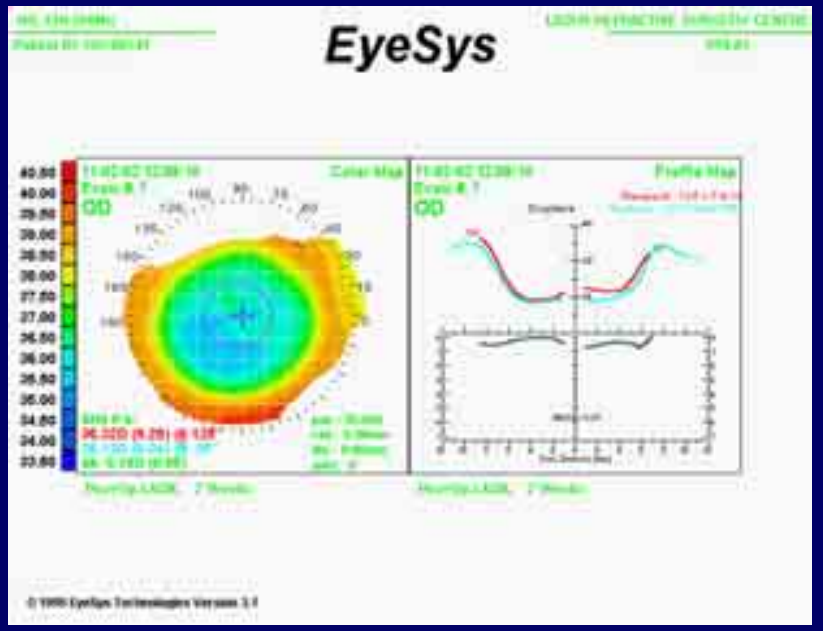
Prolate Cornea Shape with the ALLEGRETTO Wave

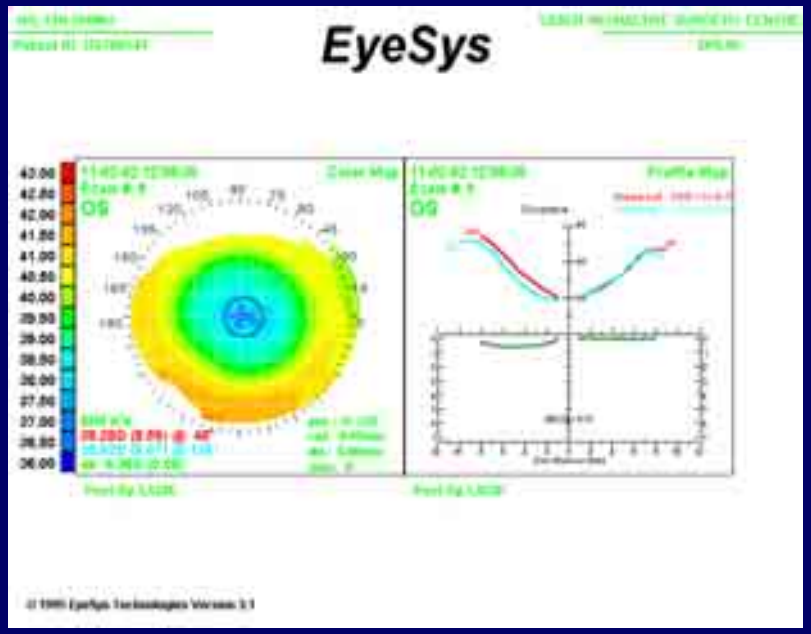


Oblate cornea shape with other refractive laser systems

# -7D myopia corrected in same pt

- One eye (top) with the Allegretto-Wave
- The other eye (bottom) with the Technolas 217z



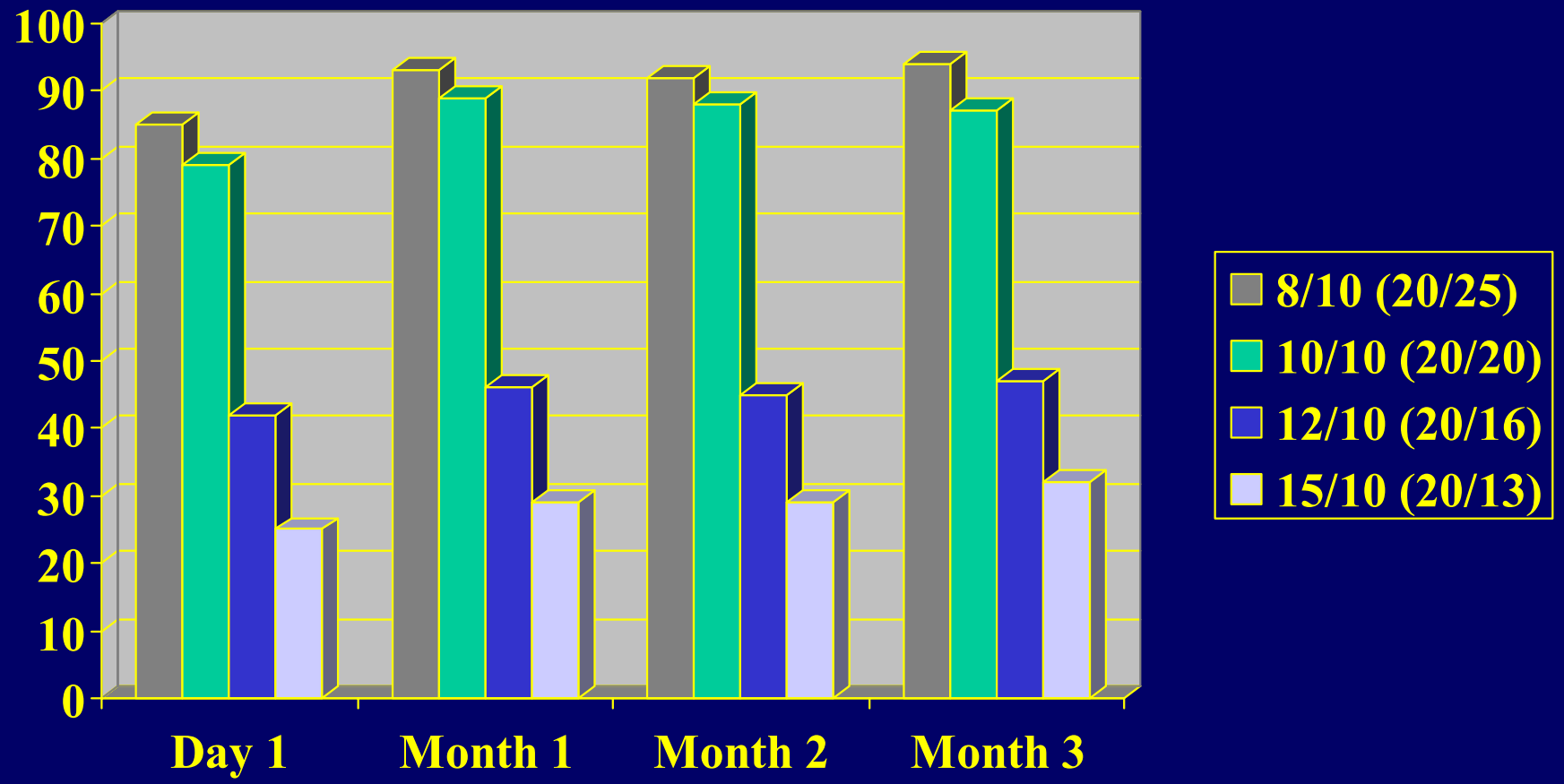




# Results:

(presented originally at the winter ESCRS meeting in Barcelona, Spain 2.2002)

- Mean values: The mean pre-operative sphere was – 4.75 D (-1.00 to –12.50) and the cylinder –1.25 (-0.25 to –3.75)
- UCVA improved from 20/200 to 20/25. At 3 months 87% of the eyes were 20/20, 47% 20/15 and 32% 20/10. 100% of eye were within +/- 1D at 3 months.

# Results

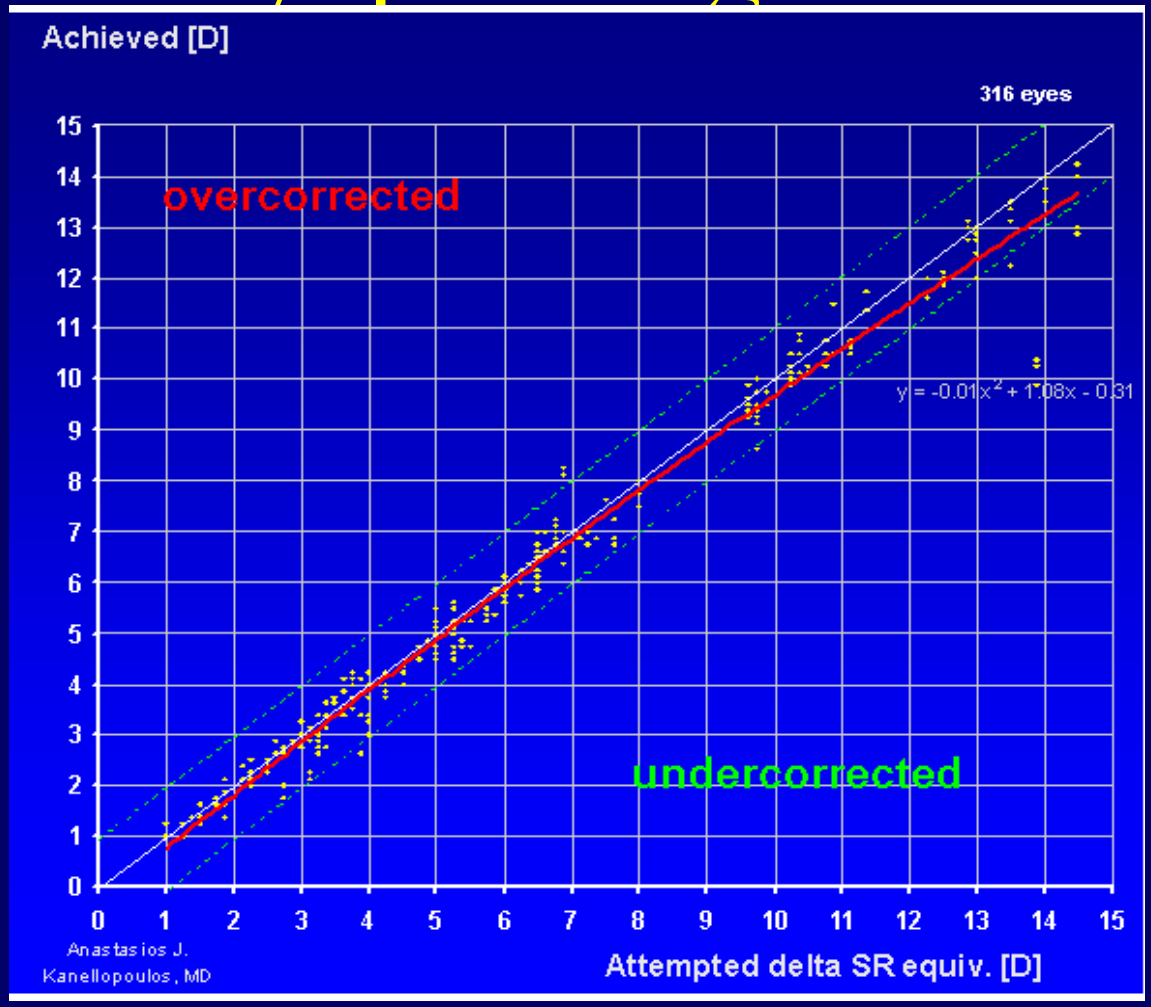

100
90
80
70
60
50
40
30
20
10
0
Day 1
Month 1
Month 2
Month 3
8/10 (20/25)
10/10 (20/20)
12/10 (20/16)
15/10 (20/13)

