

# L'Importanza della Pupilla in Chirurgia Refrattiva

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# Pupilla

- Indicatore dinamico della funzione motoria oculare e dell'apparato sensitivo a cui è dedicata, la retina
- Indicatore dell'integrità delle vie pupillomotrici
- Influenzata da:
  - illuminazione retinica
  - accomodazione
  - adattamento alla luce
  - influenze corticali

# Pupilla

- Funzioni:
  - Regola quantità di luce che giunge alla retina
  - Riduce aberrazioni cromatica e sferica
  - Aumenta la profondità di campo
- Consente visione in ampio range di illuminazione
- Diametro ottimale: 2.4 mm
- Retinal image has the highest fidelity for pupil diameter around 3 mm

# Pupilla

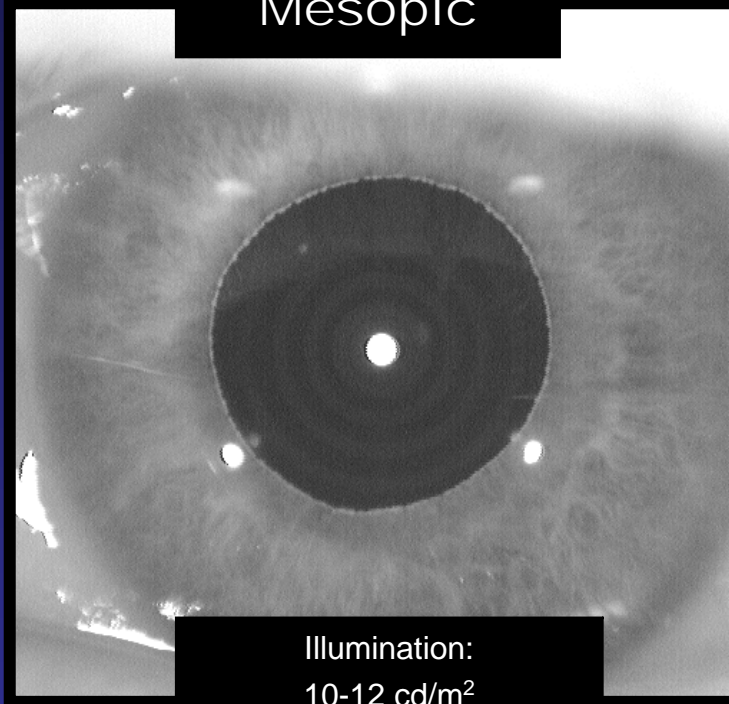
- Et : anziani hanno pupille pi  piccole
- Sesso: Donne hanno pupille pi  piccole
- Stress: pupilla si dilata
- LA MISURAZIONE E' UN'IMMAGINE VIRTUALE DELLA PUPILLA, FORNITA DALLA CORNEA, DEL 14% PIU' AMPIA DELLA PUPILLA REALE, 0.5 MM PIU' ANTERIORE ALLA PUPILLA REALE

# Diametro Pupillare

- Range: 2-9 mm
- Scotopic      6.5 mm      0.04 lux
- Mesopic lo    5.3 mm      0.4 - 1.5lux
- Mesopic hi    3.0 – 5 mm      4.0 – 22 lux

