

# Διαθλαστική Χειρουργική στον Κερατόκωνο ?

**Κ. Χ. Καραμπάτσας**

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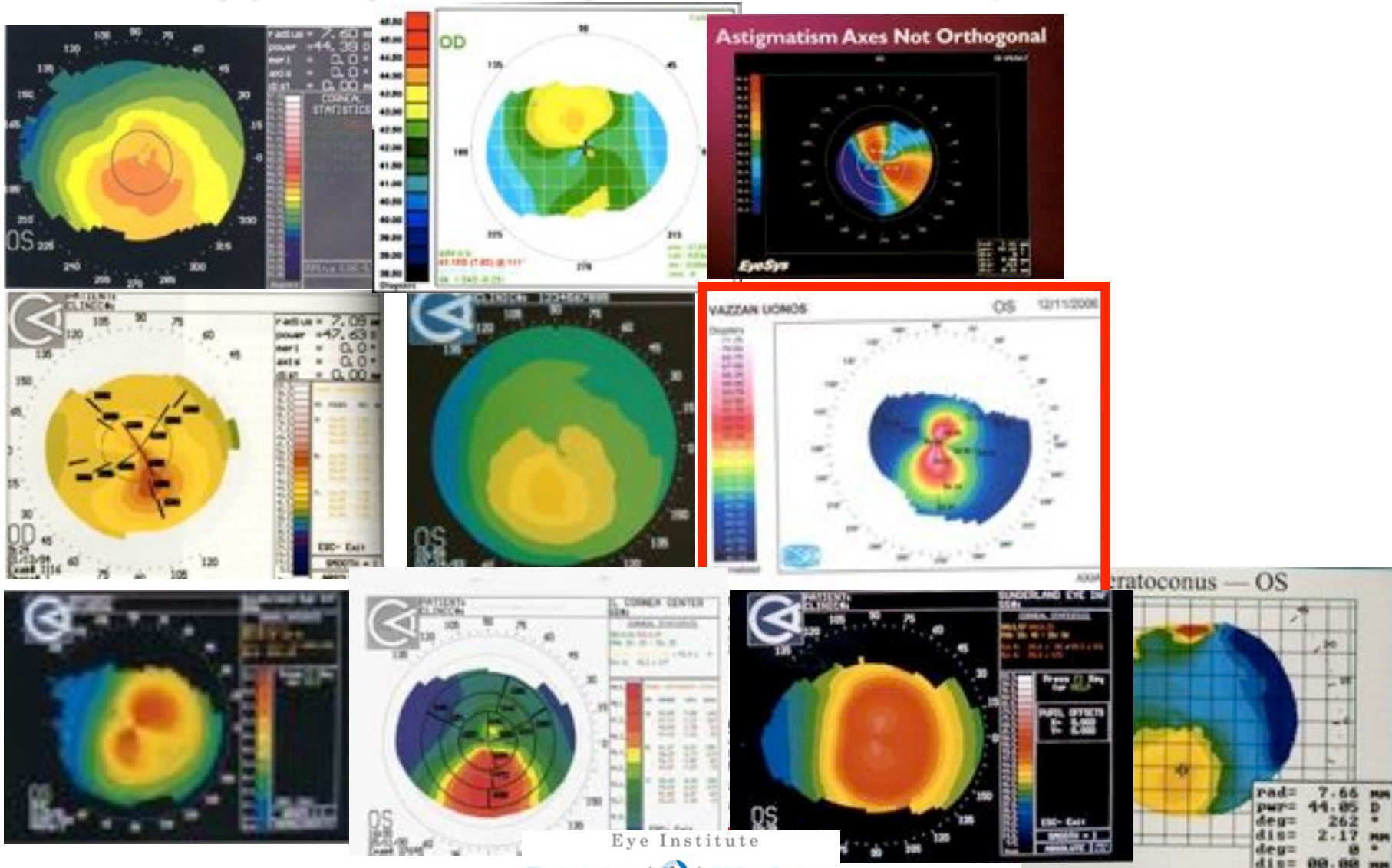
Eye Institute