# Results:

## "standard"-prolate LASIK

- Wavefront analysis showed a postoperative increase in coma of only 35% (mean coma of 6% pre-op to 9% post-op)
- 37% of eyes gained at least 1 line of BCVA
- No complications were noted in this limited group

# Results in 520 consecutive cases myopic astigmatism

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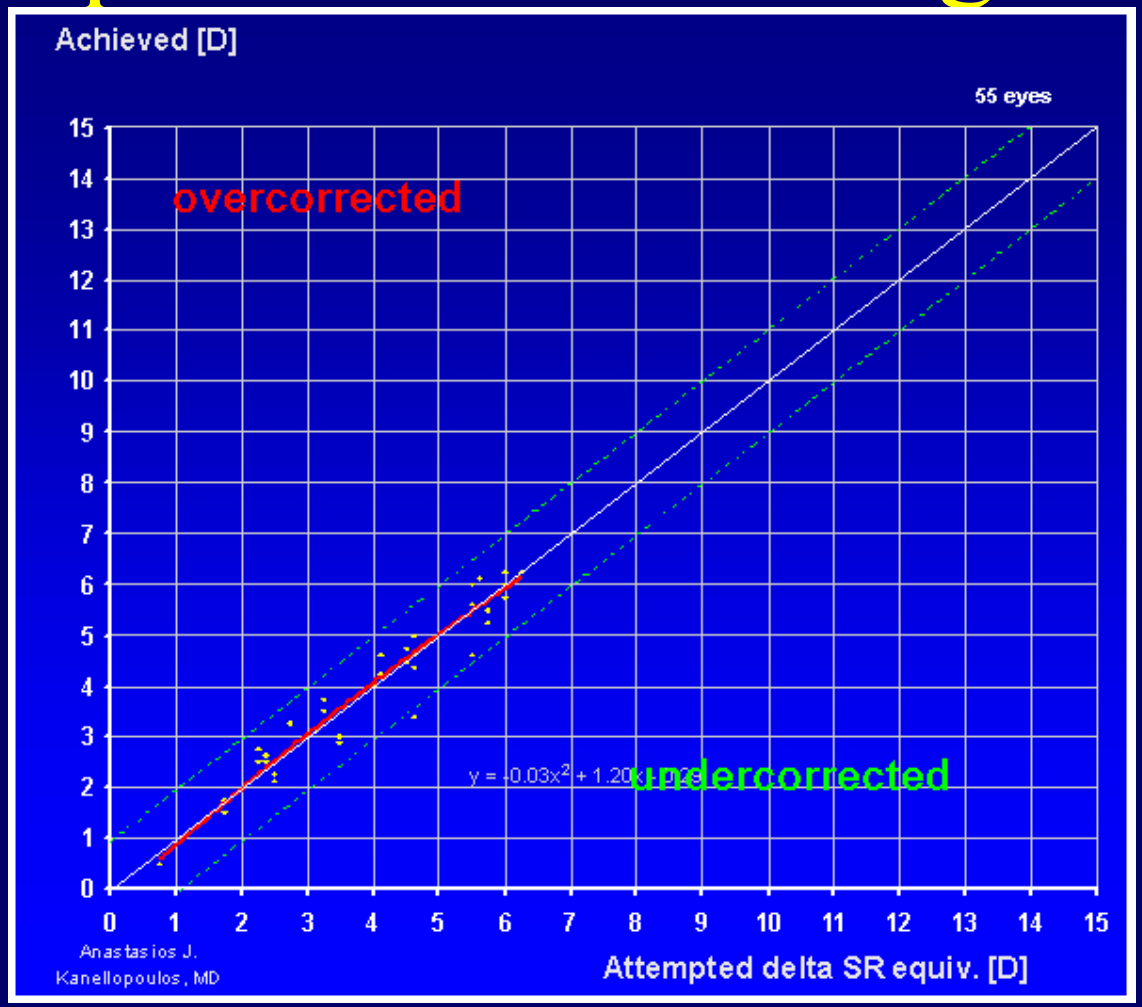
# Results in 105 consecutive cases Hyperopia and mixed astigmatism

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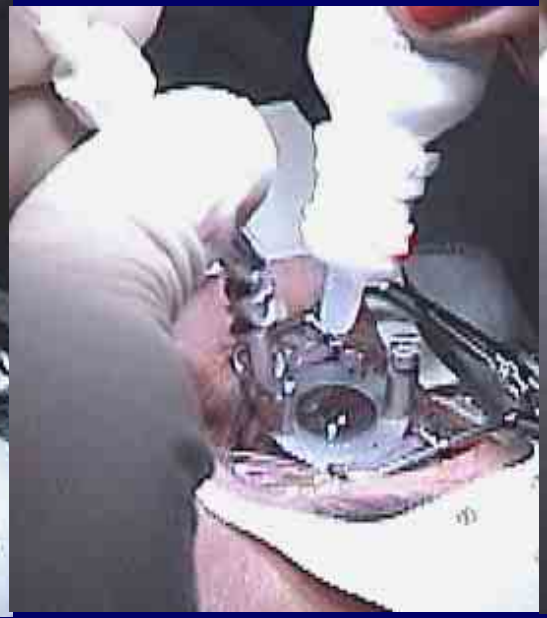
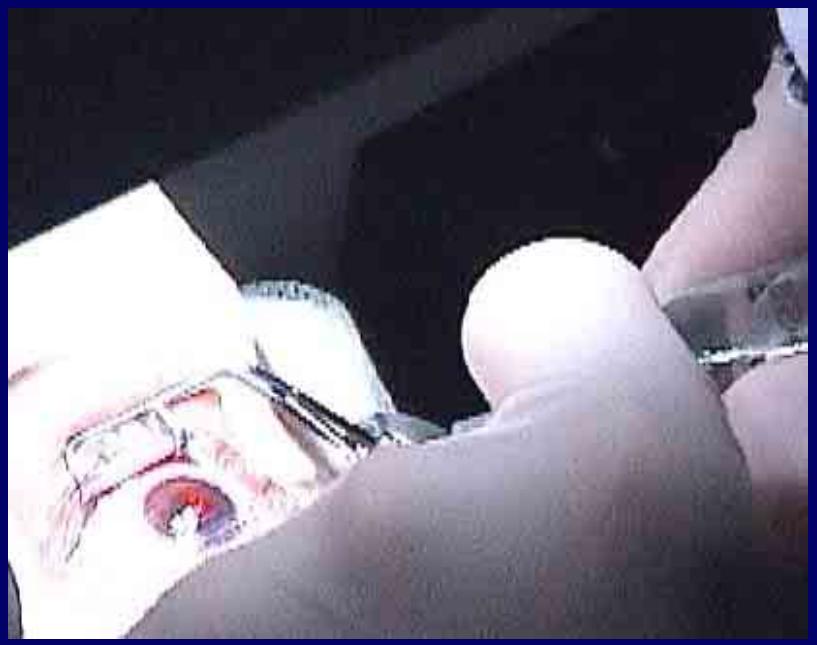
# Placement of the keratome



# Folding of flap, even moisture on stromal bed



# My technique

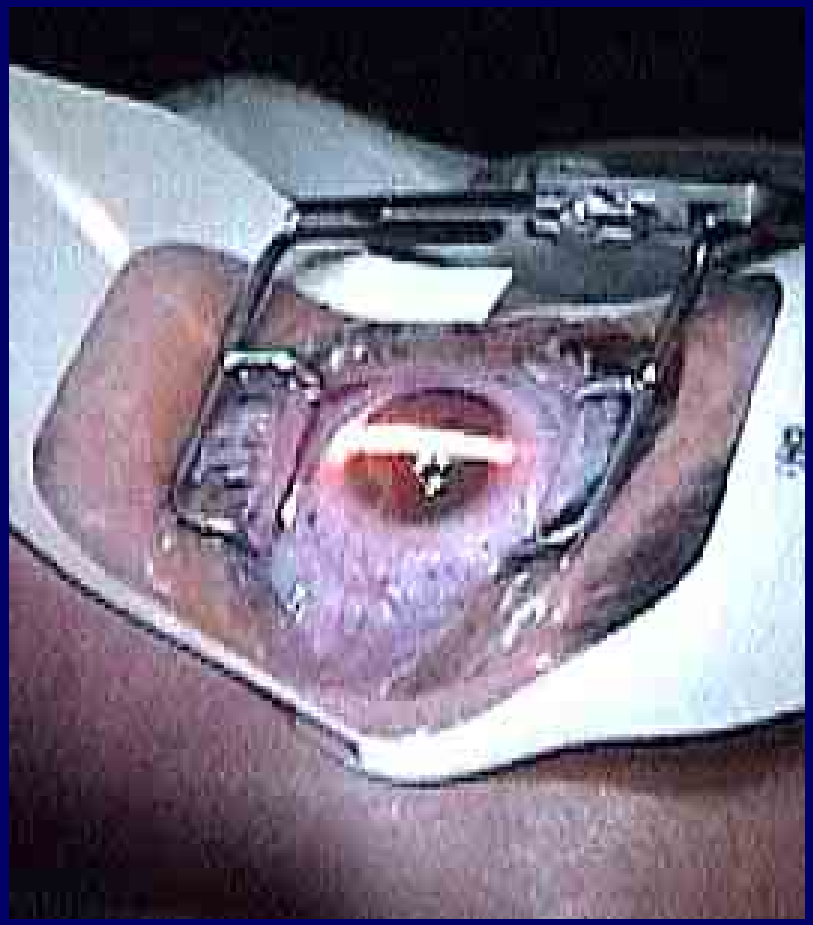
- Irrigation very important
- "Squeeze" out excees fluid and