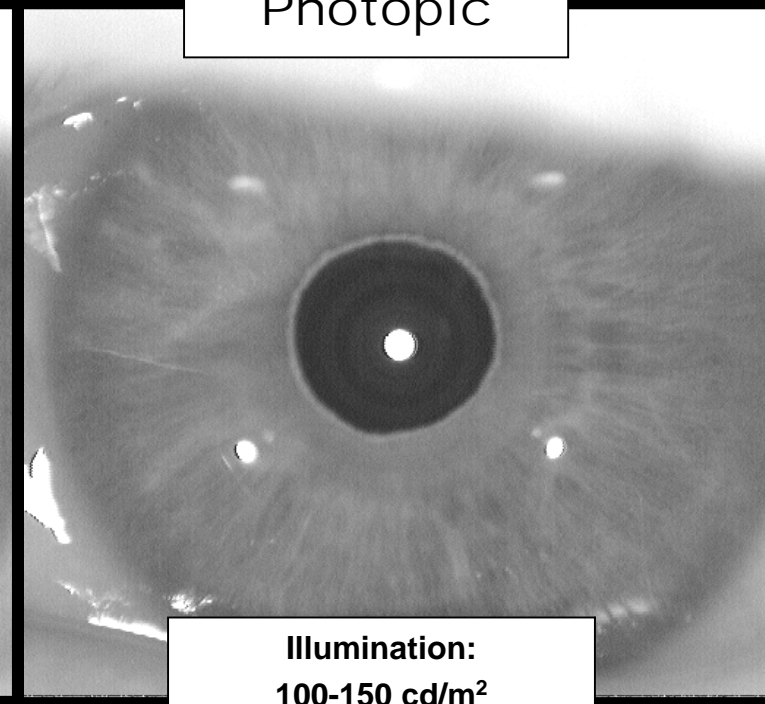
# PUPILLOMETRY

Mesopic



Illumination:  
10-12 cd/m<sup>2</sup>

Photopic

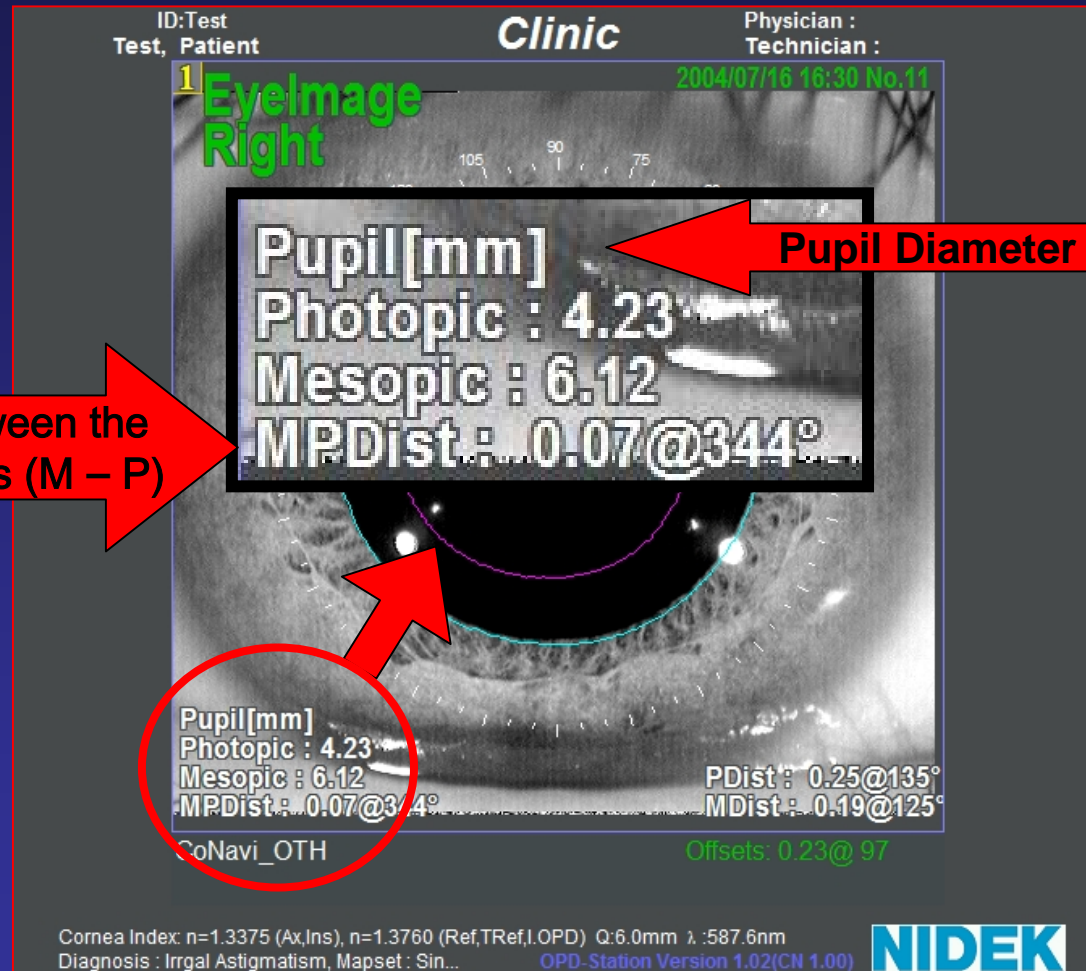


Illumination:  
100-150 cd/m<sup>2</sup>

# Pupillometry

- Acquired by infrared
- Measures:
  - pupillary diameter under photopic and scotopic conditions
  - pupil diameter variation
  - pupil diameter importance on refractive examination
- Nasal and superior **motion** of **pupil centroid** during dilation
- Much greater on x axis than on y axis

# Dilation: Pupil Center Shift



Indexes



# Pupillometry

- Pupils in constant motion (hippus)
- Pupils invariably are not equal
- Peak scotopic pupil:
  - Controlled levels of luminance
  - Multiple measurements

# Pupillometry

- Pupils affected by multiple influences in daily life:
  - Fatigue
  - Exercise
  - Medications
  - Ocular pigmentation
  - Age
  - Lighting levels (illuminance)

# Pupillometry and Refractive Surgery

- Correlates pupillary diameter to topographic and aberrometric data
- Extent of ablation and width of optical zone depends on maximum pupillary diameter
- Wider ablations: deeper ablations, check pachimetry

# Pupil Size and Refractive Surgery

- Refractive surgery uses photopic light
- Mesopic pupil size (mean 6.0, range 3 to 9.0 mm) is correlated with glare symptoms 1 month after LASIK (6.5 mm OZ, mean preop SE -3.72 D)

*Schallhorn SC, ISRS/AAO Meeting, Anaheim, CA 2003*

- No relation between glare complaints and pupil size after LASIK

*Brint SF, ISRS/AAO Meeting, Anaheim, CA 2003*

# **Pupilla e Topografia Corneale**

- **Qualunque anomalia topografica avrà un effetto sulla funzione visiva direttamente proporzionale alla sua prossimità al centro pupillare**

# Potere Pupillare Medio

- **Curvatura assiale media, espressa in diottrie, di un'area di 3 mm centrata sulcentro pupillare**
- **SE dell'area misurata**
- **Utile in cornee molto alterate (es. dopo chirurgia refrattiva) per definire reale potere corneale**
- **Utile in calcolo IOL**

# Wavefront Error, Age, Pupil Size, and Acuity

- **HO WFE varies as a function of pupil size and age**
- **Increasing pupil diameter in the normal eye :**
  - **Increases adverse effect on retinal image quality due to aberrations**
  - **Decreases diffraction problems**
  - **Fig. 2-9**

*Courtesy of R. Applegate, OD*

# Wavefront Error, Age, Pupil Size, and Acuity

- Fig. 2-10

*Courtesy of R. Applegate, OD*

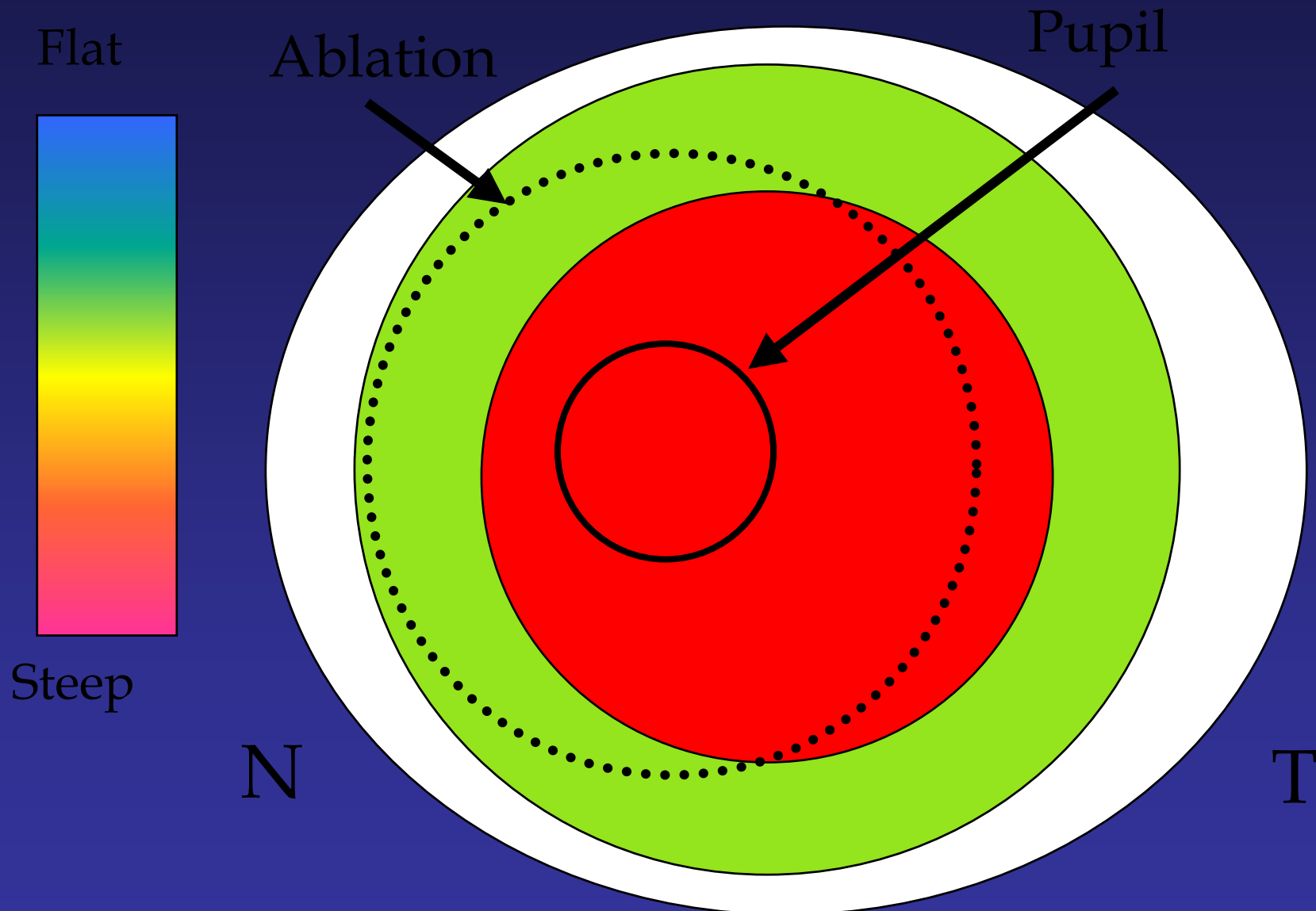


# Pupil Position

- In an eye with a nasal pupil, the TZ will involve a paracentral, steeper corneal portion in the temporal region
- Consequent higher postoperative dioptrical gradient
- Inadequate TZ causes:
  - loss of vision quality (halos, glare)
  - easier regression