**Laser**  **Vision**  
*Your Vision Our Mission*

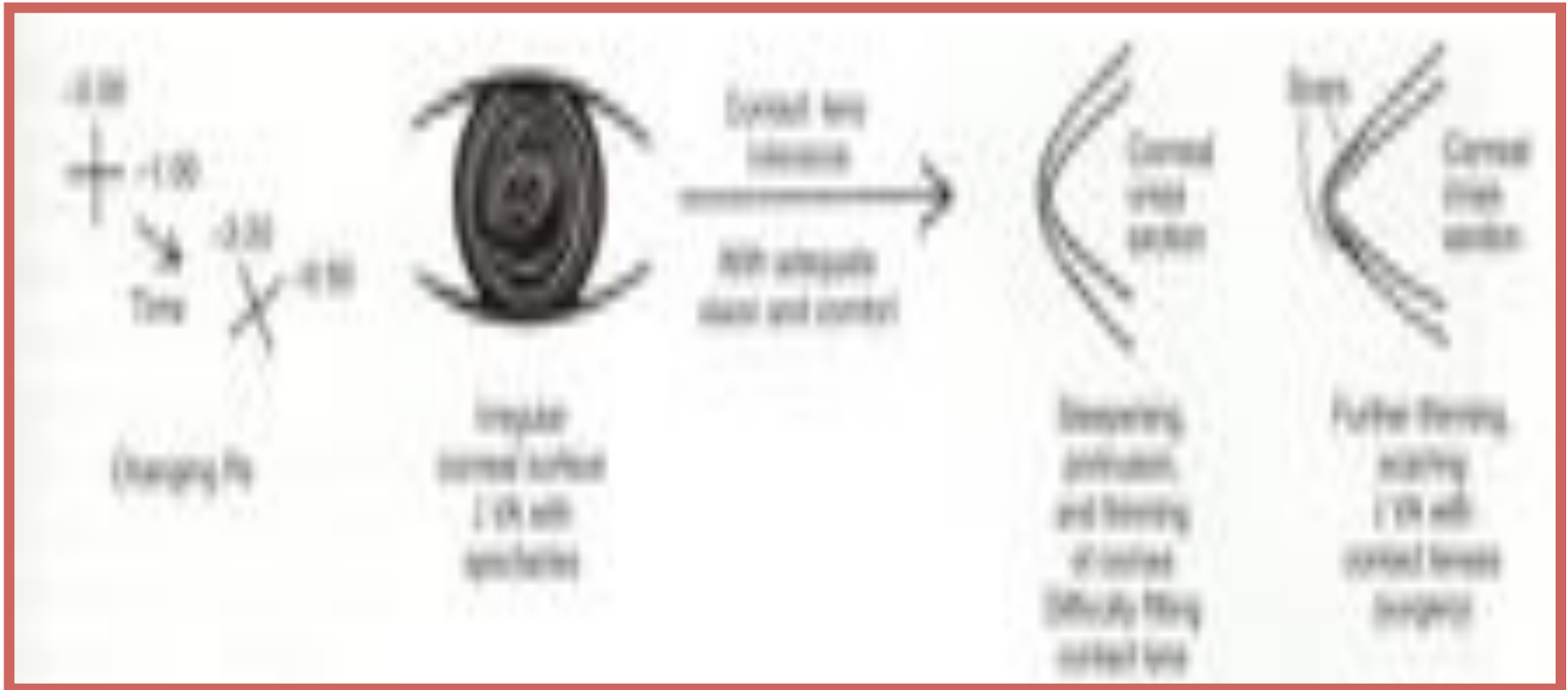
# Κερατόκωνος

- Συχνότητα
  - Στον γενικό πληθυσμό **0,05%**
  - <sup>^</sup> συχνότητας με καινούργιες διαγνωστικές μεθόδους
    - **6-17%** σε δείγματα ασθενών προεγχ. διαθλαστικού ελέγχου (υποκλινικός KC, FFC-form fruste KC)
  - Αμφοτερόπλευρη αλλά ασύμμετρη
  - Έναρξη συνήθως στην εφηβεία
  - Θετικό οικογενειακό ιστορικό σε 6-8%
    - Κυρίαρχο γονίδιο με ατελή διεισδυτικότητα (incomplete penetrance).
    - Πολυγονιδιακή αιτιολογία

# Τοπογραφία κερατοειδούς στον ΚΣ



# Πορεία του κερατόκωνου



Eye Institute

# Θεραπεία - αντιμετώπιση

- Γυαλιά
- Ημίσκληροι (κερατοκωνικοί) φακοί επαφής / μαλακοί ΚC φακοί επαφής

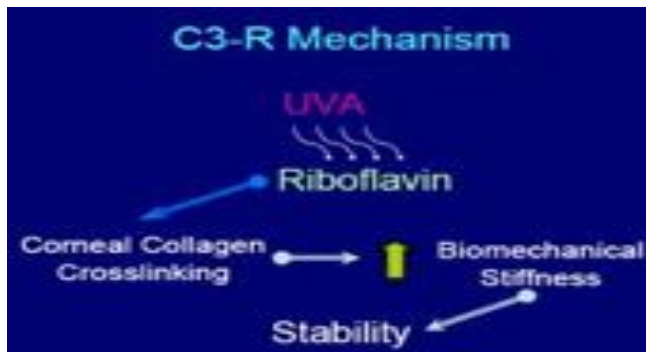
**Κερατόκωνος = μια πάθηση που αντιμετωπίζεται με φακούς επαφής**

- Διαμπερής Κερατοπλαστική
  - Υψηλά ποσοστά επιτυχίας, αλλά υψηλός μετεγχειρητικός αστιγματισμός
  - Ημίσκληροι φακοί επαφής / μαλακοί ΚC φακοί επαφής

# Θεραπεία - αντιμετώπιση

- Γυαλιά
- Ημίσκληροι (κερατοκωνικοί) φακοί επαφής / μαλακοί ΚC φακοί επαφής
- **Collagen Cross Linking**
- **+/- PRK laser**
- **Phakic IOLs (ICL)**
- **Ενδοκερατικοί δακτύλιοι (Intracorneal stromal rings)**
- **Deep Lamellar Keratoplasty (DALK)**
- Διαμπερήs Κερατοπλαστική
  - Υψηλά ποσοστά επιτυχίας, αλλά υψηλός μετεγχειρητικός αστιγματισμός
  - Ημίσκληροι φακοί επαφής / μαλακοί ΚC φακοί επαφής

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I.