Striae with moist Weck-cell

- "milky" drop (predforte 1%) to delineate gutter width, centration and striae

# 2’ observation interval

## Flap is evaluated with build-in slit-lamp



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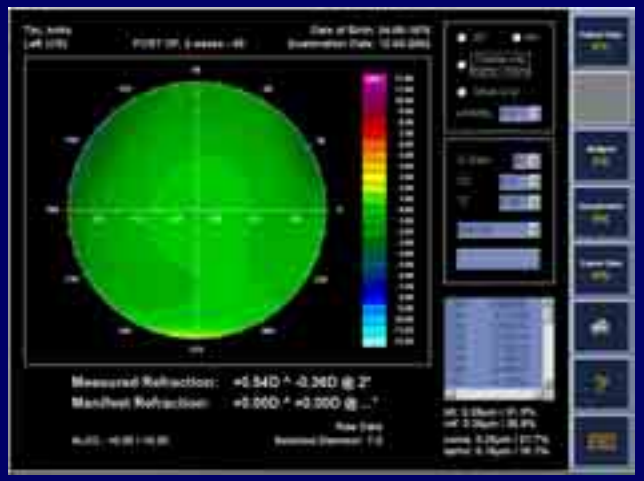
# Why Wavefront?

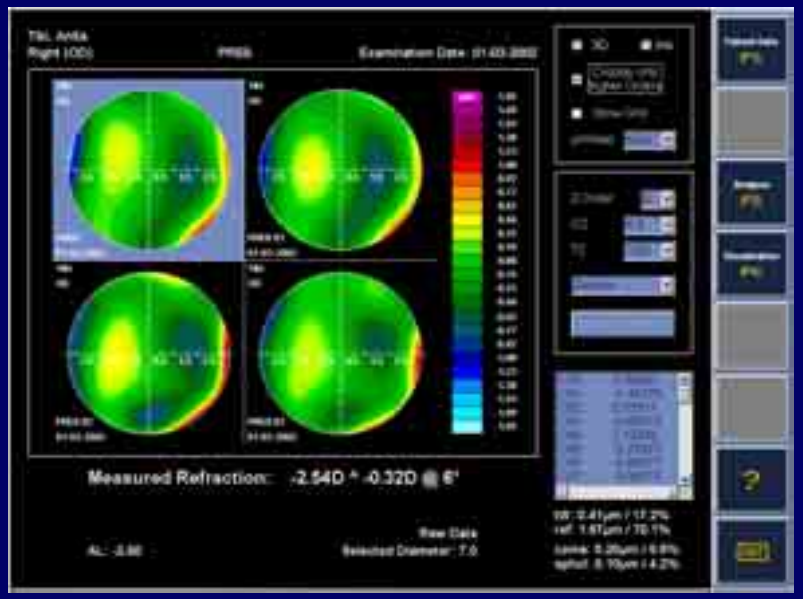
- Necessary tool in today's refractive practice
- Large (usually light-colored) pupils
- High astigmatism
- Enhancements (decentrations)
- "Enhancing" monovision

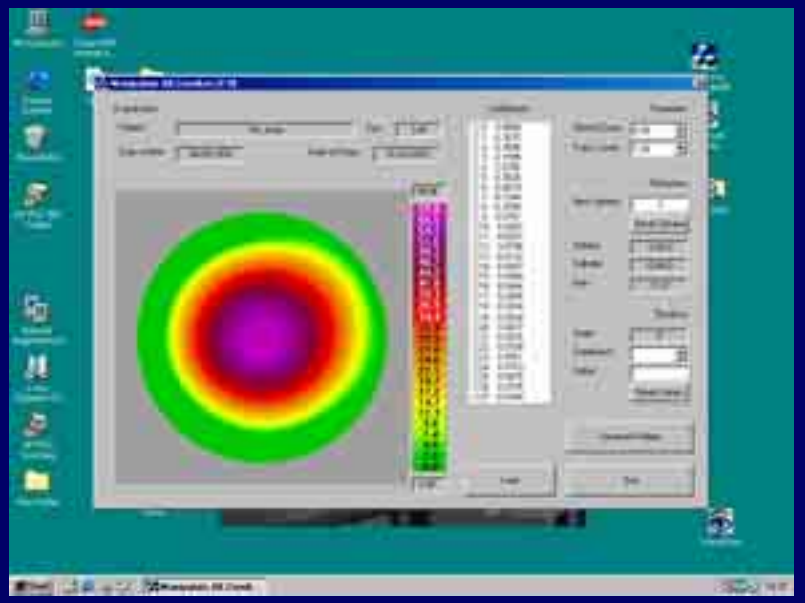
# Our Wavefront-guided experience started with a pilot study:

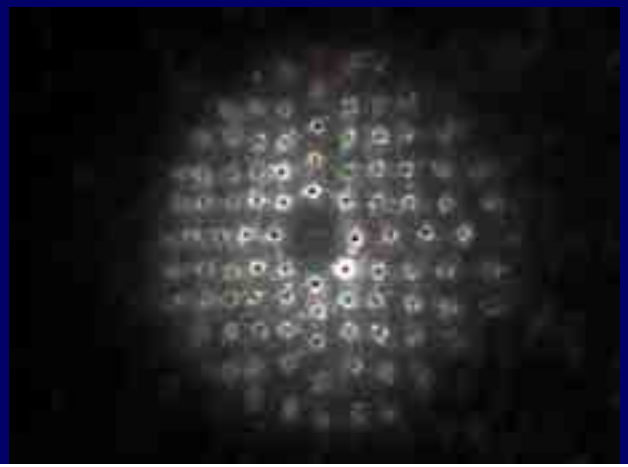


- 10 patients
- One eye wavefront-guided, the other “standard” LASIK
- Wave group: RMSh pre-op 0.12-0.35 (0.17), post-op dropped to: 0.11. A reduction therefore of HOA
- Non-wave: pre-op 0.165 post-op: 0.195 a slight increase of HOA just as in our larger standard LASIK group reported