*Vinciguerra P, Camesasca FI: Refractive Surface Ablation, 2006 Slack Inc.*

# Left Eye Curvature Gradient Map



# Evolution of Alignment Systems

- **Manual adjustment** of patient's head
- **Suction ring**
- First eye-tracker system: **surgeon identification** of the pupil center (Chiron)
- **Automatic identification** of pupil center (Nidek)
- **Tracking of pupil center** with high speed movements (Autonomus) and high overall reaction time
- **Tracking of cyclotorsion movements** (Torsion Error Detector - TED): **iris pattern identification** (Nidek, Visex)

# Parameters

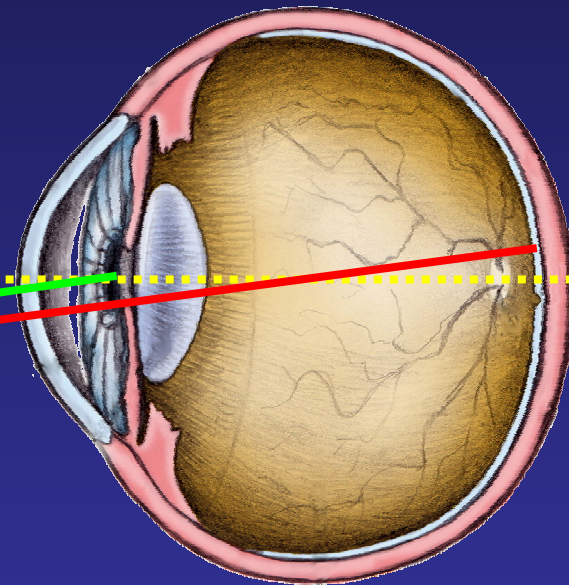
- **Geometrical corneal center**
- **Optical axis (theoretical)** line between anterior vertex (pole) of the cornea to posterior pole of the eye – defined by geometric centers of the two lenses of the eye
- **Visual axis:** line between the fovea and the fixation object (it goes through lens and corneal nodal points)
- **Line of sight (LOS):** line between the center of the entrance pupil and the fixation object
- **Pupillary axis:** line perpendicular to the cornea, it goes through pupil center