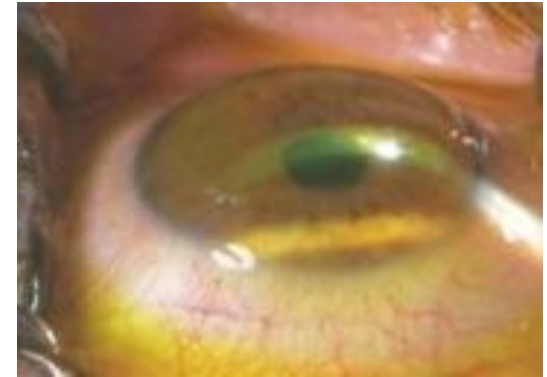
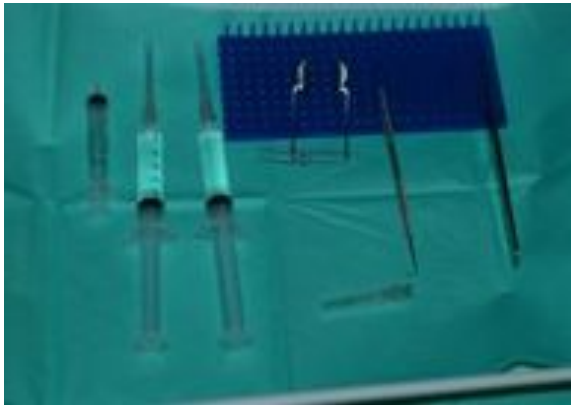
Αντιμετώπιση κερατόκωνου\* μόνο  
με διασύνδεση κολλαγόνου (CXL)

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# Στόχοι της αγωγής

- Η αναστολή της εξέλιξης της εκτασίας :
  - **Corneal cross- linking**
- Η βελτίωση της όρασης με:
  - **Γυαλιά**
  - **Φακούς επαφής**
  - **Συμπληρωματική παρέμβαση**
    - PRK
    - ICL
    - INTACS

# X-linking



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**UVA 370 nm**  
**Irradiance 3 mW/cm<sup>2</sup> for 30 min**  
**Dose of 5.4 J/cm<sup>2</sup>**



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# S. A., (f), 25yo

OD KC

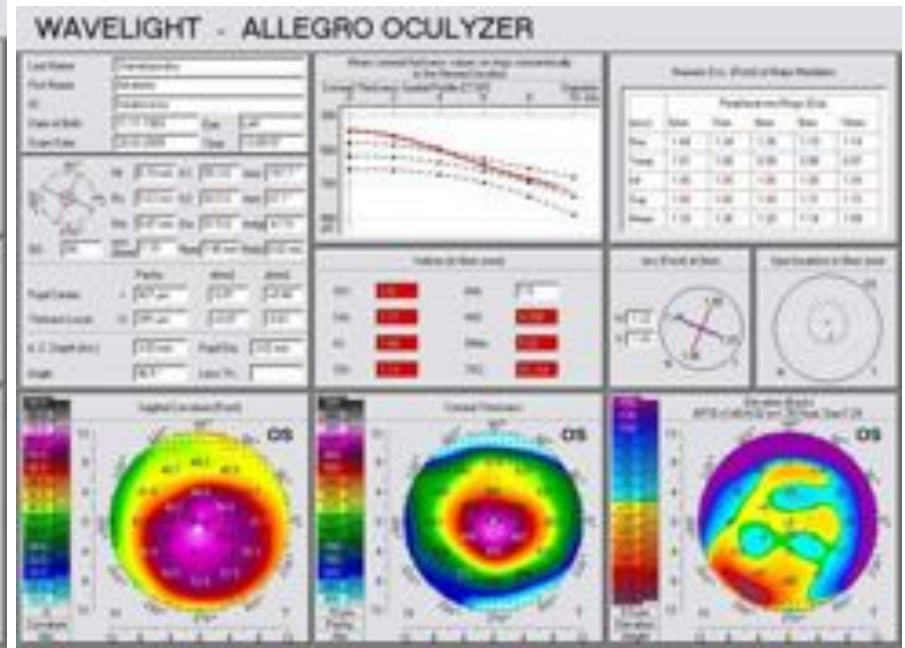
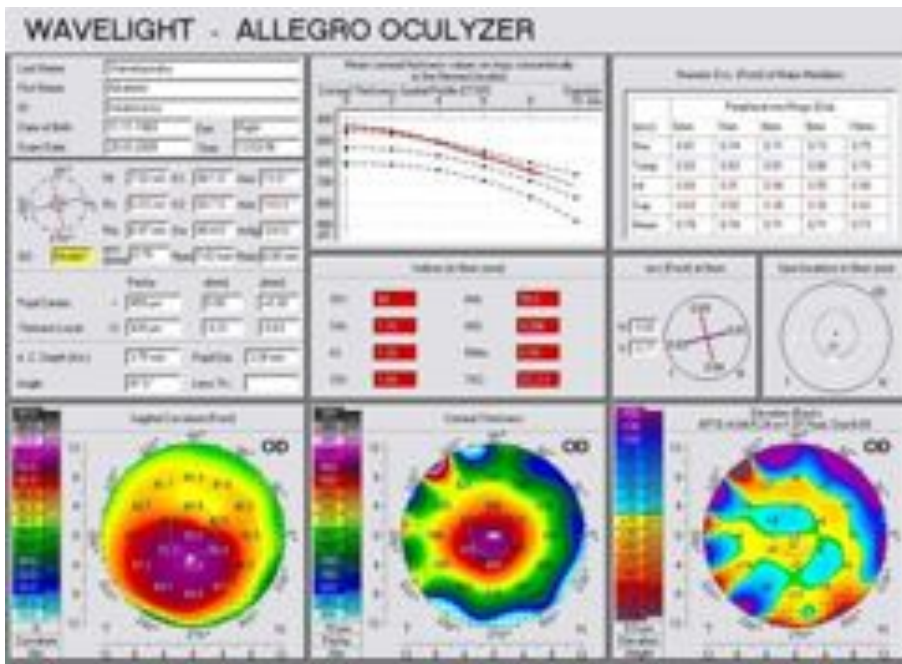
VA s 5/10