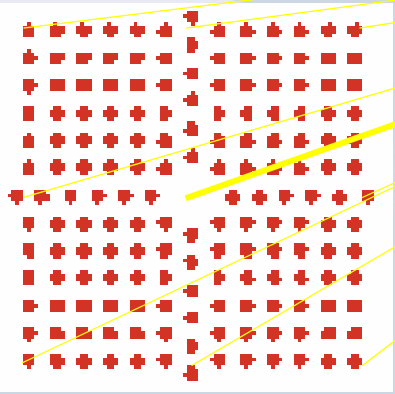
# Wavefront-guided

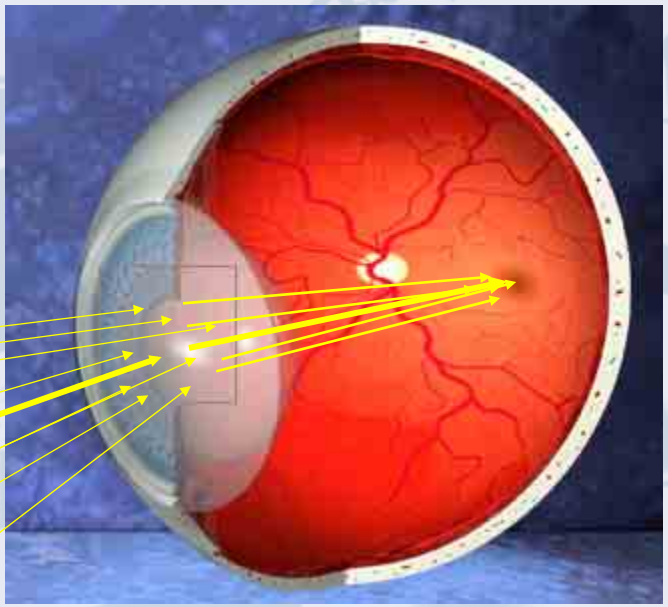


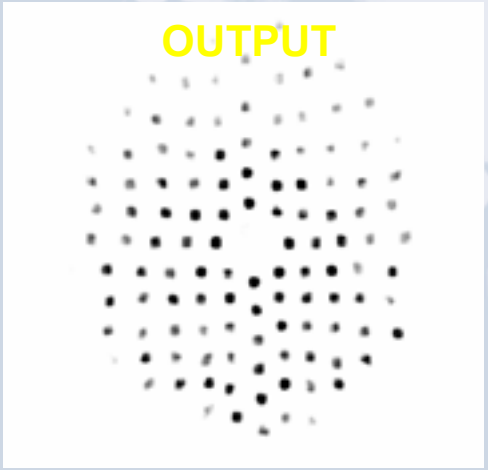





# Measurement Principle

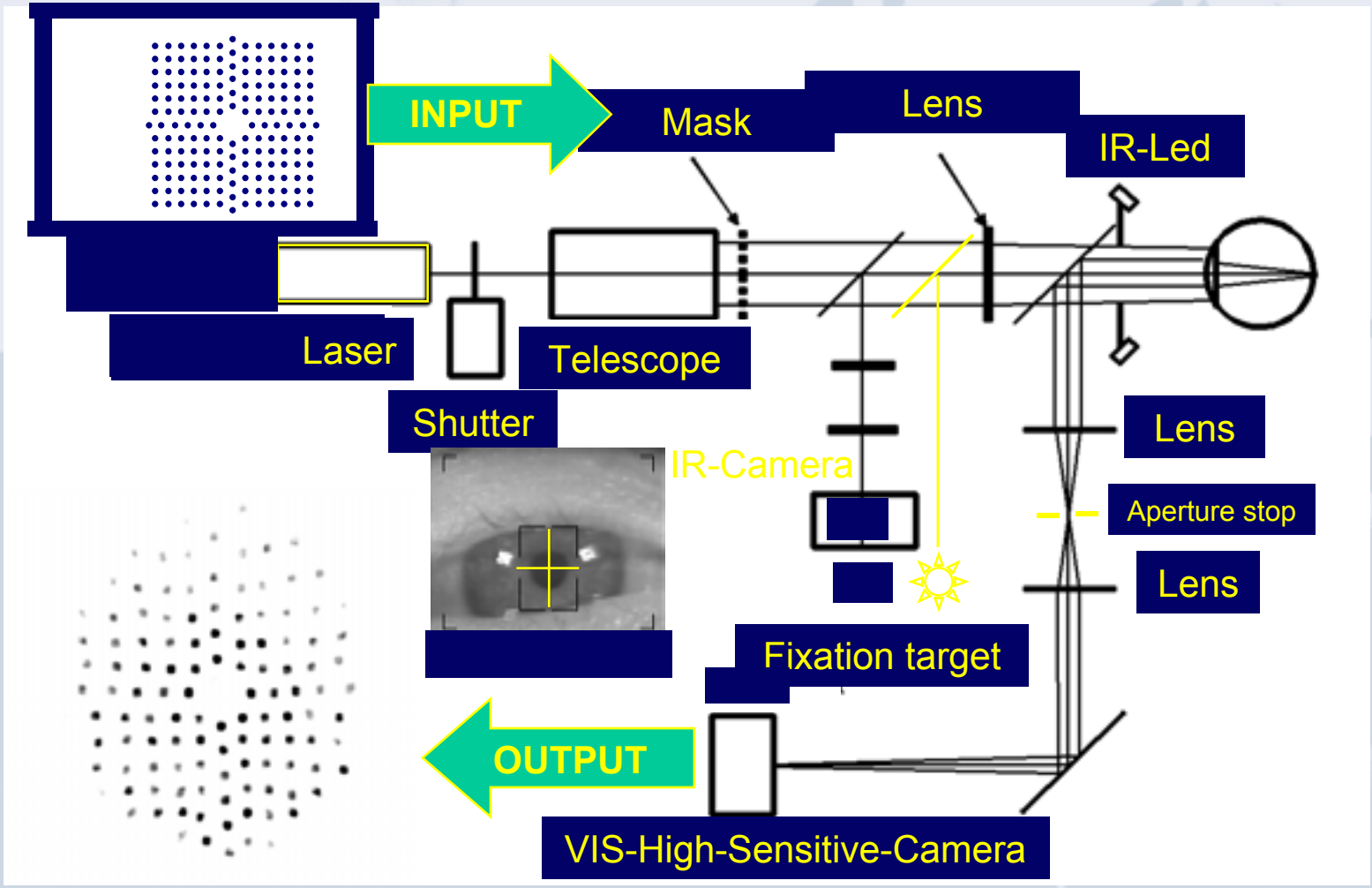





WaveAnalyzer

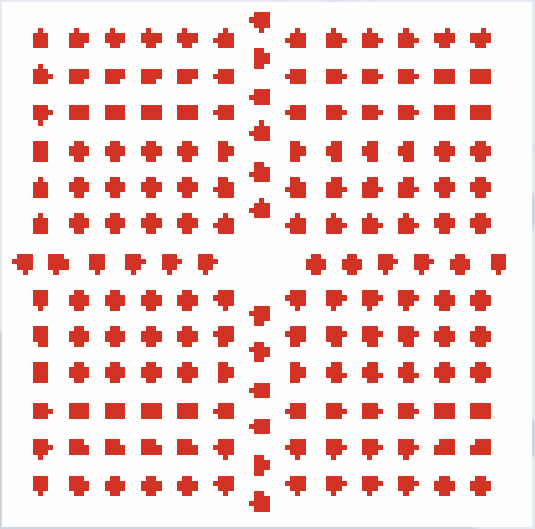
# WaveFront basics




ALLEGRETTO WAVE

# Data Flow

INPUT



Optical Ocular Aberrations

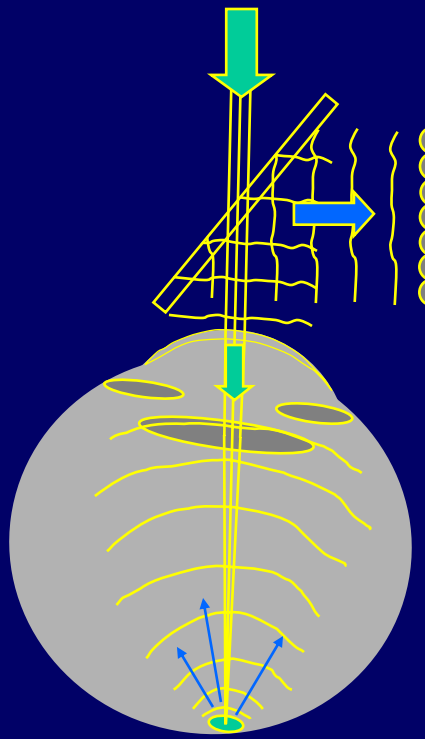
OUTPUT

Measurement of local distortions

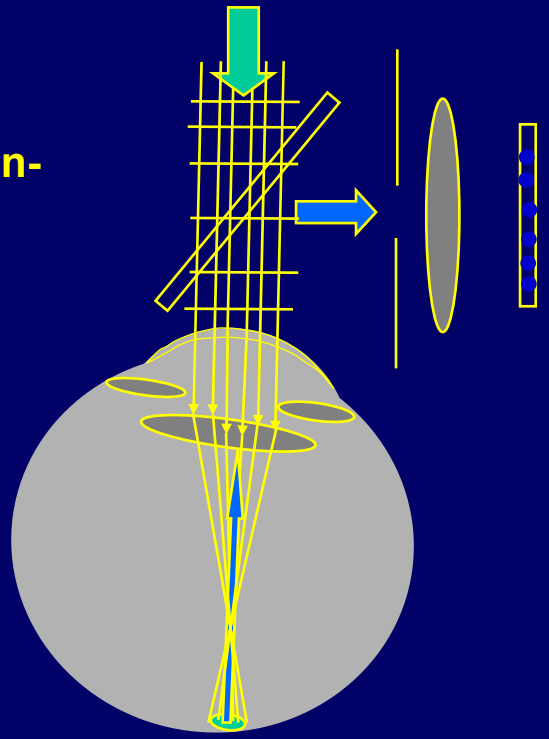
Local distortions → Calculation of Wavefront Error → Calculation of Ablation Profile → Custom LASIK

WaveAnalyzer

# WaveFront basics



**Hartmann-Shack-Sensor**



**Tscherning-Sensor**

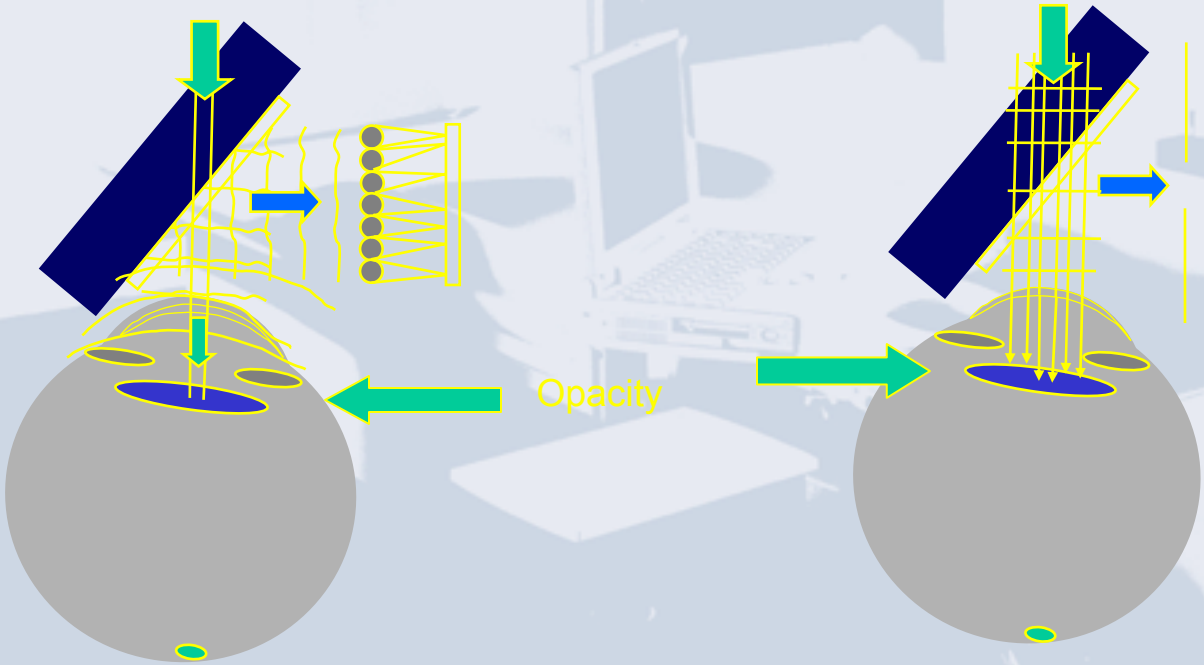
**+ well-known technique**
**+ central cornea information**
**- expensive sensor**
**- incoming light must be diffraction limited**
**- insensitive of opacities**

**+ variable incoming pattern**
**+ patient sees own aberrations**
**- expensive low light sensor**
**- sensitive against scattering**
**- no central cornea information**

# THE ALLEGRETTO WAVE ANALYZER

**HS Sensor**

**TS-Sensor**




Unsafe and misleading
It appears that even opaque eyes can be measured because a clear image is seen on the instrument display
But it is really caused by reflections of the lens.