# Axes of the eye

**Optical Axis  
(theoretical)**

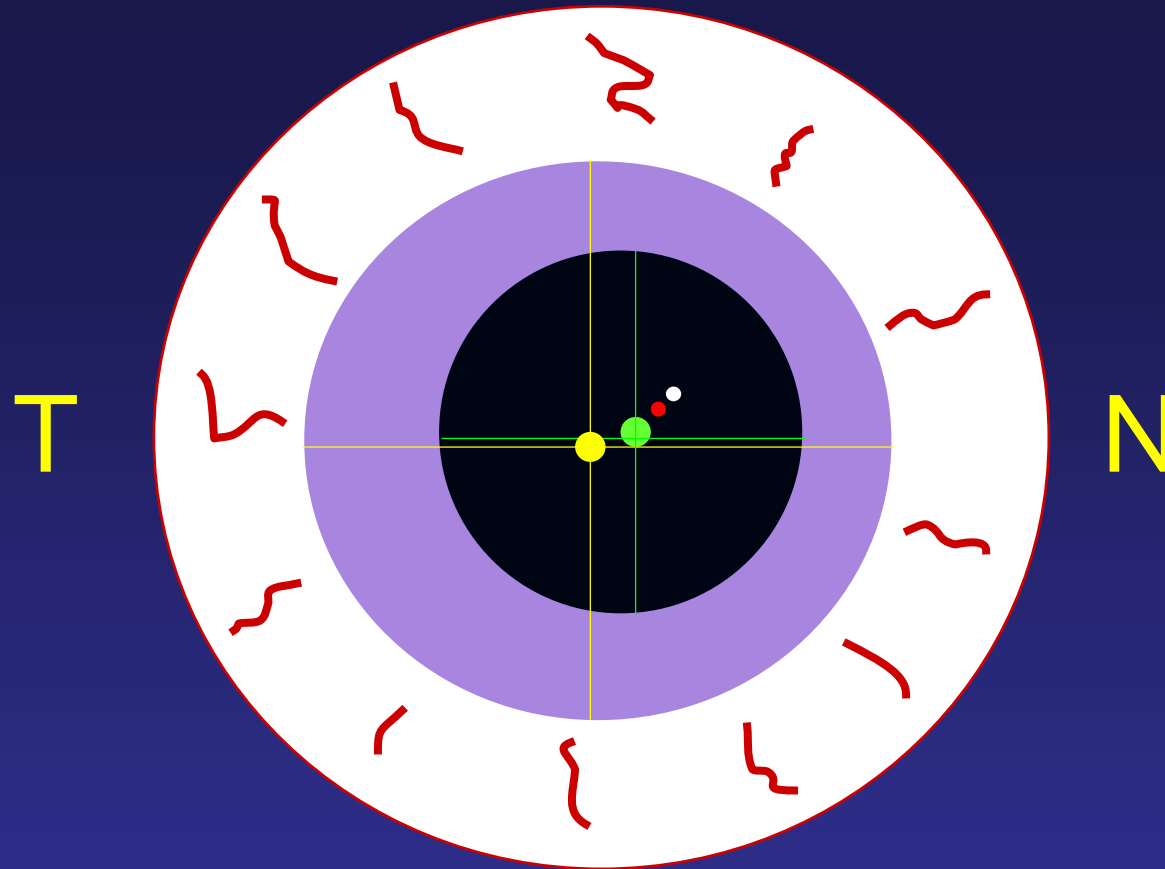


**Line of Sight (LOS)**



**FOVEA**

**Visual Axis**



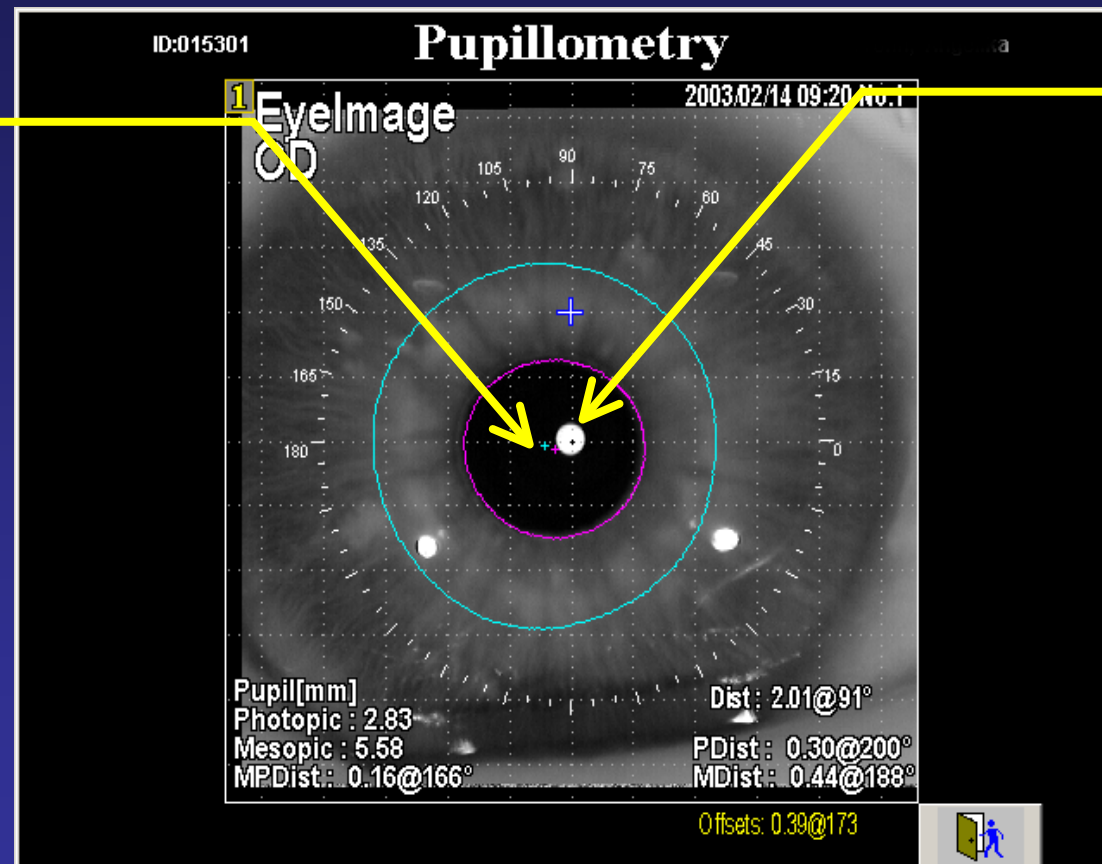
- Geometrical corneal center (Optical Axis)
- Entrance pupil center (LOS)
- Visual axis
- Coaxially sighted corneal reflex (depends on the position of the light source!)

# PUPILLOMETRY

## Pupil dynamics

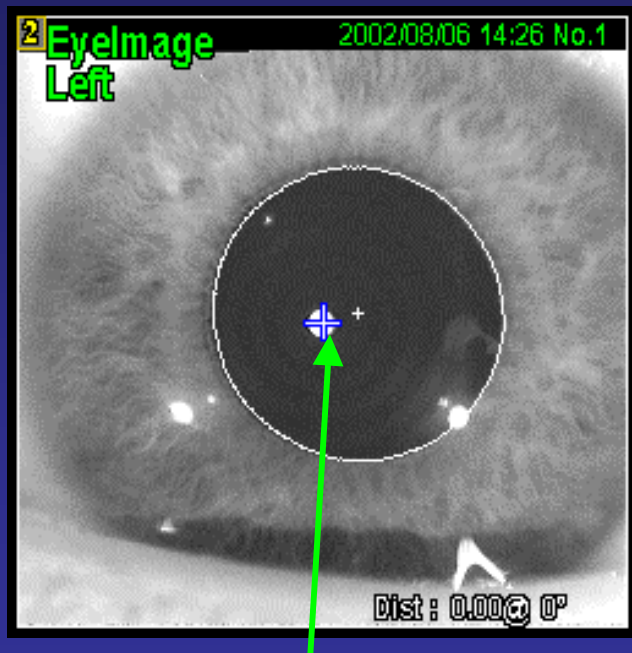
Pupil  
center/LOS

(Photopic or  
Mesopic)



Visual  
axis  
(fovea-  
fixation  
object)

# Conflict: Centration on **LINE OF SIGHT** or **VISUAL AXIS** ?



**OPD measures on  
VISUAL AXIS !**

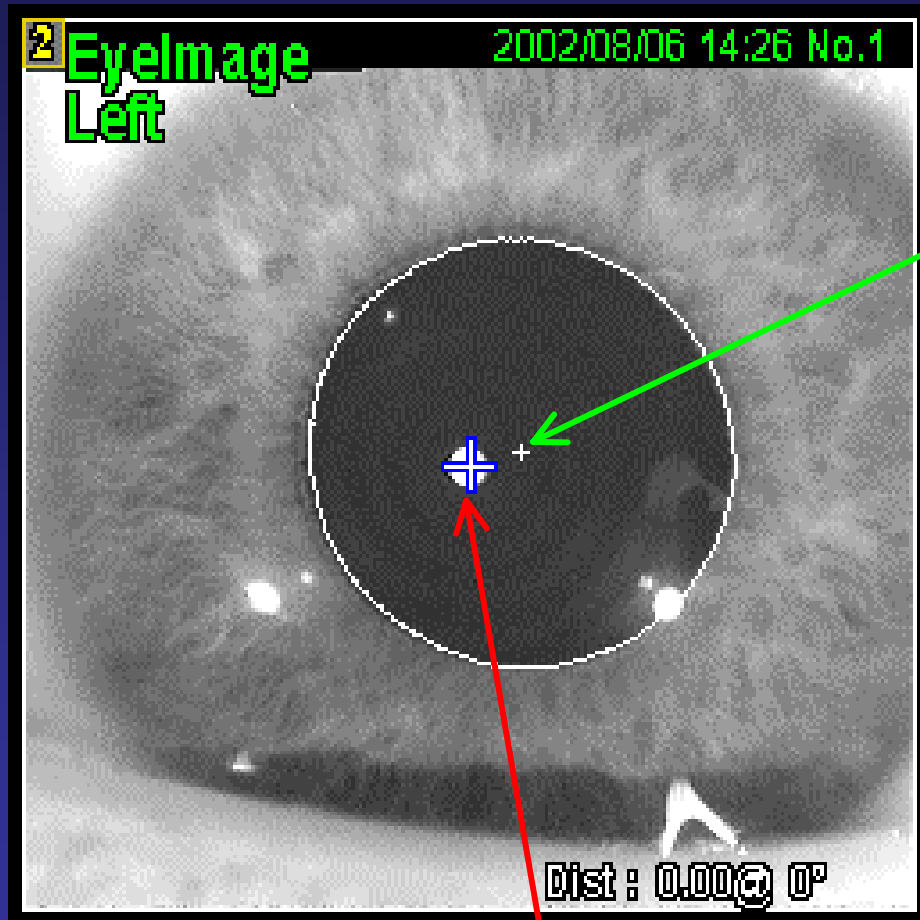


**Eye Tracking Syetem  
follows L O S !**



80% pts Kappa @  $< 0.3$  mm

20% pts Kappa @  $> 0.3$  mm



Line of Sight  
(Pupil Center)