BCVA 9/10

OS KC

VAs 2/10

BCVA 6/10



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**OD**

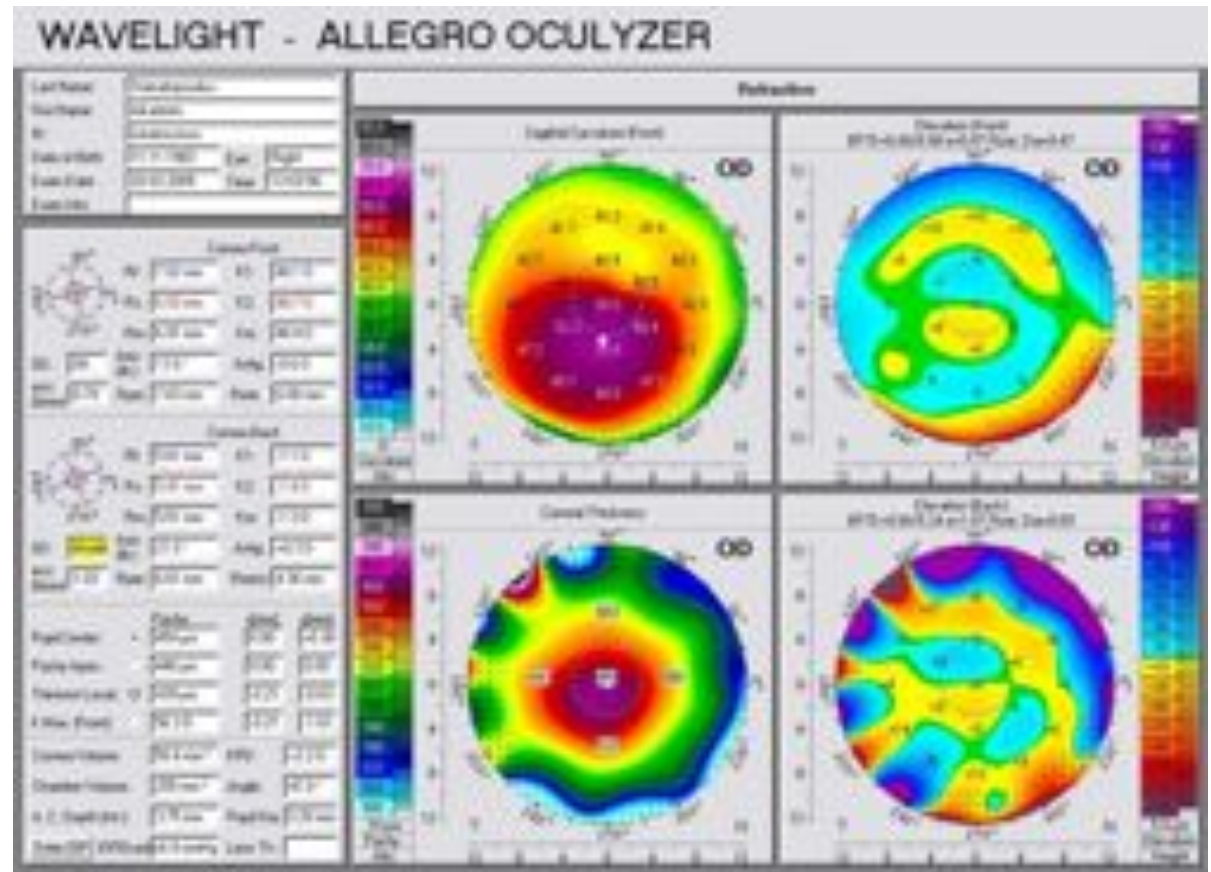
Min CT : 436

CT after epith removal 387

Procedure :