Safe, only valid images can be processed
The individual beams are distracted by the Opacity. No clear image can be seen, low risk of accidentally treating with wrong data

By Thomas Zieger WaveLight Laser Technologie AG

ALLEGRETTO WAVE

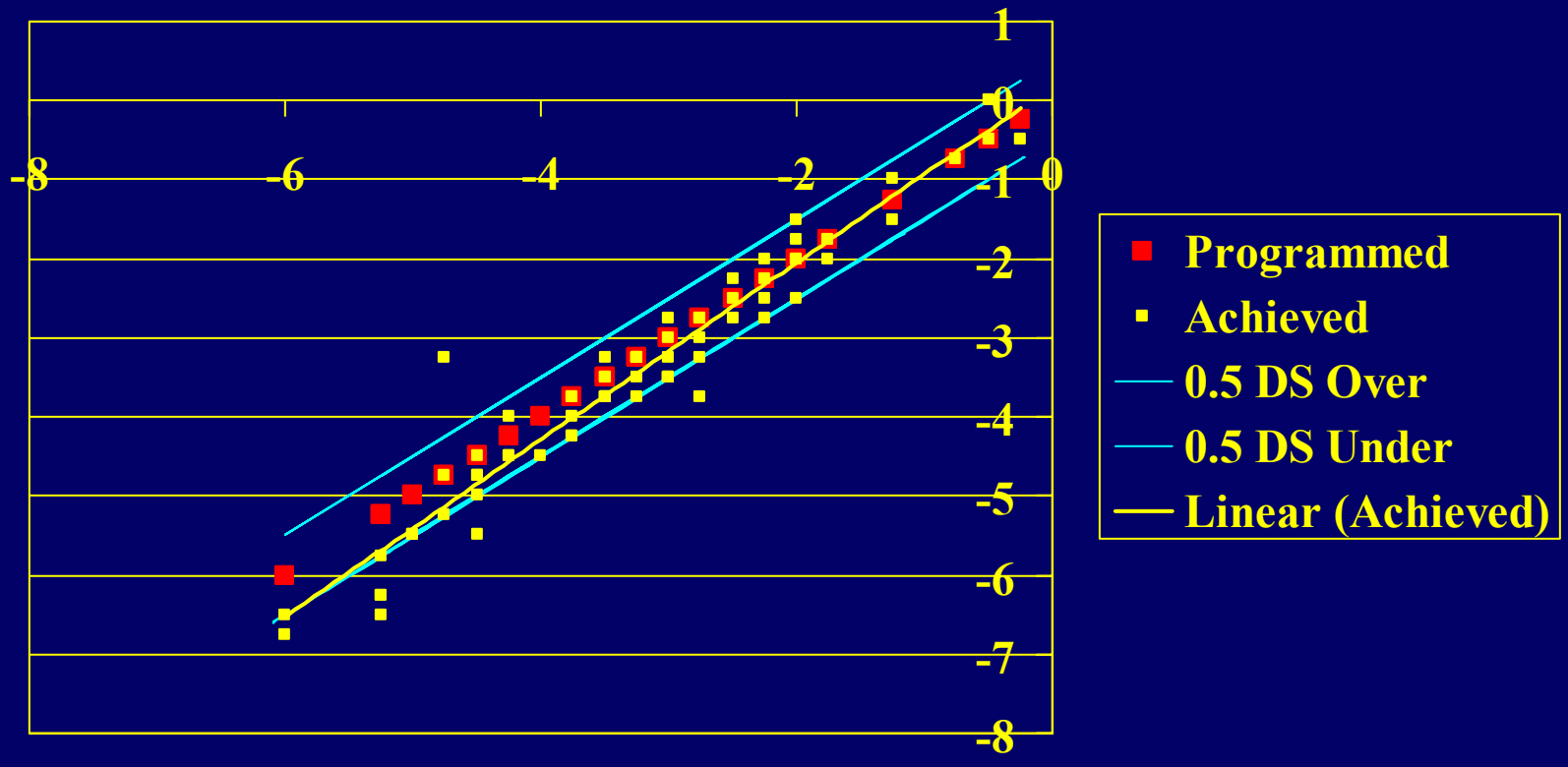
# Top pearls of my technique

- Wavefront monitoring essential for refractive surgery
- Pt expectations
- Understand the technology (surgeon-staff)
- Aberration indices that REALLY matter?
- Preoperative measurements RE and monovision
- Preoperative planning mesopic-scotopic pupil
- Wave map evaluation #, quality-before surgery
- Wavefront-guided OZ size
- Consistent flap, tracker, excimer energy

# Results:

- Able to include 142 cases
- Mean values: The mean pre-operative sphere was – 4.85 D (-1.00 to –6.50) and the cylinder –1.25 (-0.25 to –2.75)
- UCVA improved from 20/200 to 20/18. At 3 months 92% of the eyes were 20/20, 57% 20/15 and 34% 20/10. 100% of eye were within +/- 0.5D at 3 months.

# Results Day 1:
# Programmed vs. Achieved



# Management of decentered ablation with the use of wavefront-guided LASIK


A. John Kanellopoulos, MD
Laservision.gr Eye Institute, Athens, Greece
Manhattan Eye, Ear and Throat Hospital, NY
Michael Mrochen, PhD- Un. Of Zurich

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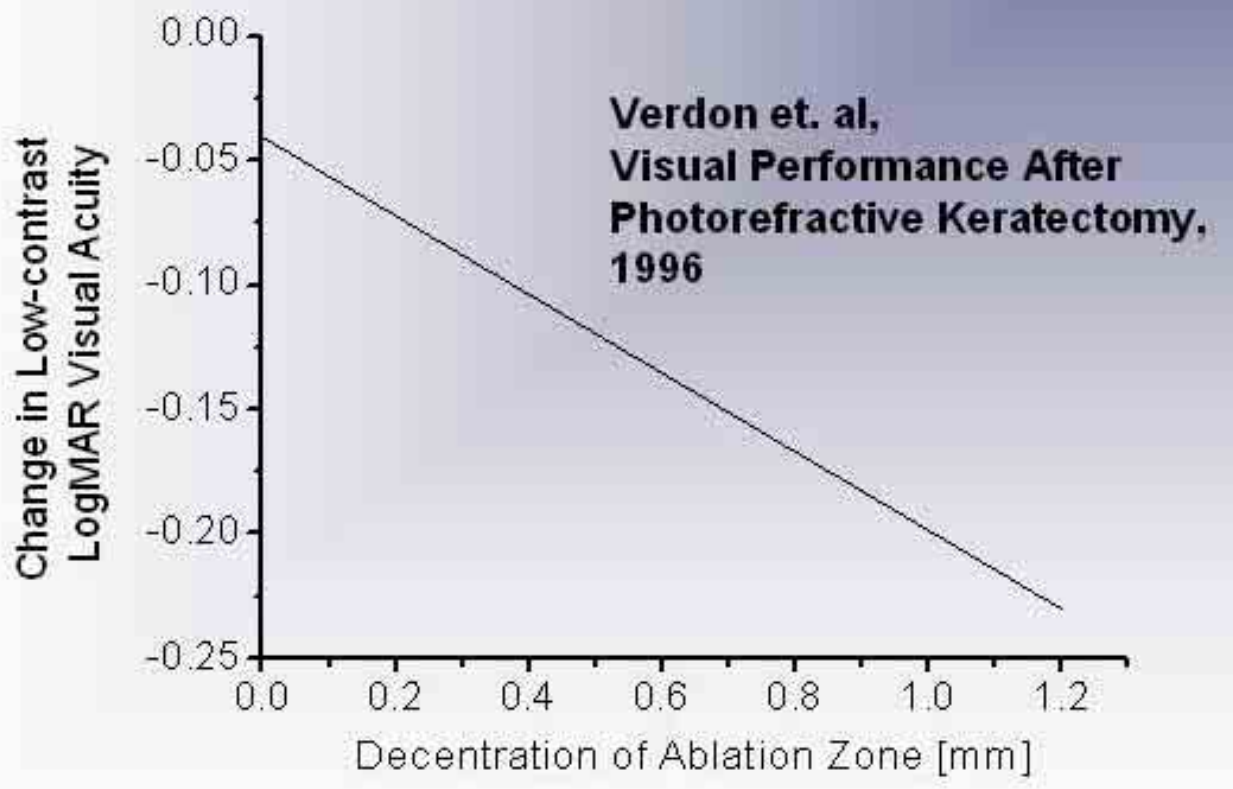
# Ablation decentration

- Troublesome compl. c serious visually debilitating side-effects.[1, 9, 10] Causes:
- Intra-op fixation error and/or drift of the patients' fixation;
- Ecc.-displaced treatment (surgeon error or equipment calibration error; and eye tracker or eye tracker calibration error[2)].
- **Larger decentrations are usually associated with larger reductions in low contrast sensitivity and visual acuity.** **3**
- Mrochen M, Krueger RR, Bueeler M, Seiler T. Aberration-sensing and wavefront-guided laser in situ keratomileusis management of decentered ablation. J Refract Surg 2002; Jul-Aug, 18(4)418-29.

## Larger decentrations associated with larger reductions in low-contrast visual acuity



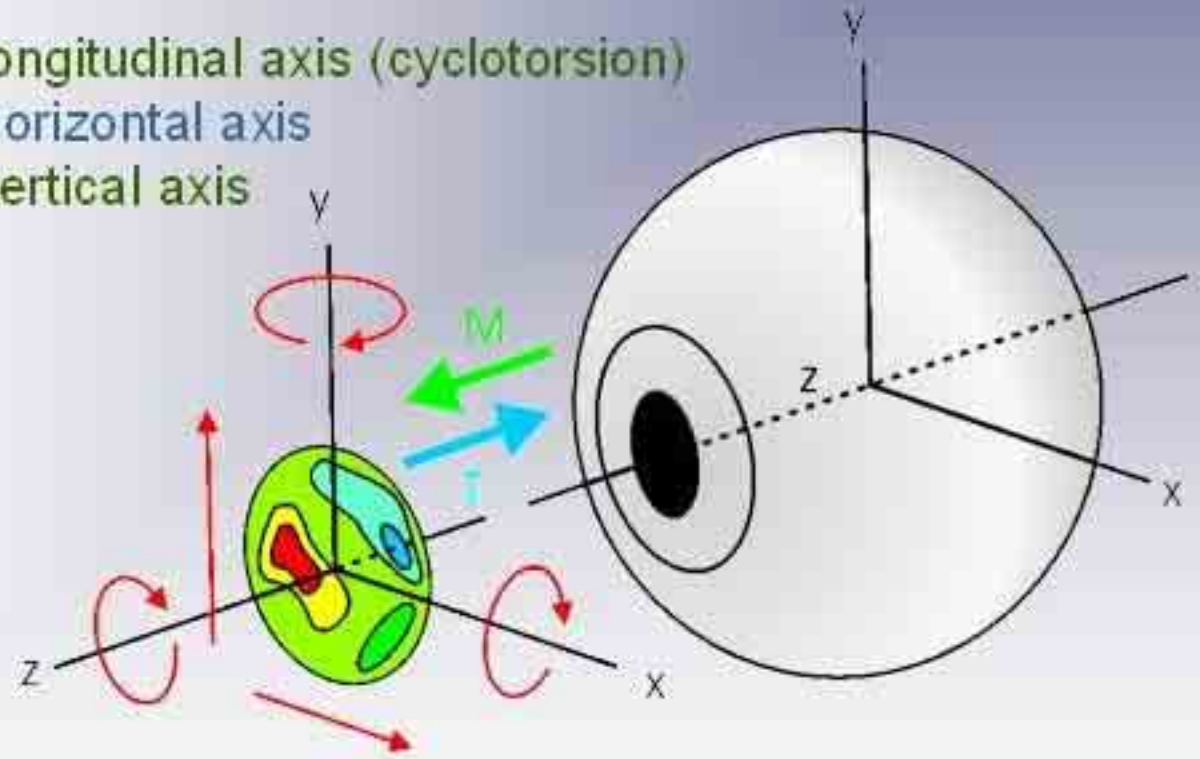

**Verdon-W; Bullimore-M; Maloney-RK**
**Visual performance after photorefractive keratectomy: A prospective study Arch-of-Ophthalmol 1996;(114/12):1465-1472**

# Treatment Centration

- **Centration = important bias in measmnts as well as reference points in laser treatments.**
- **The actual clinical measmnts of wavefront, are centered by the coaxially cited corneal reflex, the geometrical center of the cornea, the corneal apex, and the entrance pupil, which is the actual point where the visual axis goes through.**
- **There are several the potential biases of decentration of the human eye**

# **Centration:** A task with **5 degrees of freedom**

- Horizontal shifts
- Vertical shifts
- Rotation around longitudinal axis (cyclotorsion)
- Rotation around horizontal axis
- Rotation around vertical axis




➔ The coordinate systems used in the measurement (M) and the treatment (T) have to coincide exactly!