Angle Kappa : distance  
between the Pupil  
Center and the visual  
axis

Visual Axis



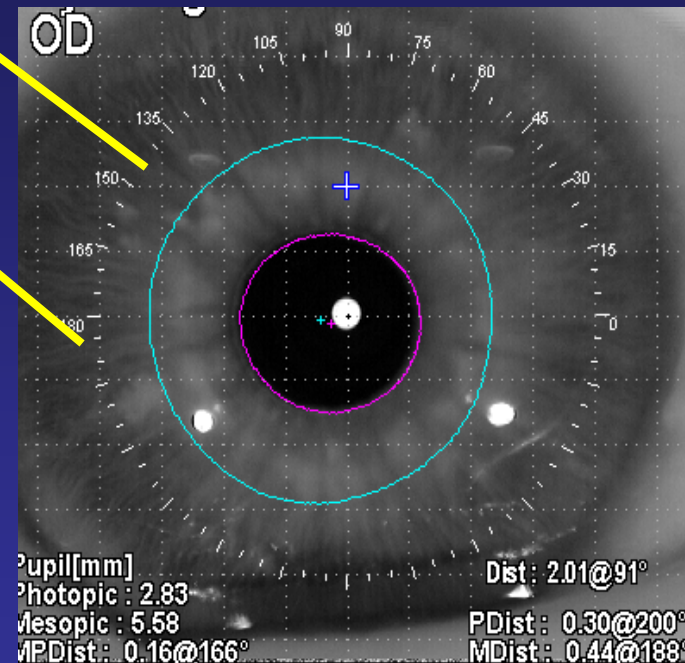
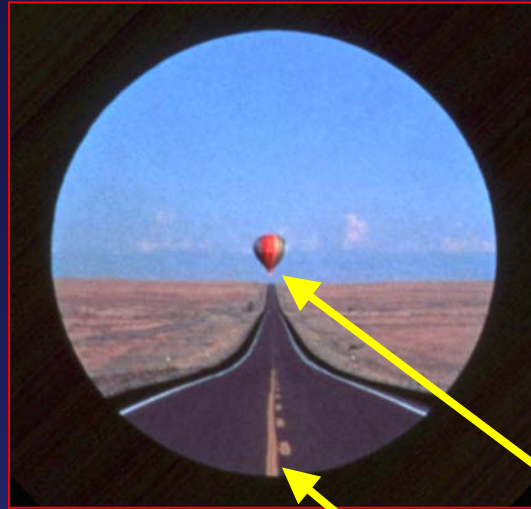
Dist: 2.01@91°

PDist: 0.30@200°

MDist: 0.44@188°

Offsets: 0.39@173

**OffsetS: difference between photopic and mesopic fixation (the bright corneal reflex spots serve as reference points when matching both images. The amount of translation needed to match both images is called Offsets and can be an indicator for bad fixation; it is color coded green-yellow-red for good-or-bad**



**Pupil diameter and LOS vary when the pt looks to an object located near or at distance**

**Laser Fixation Target corresponds to infinity**

# Conflict: **LINE OF SIGHT OR VISUAL AXIS ?**

Measurement syst



Visual axis

Laser alignment syst



Pupil

- **Is it a conflict or a measurement difficulty**
- **Which of the two gives us the best result?**
- **Possible induction of Coma**
- **Need to analyze the distance between center of Mesopic and Photopic pupil**

# PROs of Visual Axis Centration

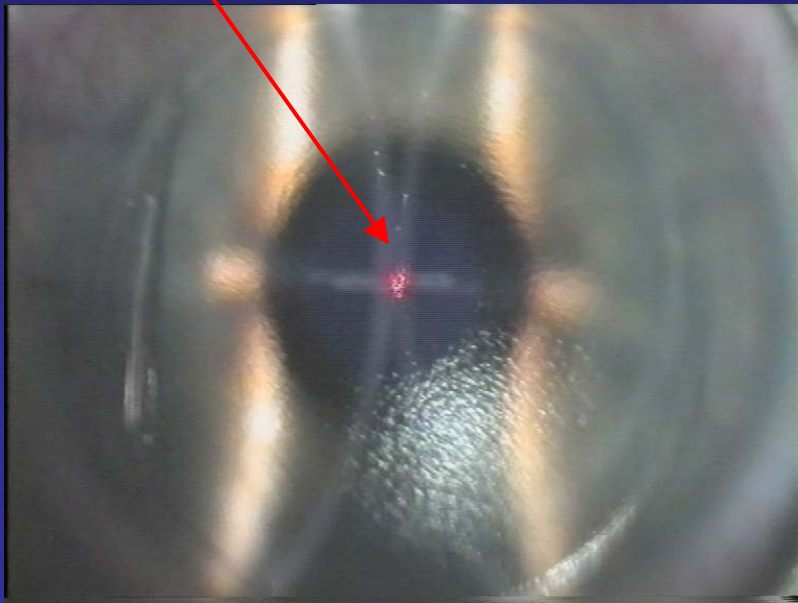
- Physiologic formation of the retinal image (fovea – fixation object)
- Reduction of decentered treatment currently avoided through wide optical zones
- Prolate or aspheric surfaces on corneas that are not decentered
- Reduction of optical aberrations: coma
- Better contrast sensitivity
- Best Visual Acuity → “Supervision”

# Factors of proper alignment with NAVEX Platform –NIDEK

- Lateral alignment: X/Y axis
- Z-plane focusing
- Tilt control
- Torsion Error Detector (TED)
- 200Hz Eye Tracking movement during ablation

# Manual TE Offset (Current Method)

Center of Ablation



EC-5000

### OPTIONS

**Parameters**

Laser Repetition Rate Myopia : 40 Hz      Vertex Distance : 12.50 mm  
Desired Ablation Rate on PMMA : 0.300  $\mu$ m      Limit of Total Ablation Depth : 190  $\mu$ m  
Default Flap Thickness : 160  $\mu$ m

**Control condition**

Printer control :       No print       Manual print       Auto print  
Save Operation Data :       Auto       Manual  
Sph./Cyl.order :       Sph. first       Cyl. first  
Enable Delivery Position Movement :       Yes       No  
OZ/TZ Cyl.independent of OZ/TZ Sph. :       Yes       No  
Offset Control in Eye Tracking :       Yes       No  
Enable TEST ABLATION on plate :       Yes       No  
Enable Multi Stage Operation :       Yes       No

Enable OZ/TZ size Recommendation :       Yes       No  
Axis setting independent of PreOP axis :       Yes       No

Back (B)      Nomogram (N)      Print (P)      OK (O)

SYSTEM POWER OFF      5/12/2004      12:26 PM

EC-5000 Myopia Stage 1

Patient Name & ID : Lucardi Marica 493041 Eye : L

Physician's ID : [ ]

NIDEK Standard

Nomogram ID : MYO\_SUR\_UNDER40

**1 Eyelimage** 2003.02.14 09:20 No.1

OD

Pupil[mm]  
 Photopic : 2.83  
 Mesopic : 5.58  
 MPDist: 0.16@166°

Dist: 2.01@91°  
 PDist: 0.30@200°  
 MDist: 0.44@188°

X, Y  Radius, Angle

X : 0.00 mm  
 Y : 0.00 mm

P.Dist  
 X : 0.00 mm  
 Y : 0.00 mm

M.Dist  
 X : 0.00 mm  
 Y : 0.00 mm

Set (S)

Back (B) OK (O)