Hypotonic ribo 30 min

30 min UV

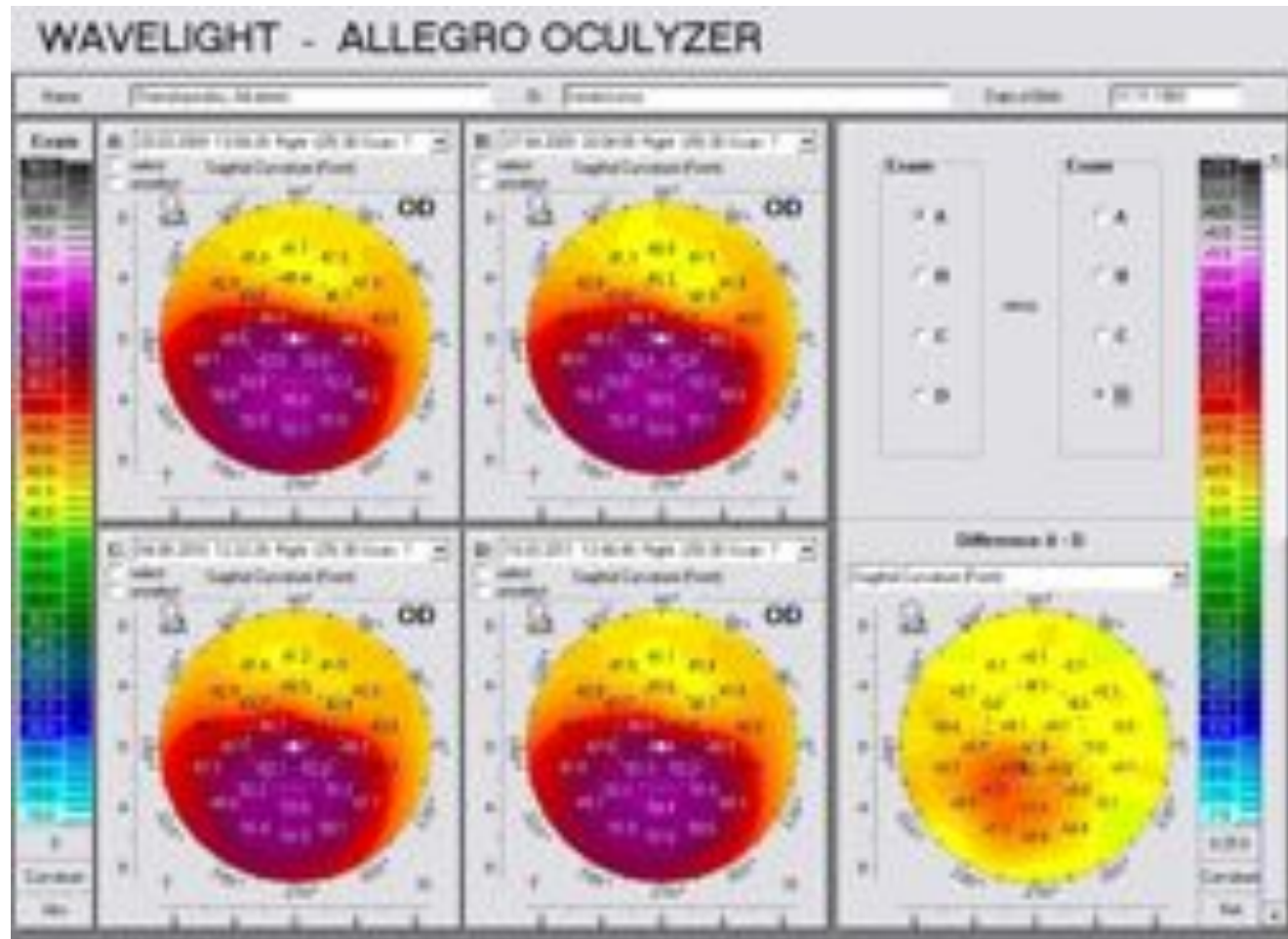


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## OD serial

### Result

- Kms flattening (1.50 D)
- VA s 6/10 > 7/10
- BCVA 9/10 > 10/10  
(pl/-1.50x85)
- Good VA even with glasses
- Easier CL fitting



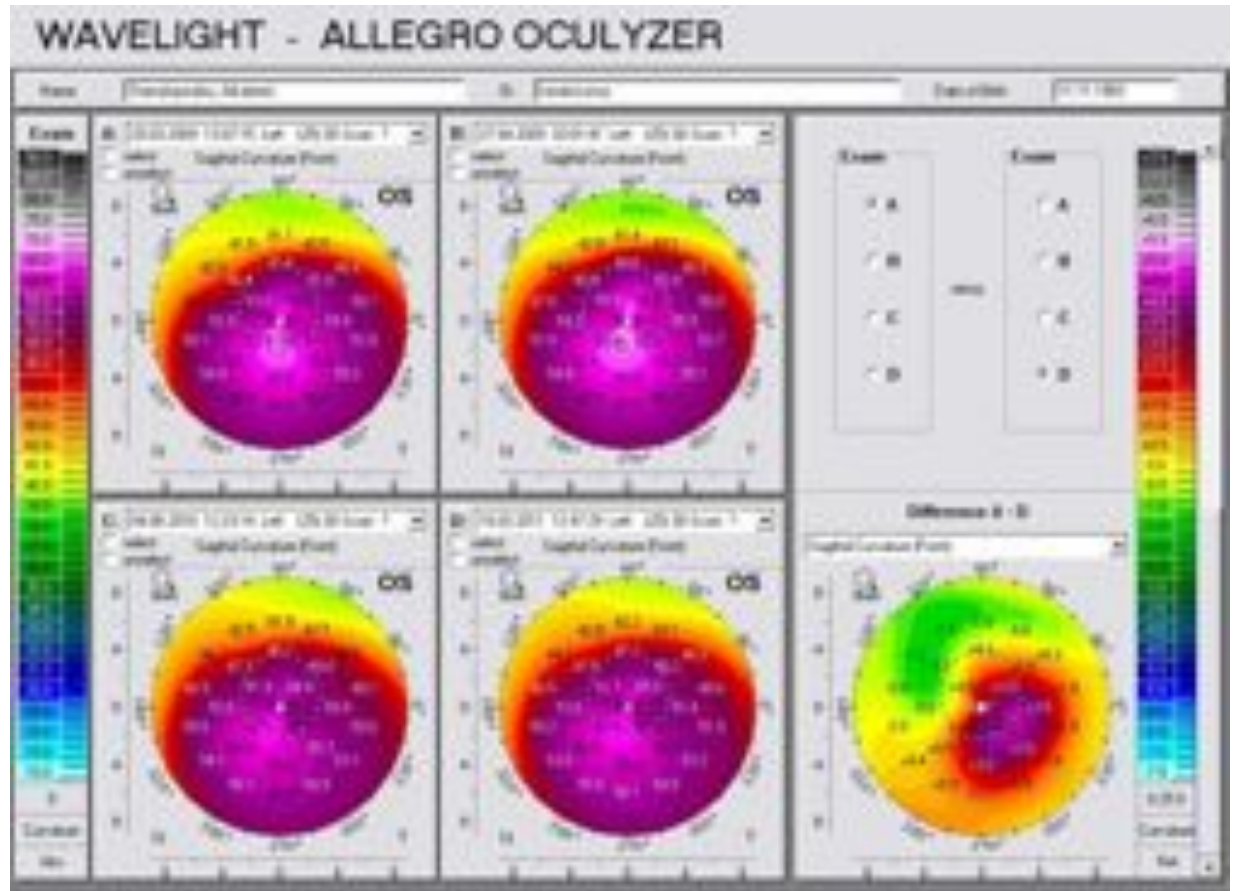
Eye Institute



## OS serial

### Results

1. Kms flattening (3.50 D)
2. VA s 2/10 > 3/10
3. BCVA 6/10 > 7/10  
(-1.75/-2.25x100)
4. Relatively good VA even with glasses
5. Easier CL fitting
6. Suggested ICL ..... >