# Centration errors sytematic and random

Systematic: a constant decentration

systematic caused by different axes (coordinate systems defined in measurement and treatment, or the defined axis where the coordinate system is not stable, the eye tracker is calibrated imprecisely, there is head tilt, or the initial alignment by the operator is not precise, or there is a fixation problem from the patient).

# Centration errors

Systematic centration errors can be avoided with precise alignment techniques. Random or dynamic centration errors are avoided only with active eye tracking.

Random or dynamic centration errors, which cause "smearing" of the ablation.

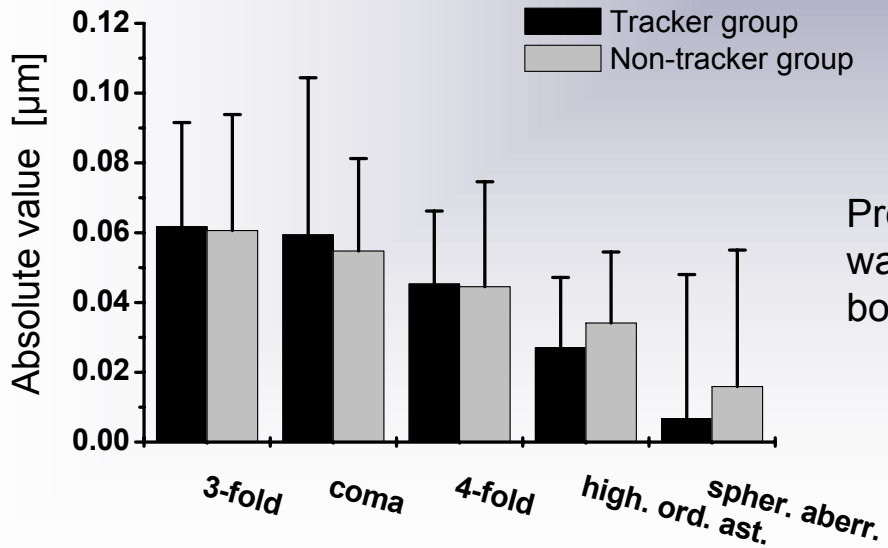
# Active tracking

- A small pilot study compared the advantage of active eye tracking. Twenty eyes treated with eye tracking and 20 eyes treated without eye tracking were evaluated with regard to their wavefront indices.
- There was difference in wavefront measurements in trefoil, quadrafoil, higher order astigmatism, and spherical aberrations.
- Less stat. significant aberrations with the tracker-treated patients. This study confirms others that show eye tracking appears to improve the visual outcome of refractive surgery.

UniversitätsSpital Zürich

# Advantage of active eye tracking in refractive surgery

- 20 eyes treated *with* eye-tracker
- 20 eyes treated *without* eye-tracker




Preoperative higher-order wavefront deviations in both examined groups

*On the importance of centration*

Mrochen-M; Eldeine-MS; Kaemmerer-M; Seiler-T; Hutz-W Improvement in photorefractive corneal laser surgery results using an active eye-tracking system .J Cataract-and-Refractive-Surgery. 2001; 27/7 (1000-1006)

# Methods

- We define the decentration zone by obtaining the difference between the pre- and postoperative corneal topographic measurements, which is a tangential map.
- The ablation is surrounded by a region of approximately zero power, determined with this method described by Mrochen.[2]
- The decentration of the ablation is determined as a distance of the center of the flattened zone from the center of the pupil.

# Methods

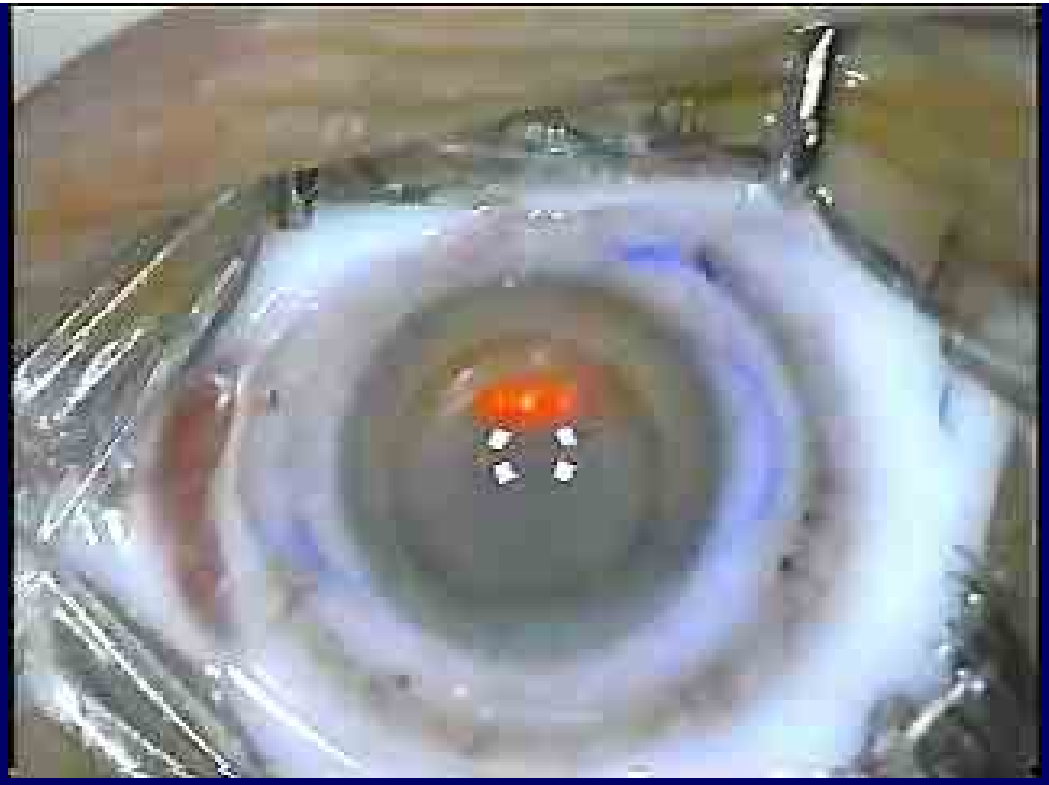
- We term an ablation grossly decentered if this decentration is more than 1 mm
- There is evidence that decentration, even as much as 100 microns, will significantly increased higher aberrations and the possibility of the symptoms described previously to affect the patients' visual quality[3]

# Treatment

- We treat decentered ablations with a preop evaluation using wavefront measurements and topographic measurements of the decentered ablation.
- The preoperative measurements include visual acuity, topography, OrbScan measurement as mentioned previously, and wavefront measurement.
- low contrast sensitivity measured by the Vector Vision 3000 device

# Treatment

- The wavefront-guided treatment is relatively standard.
- Only one drop of Alcaine (proparacaine 0.5%, Allergan, Irvine, CA) as a topical anesthetic.
- We instill a drop of ofloxacin (Ocuflox, Allergan, Irvine, CA) mixed with preservative-free Acular as antibiotic prophylaxis several times during flap repositioning, and a drop of PredForte.. (Fig. 6)

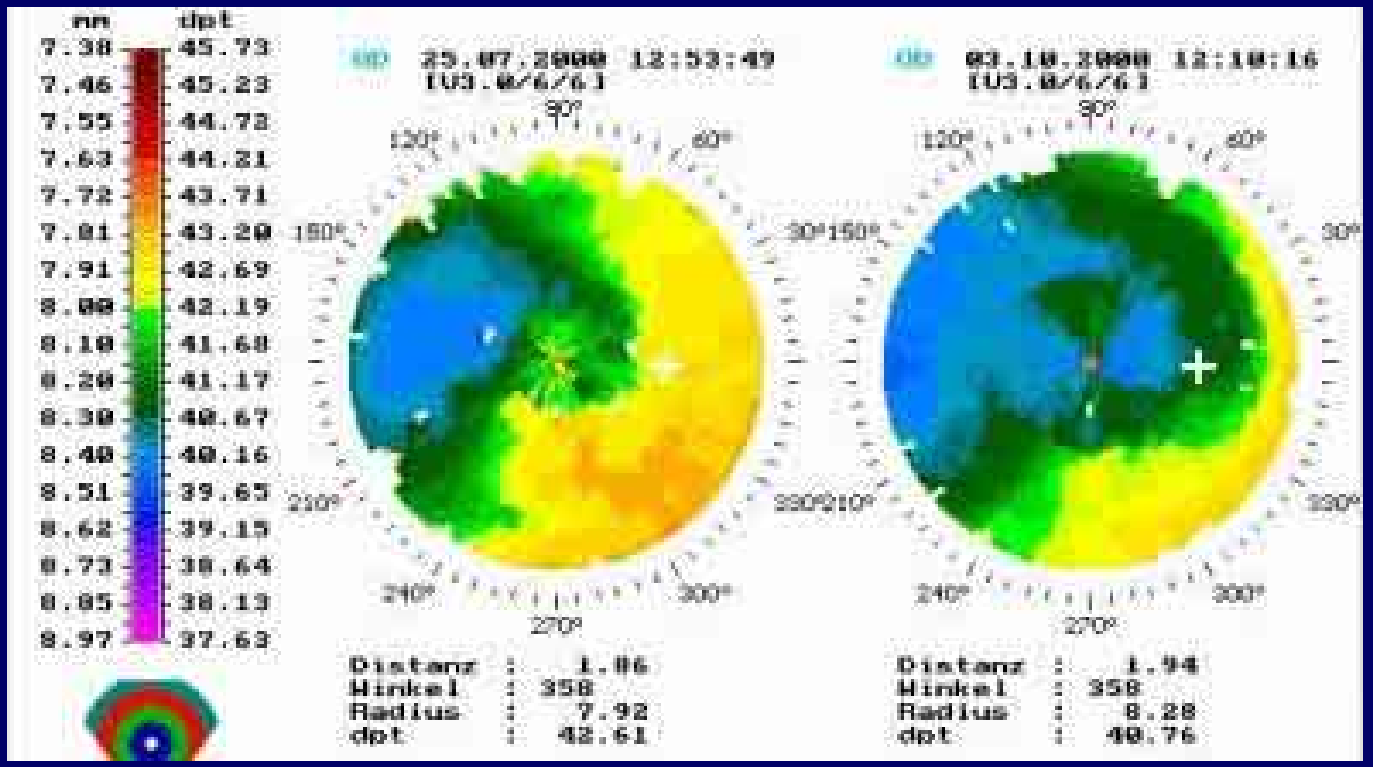


- We use PredForte  to delineate the flap gutter and ascertain good centration of the repositioned flap.
- Any differences in the gutter width, either on the X or Y axis, even if the corneal markings are perfectly aligned, indicates a decentration of the flap, which requires repositioning.