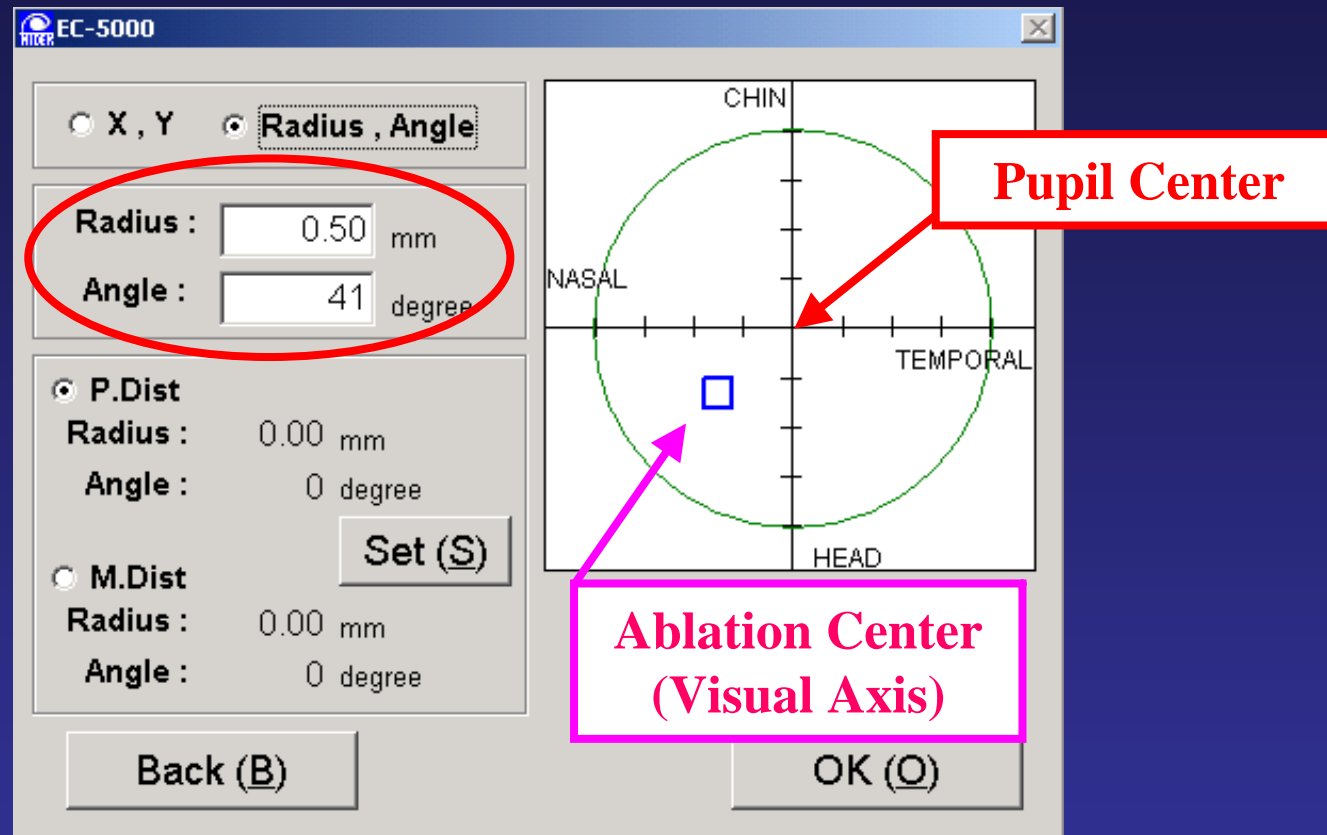
Back (B) System Data (D) Start OP (O)

Mode = EGY NGR  
 DATA RECEIVE ENABLE 07/27/06 2:26 PM

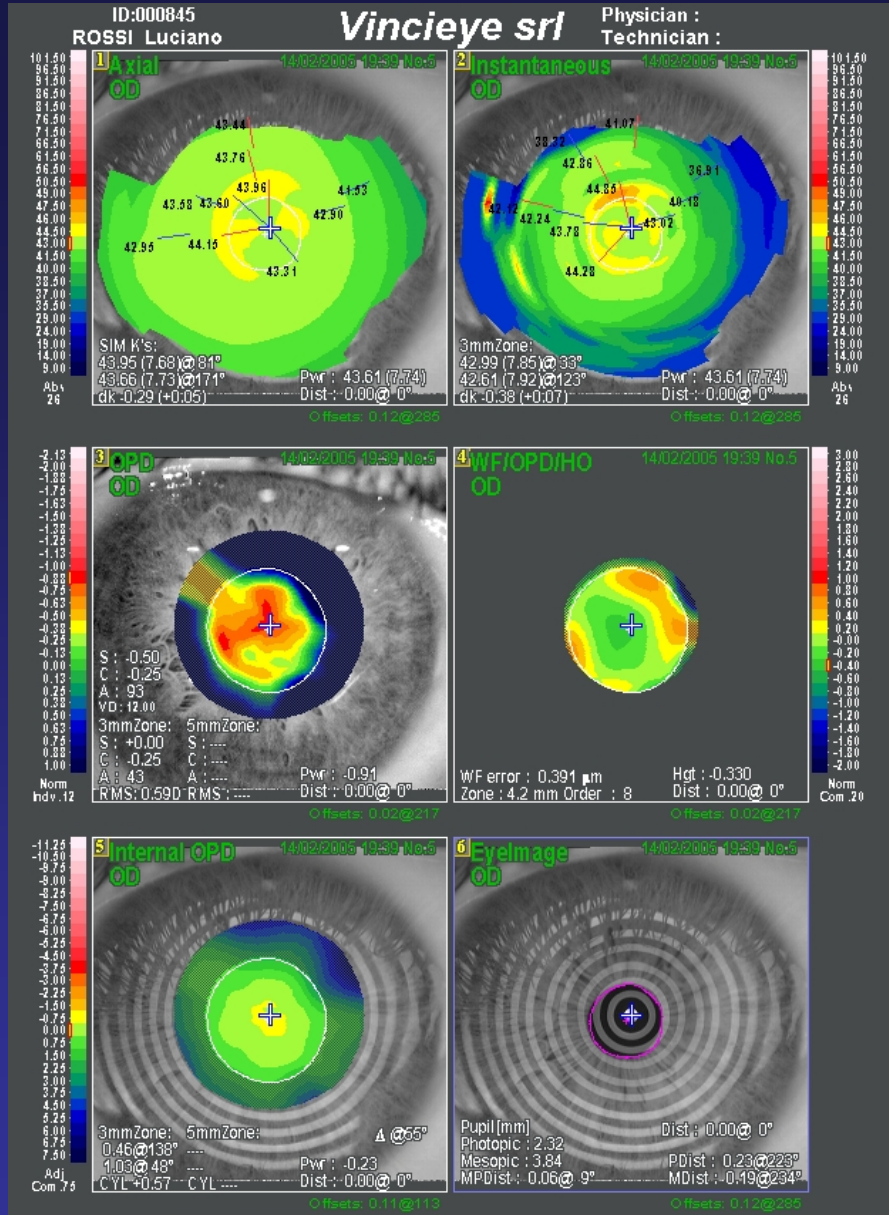
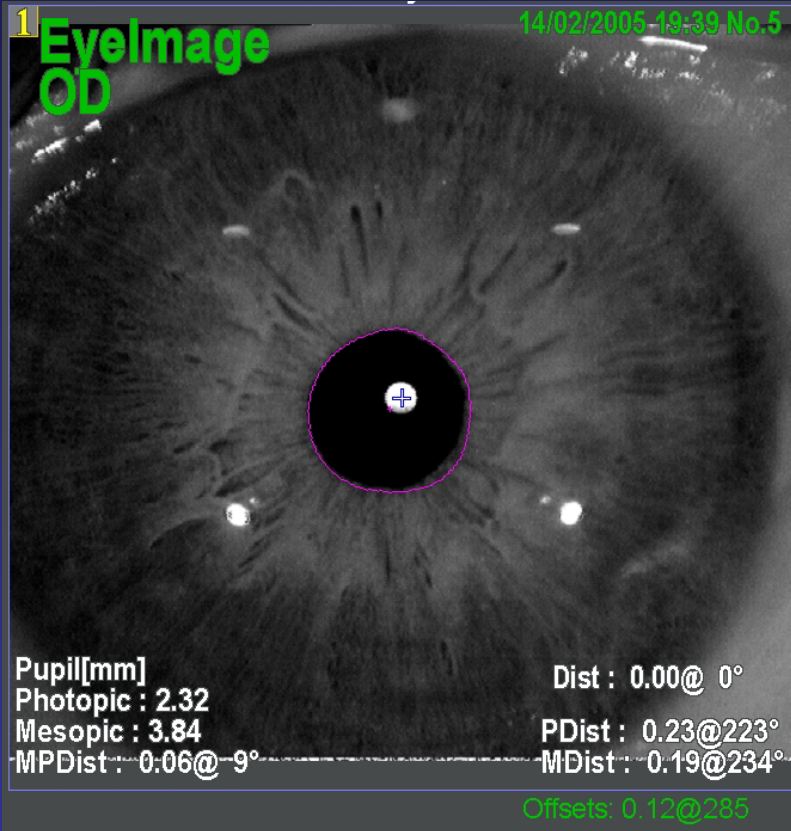
Presently one must use the eye tracking offset function to enter the difference between visual axis and pupil center, defined as Cartesian or polar coordinates.