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**K.A. (f), 19 yo,  
OD KC**

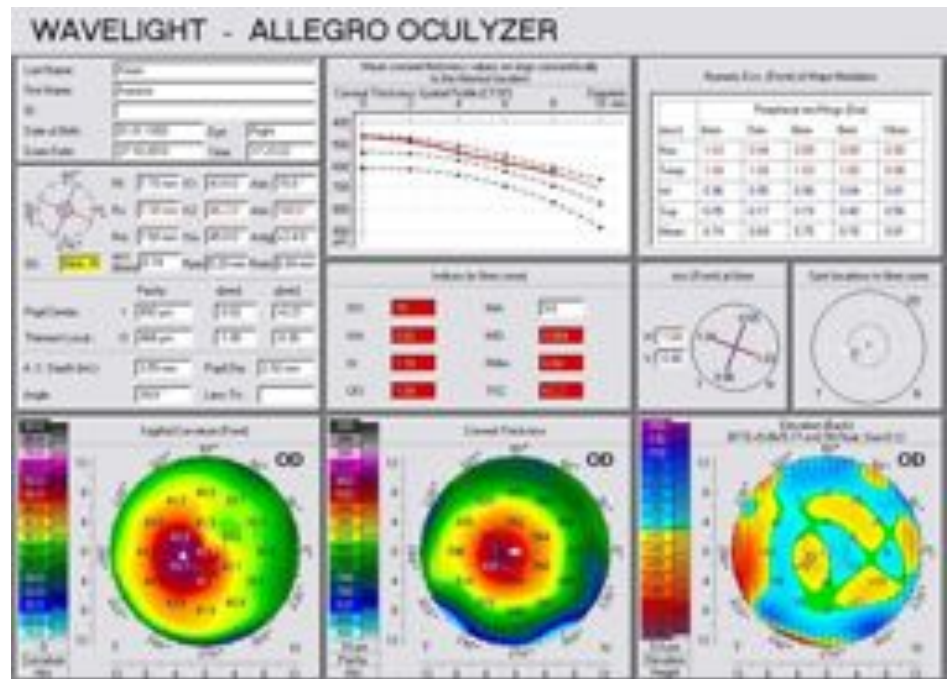
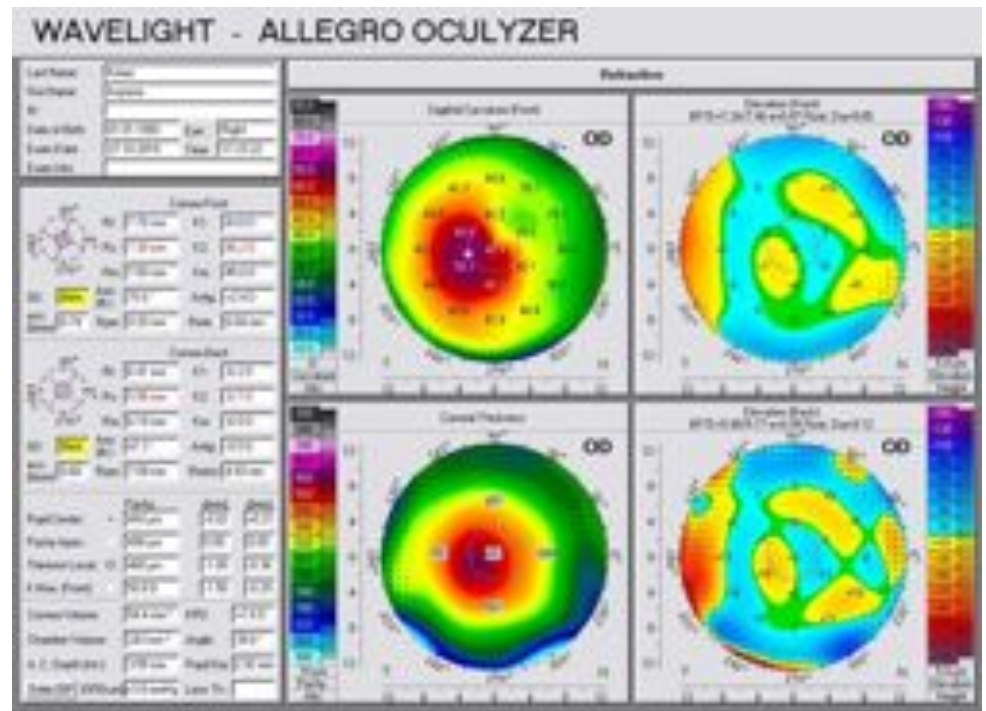
CCT 460  $\mu\text{m}$