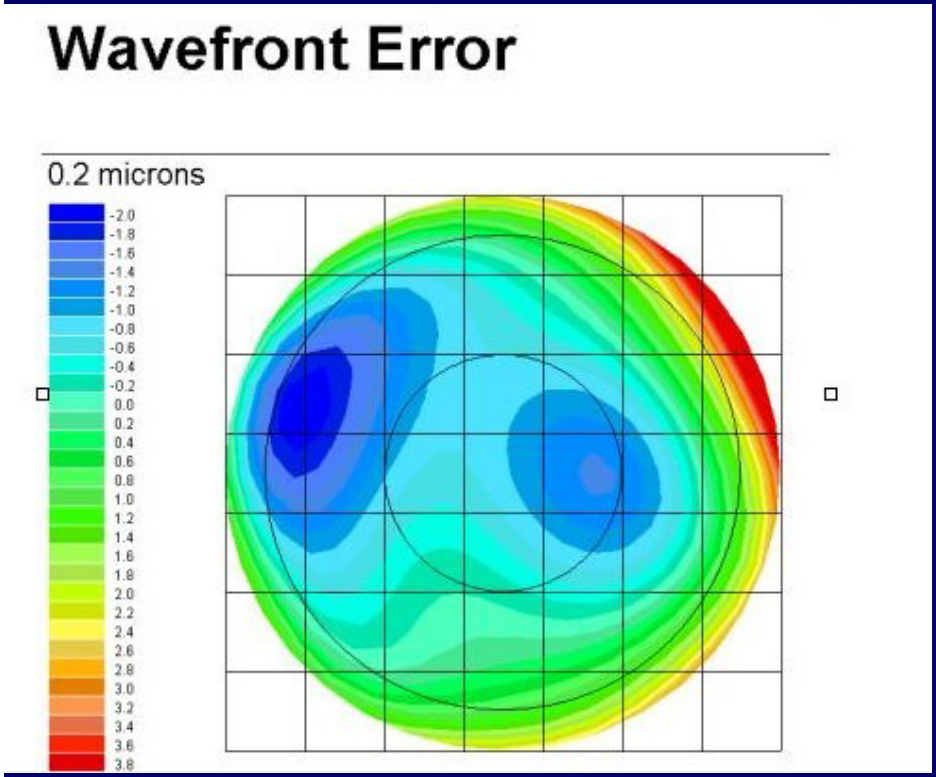
# Results

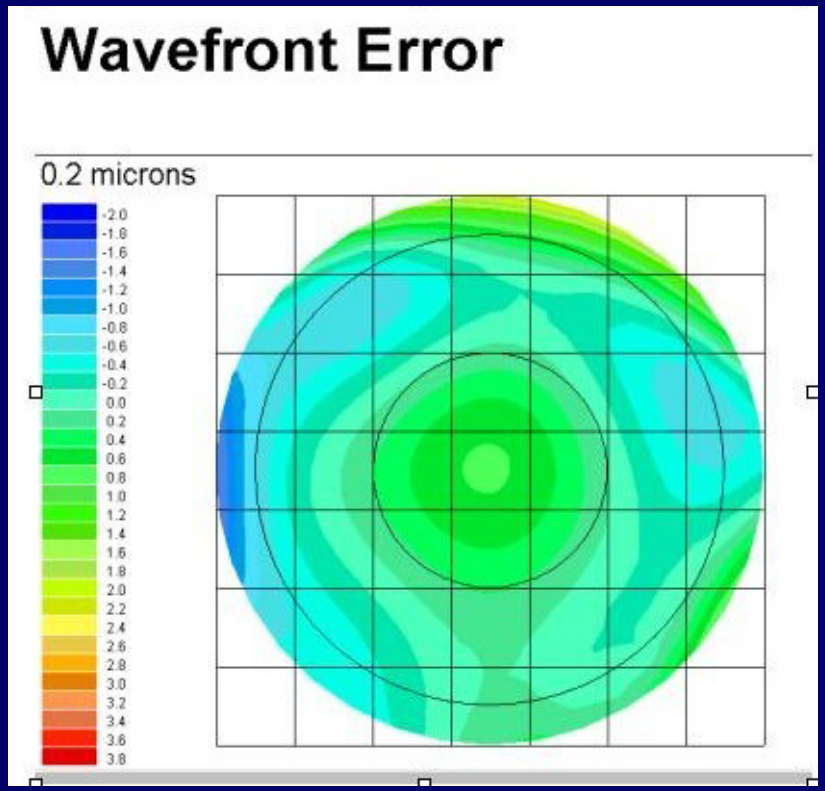
- The 3 patients were followed the first day, first week, first month, and then at three month intervals.
- The initial group of patients have subjectively improved symptoms including night driving and quality of night vision.
- All symptoms of monocular diplopia, ghosting and most of the glare subsided after this treatment.

# The pre-op and post-p corneal topography,



# The pre-op and post-p wavefront map



# Conclusions

- In this small group we achieved significant improvement, both in the signs and symptoms of decentered LASIK.
- Obvious limitations the relative corneal thickness and our ability to obtain reproducible maps.
- Extreme decentrations, refractive errors, and higher order aberrations may exceed the limits that this technology can measure precisely.
- Better knowledge of the specific Z coefficient importance in human Va may create more effective customized enhancements.[12,13]


- Applegate, RA, Sarver EJ, Khemsara V. Are all aberrations Equal? J Refract Surg 2002. 18:S556-562.
- Applegate, RA, Ballentine C, Gross H, et al. Visual acuity as a function of Zernike Mode and Level of RMS Error, Optom and Vis Sci, in press.

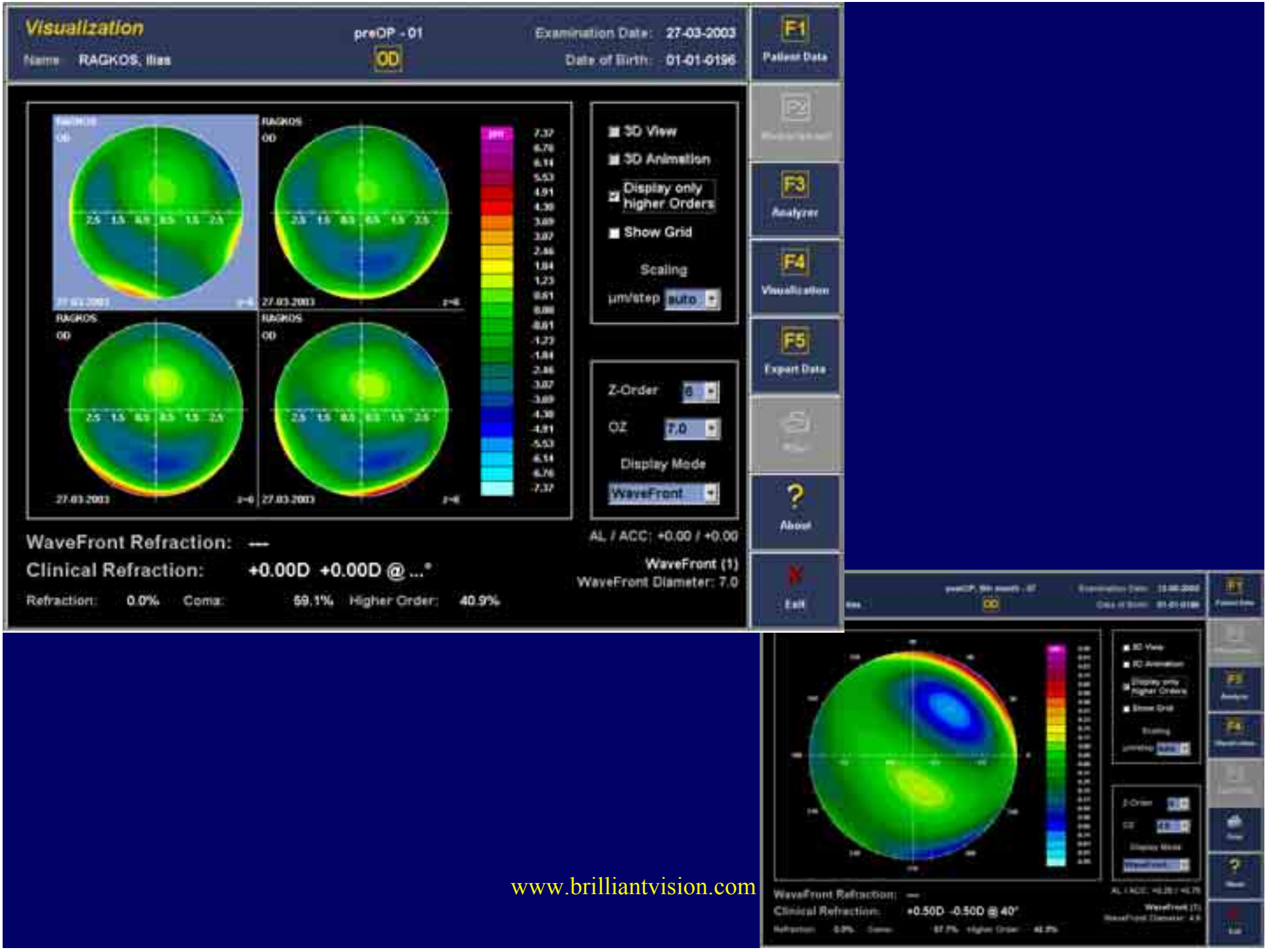
# Unhappy eye study with Wavelight

**Methods:**26 consecutive eyes that had LASIK and were symptomatic, underwent wavefront-guided treatment, based on 4 reproducible aberration measurements. We evaluated pre-, and post-operative refraction, total and high order aberrations (RMSH), cornea and flap thickness, low contrast sensitivity (LCS) and possible complications. Follow-up was 3-7 months (4.5)

**Results:** 22 eyes were included. The mean values were: refractive error: sphere: –0,92D (plano to –1.50) and cylinder: -0.85D (0 to –1,75). UCVA improved from 20/25 to 20/18. There was no loss of BCVA in any case. The RMSH decreased from 0.62 to 0.25. LCS improved by 55%.