# New Eye Tracking Offset Function



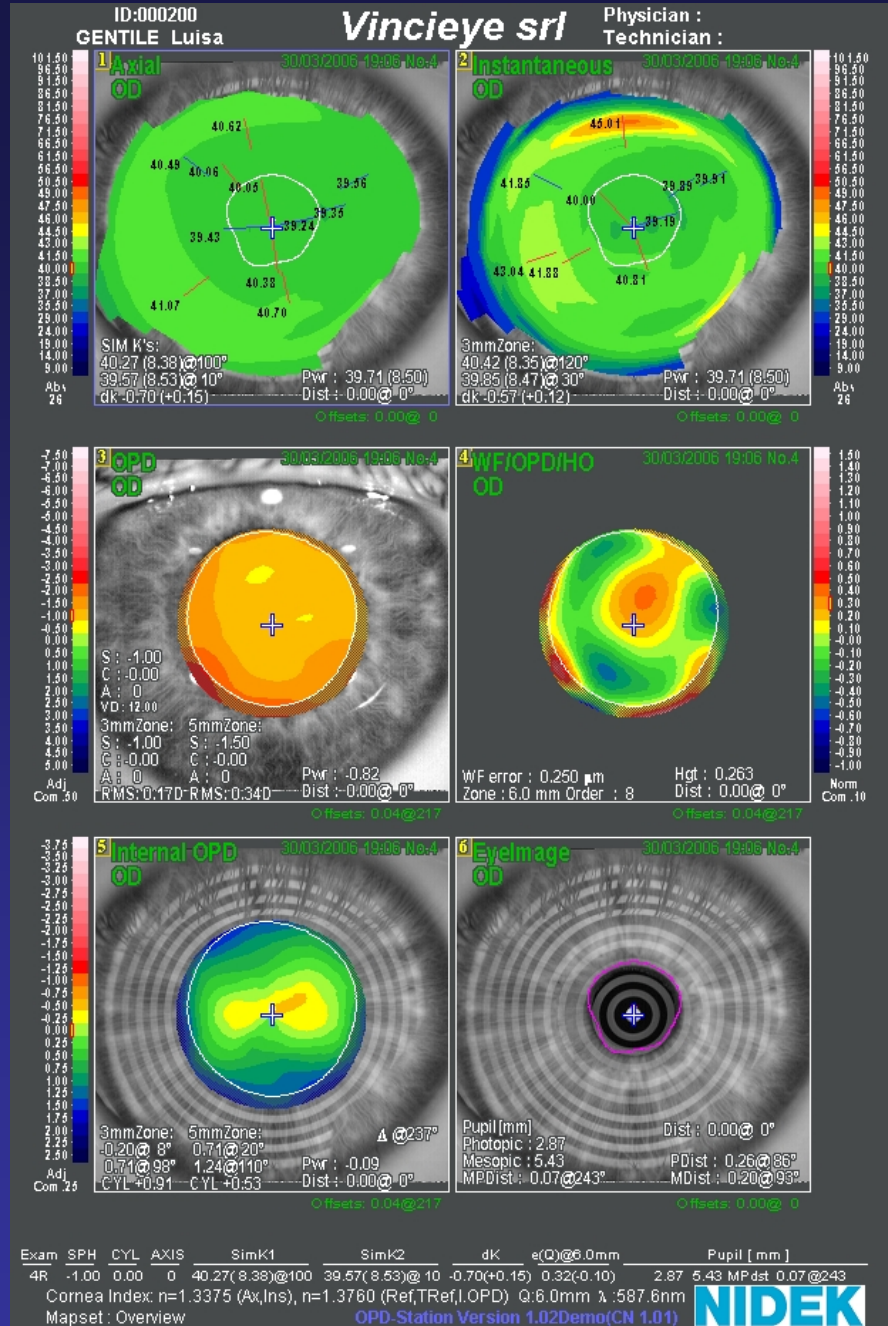
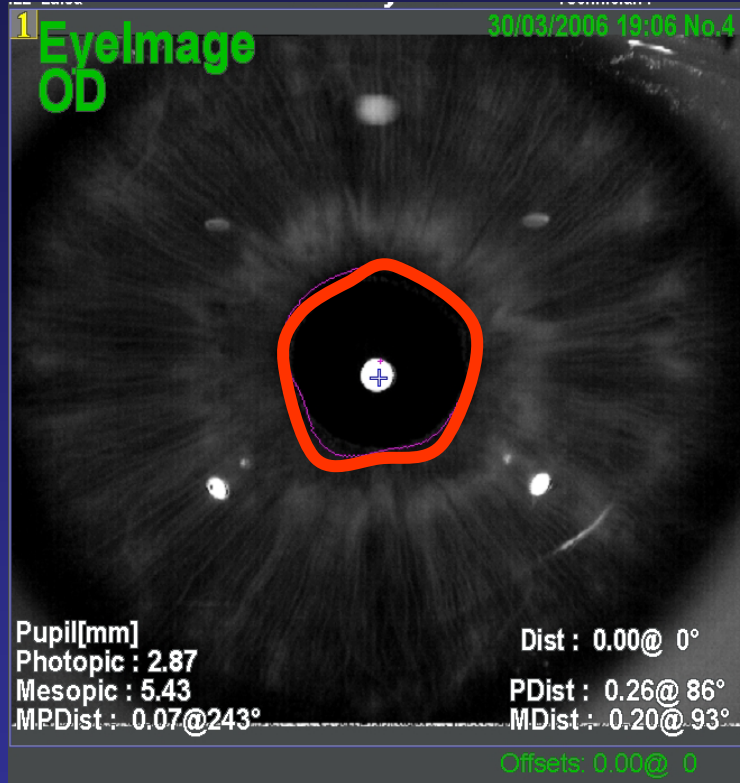
Future software version will automatically transfer this numbers via FinalFit as it is included of the OPD – Scan data.