VA s 2/10

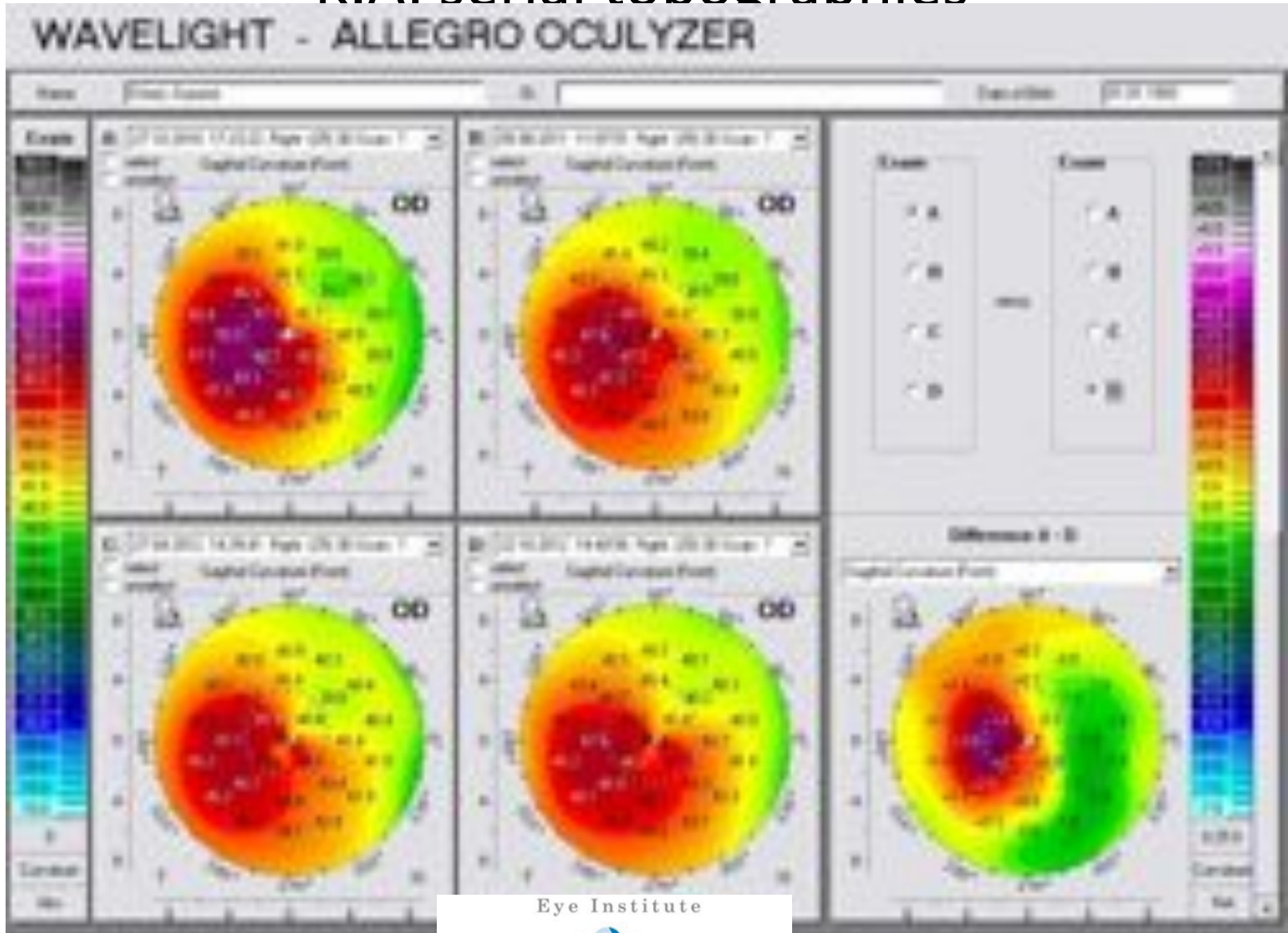
BCVA 5/10 with -1.25/-4.50x55

Procedure : Dresden protocol

Pach 400  $\mu\text{m}$  after epithelial  
removal



# K.A. serial topographies

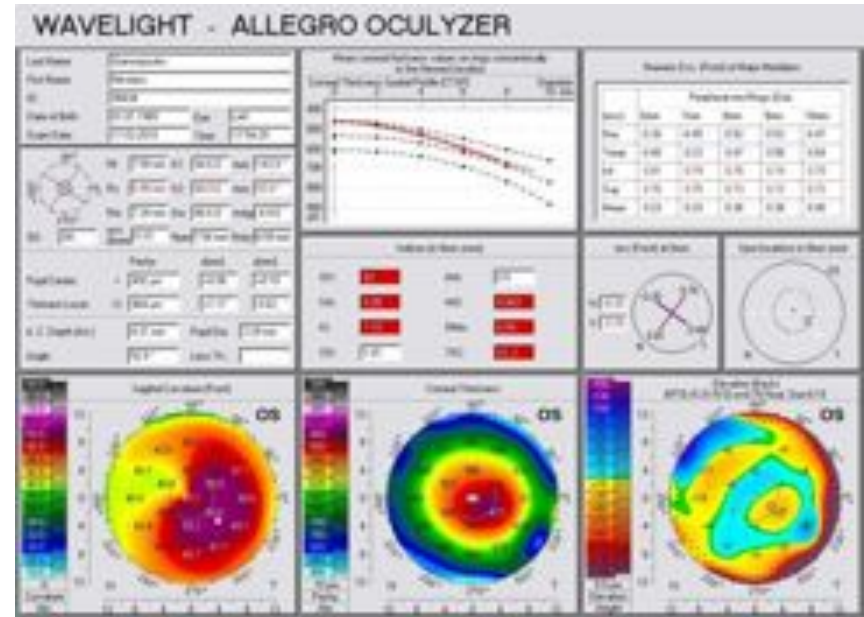