# Sample study cases

- 45 y/o male s/p LASIK for -5
- OD : plano, BCVA 20/25+, LCS C4
- OS: -0.50, BCVA 20/25+ LCS C5
- WG enhancement OU, 6.5mm OZ
- Post-op:
- OD UCVA 20/20, LCS C6
- OS UCVA 20/20, LCS C5


Visualization
preOP - 01
OD
Name RAGKOS, Ilias
Examination Date: 27-03-2003
Date of Birth: 01-01-0196
F1
Patient Data
F2
F3
Analyzer
F4
Visualization
F5
Export Data
F6
F7
?
About
Exit
3D View
3D Animation
Display only higher Orders
Show Grid
Scaling
µm/step
auto
Z-Order
OZ
7.0
Display Mode
WaveFront
WaveFront Refraction: ---
Clinical Refraction: +0.00D +0.00D @ ...°
Refraction: 0.0% Coma: 59.1% Higher Order: 40.9%
AL / ACC: +0.00 / +0.00
WaveFront (1)
WaveFront Diameter: 7.0
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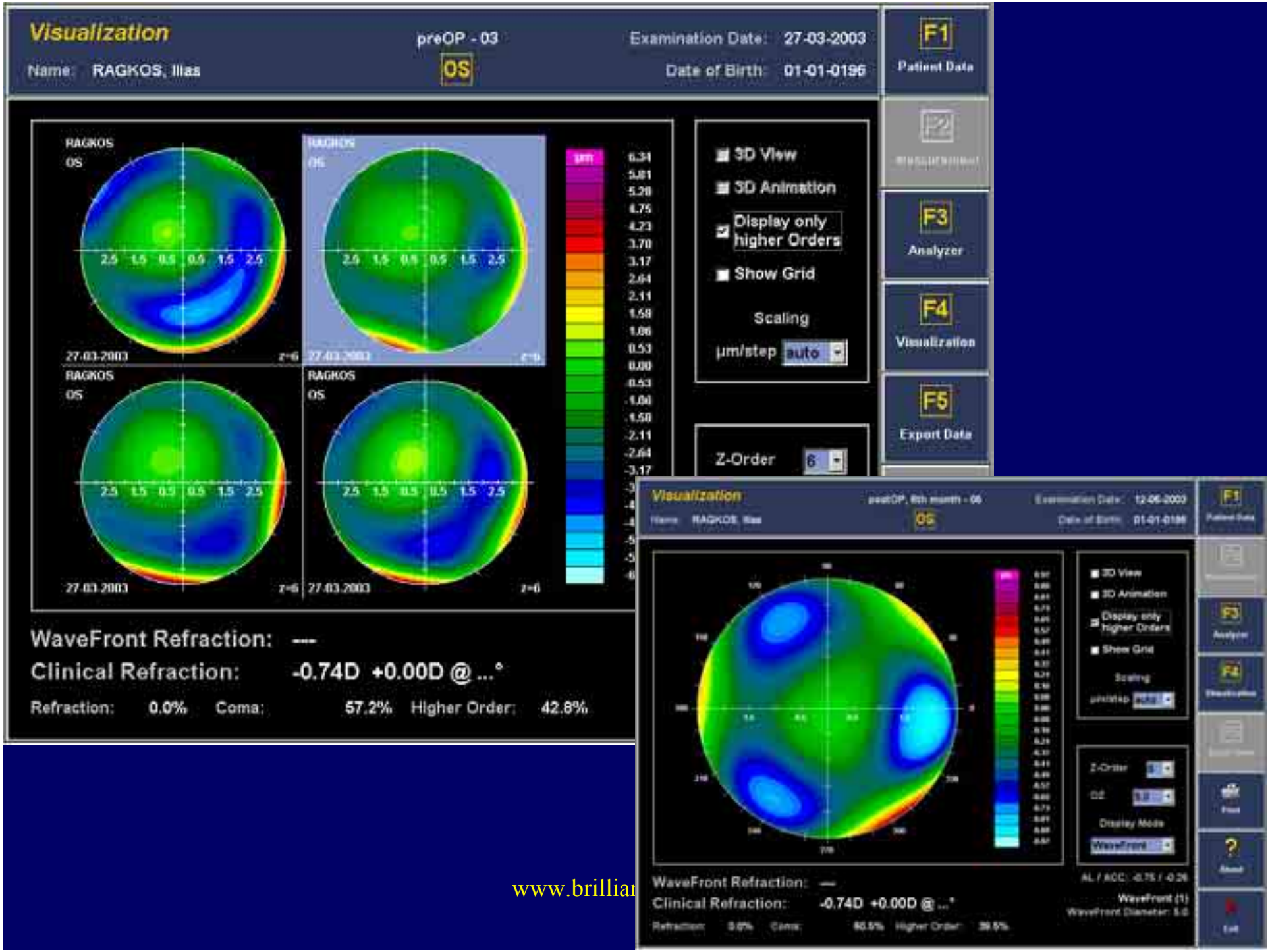
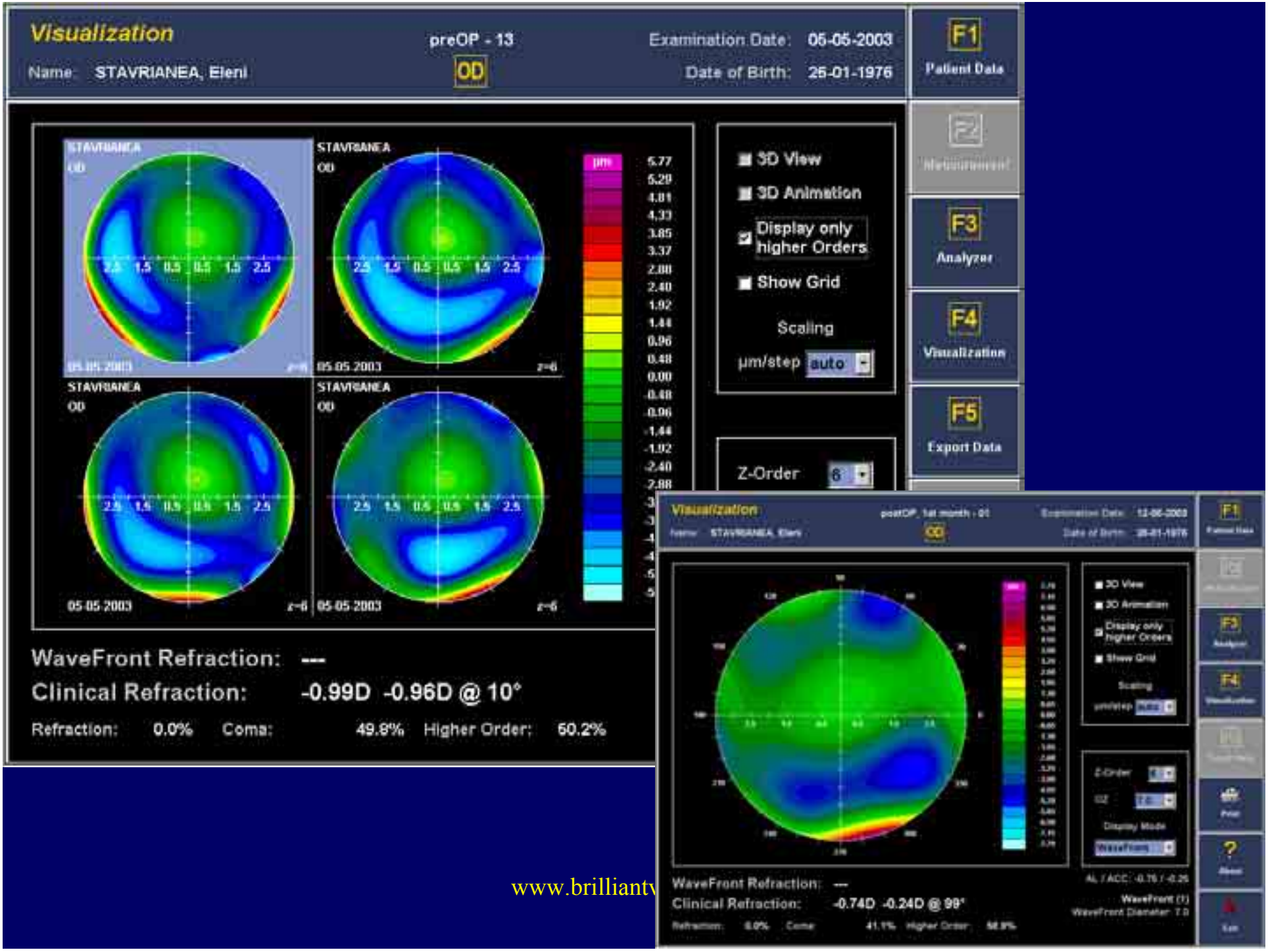
WaveFront Refraction: ---
Clinical Refraction: +0.50D -0.50D @ 40°



# Sample case

- 28y/oF
- LASIK for -7
- OD UCVA 20/25, -0,75-1,00 15 C4
- OS UCVA 20/15 plano C6
- WG enhancement OD, 6,5mmOZ
- Post-op UCVA 20/15, C6



# Case 5

- Old LASIK when 20y/o
- Did well for 2 years then developed KCN picture
- Management with INTACS-very happy but large fluctuations of sphere (-2 to –8)
- Removed intacs placed ALTK sliver 120 microns
- Enhancement at 2 ms for -2.50-3.50 X  165
- 3 months post-op: 20/20


QuickTime™ and a DV - PAL decompressor are needed to see this picture.

# Conclusions

- In our hands this technology appears to improve high order aberrations and the quality of vision (Contrast sensitivity)
- The postoperative results at day one were very impressive, possibly deriving from the smooth ablation pattern of corneal stroma bed and/or the smooth microkeratome pass.
- We use it in 100% of enhancements and pre-op cases that are high risk (cylinder, pupil, high RMSH)

# Thank You

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