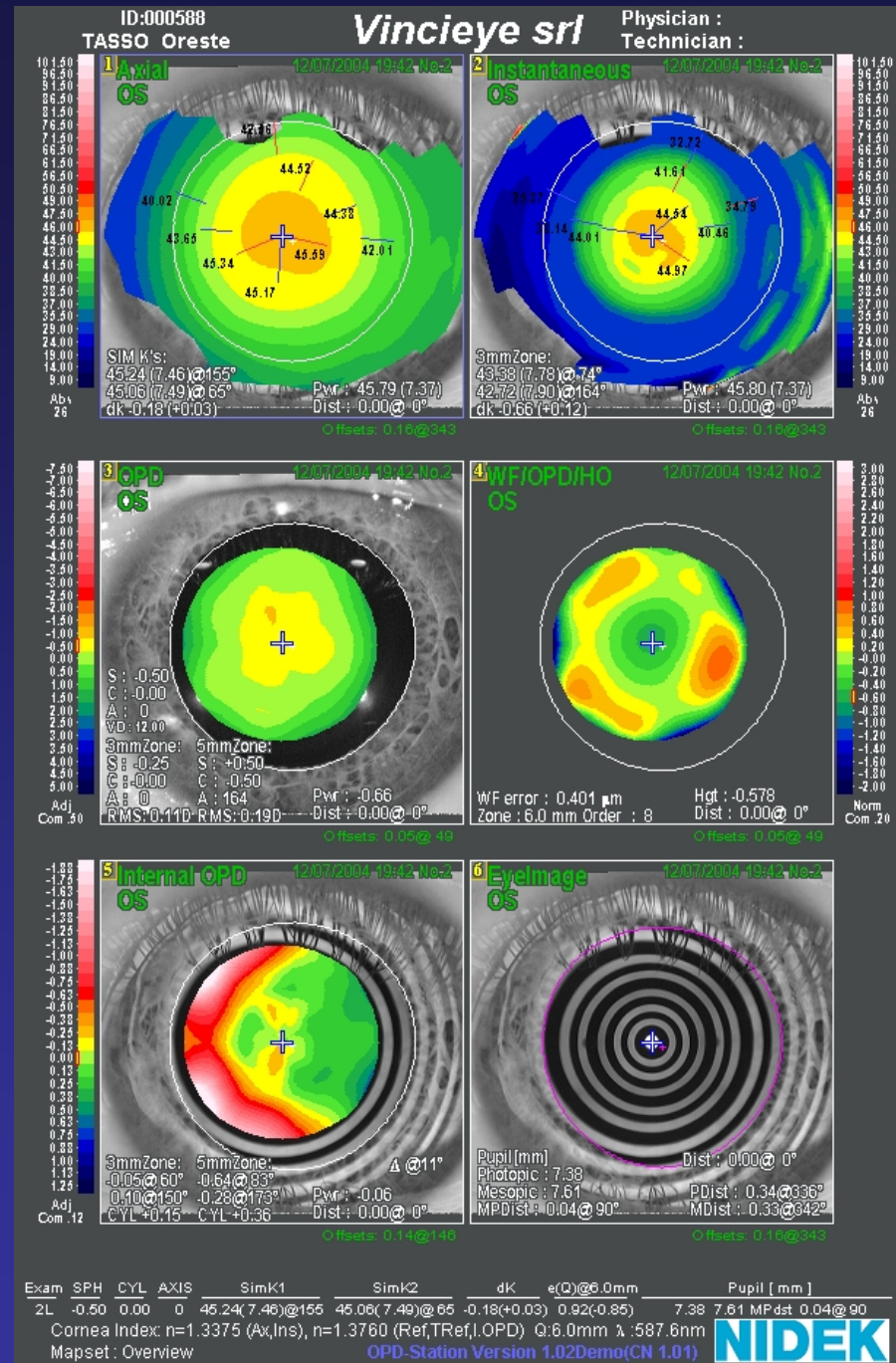
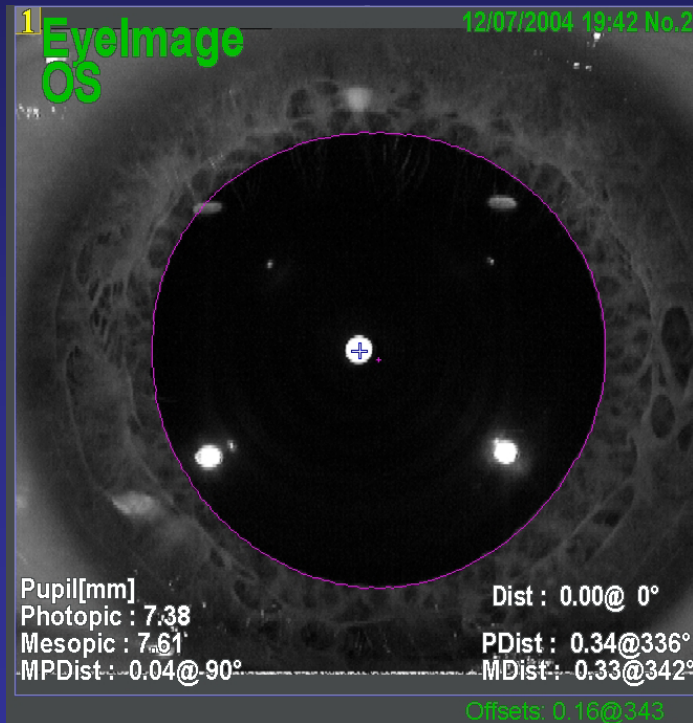
Exam	SPH	CYL	AXIS	SimK1	SimK2	dK	e(Q)@6.0mm	Pupil [ mm ]
5R	-0.50	-0.25	93	43.95(7.68)@81	43.66(7.73)@171	-0.29(+0.05)	0.36(-0.13)	2.32 3.84 MPdst 0.06@ 9

Cornea Index: n=1.3375 (Ax,Ins), n=1.3760 (Ref,TRef,I,OPD) Q:6.0mm λ:587.6nm  
 Mapset : Overview **OPD-Station Version 1.02Demo(CN 1.01)** **NIDEK**

# Asymmetric Pupil



# Hyperopic treatment



# Conclusions

Correct alignment is mandatory for successful custom ablation

Correct alignment requires identification of:

- Ocular Axes:

**Line of Sight (LOS)** and **Visual Axis**

- Cyclotorsion error :  
astigmatism and HOA

# Conclusions

Pay attention to pupil size

More demanding surgery in pts with large pupils

Counsel all patients that there may be an increase in glare and halos after surgery

Wavefront data must be centered on a fixed eye structure rather than the pupil center, or take into account pupil center variability



**Arrivederci**  
**Refr@ctive.online**  
**September 2007**

**[www.refractiveonline.it](http://www.refractiveonline.it)**