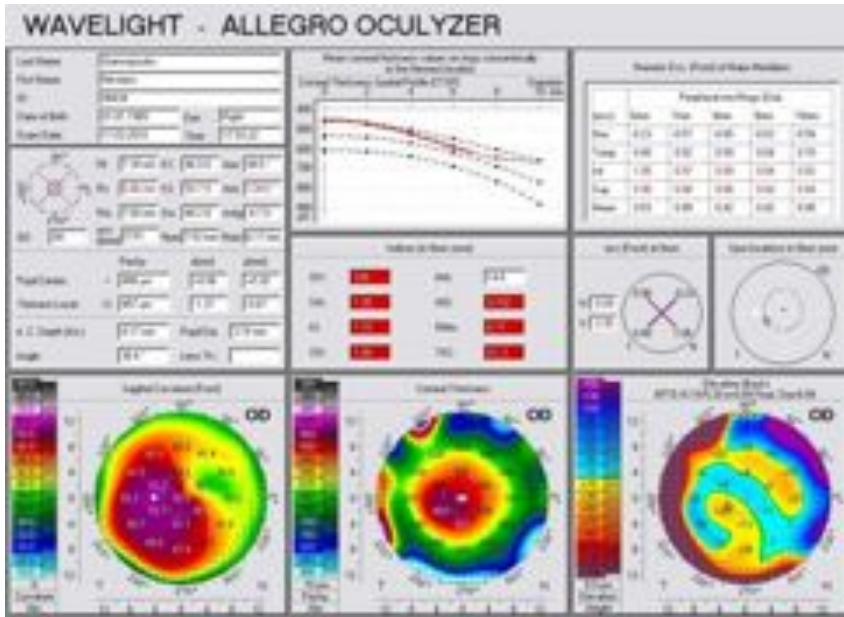




# G.N, (m), 21 yo

OD KC, gl only

OS KC, gl only



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**OD**

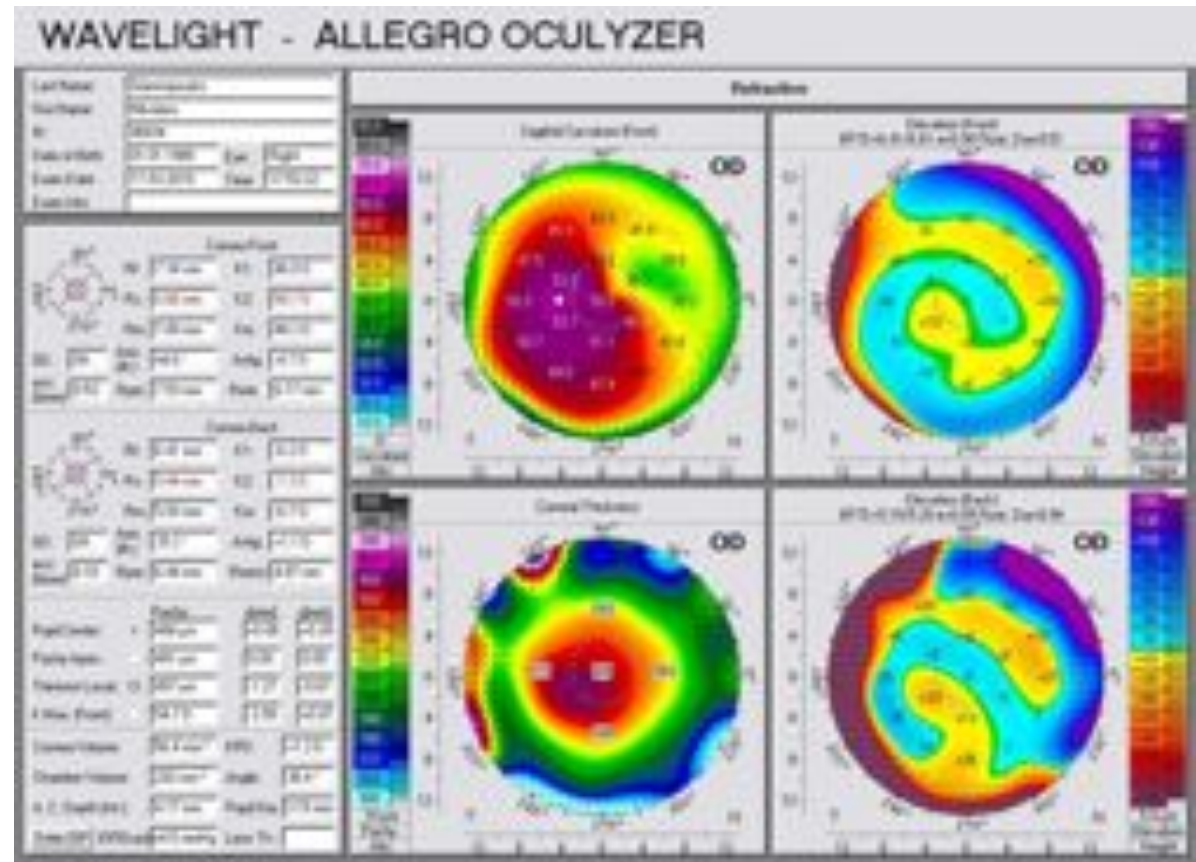
VA s 2/10

BCVA 6/10 (-1.00/-4.50x50)

CCT 480  $\mu\text{m}$

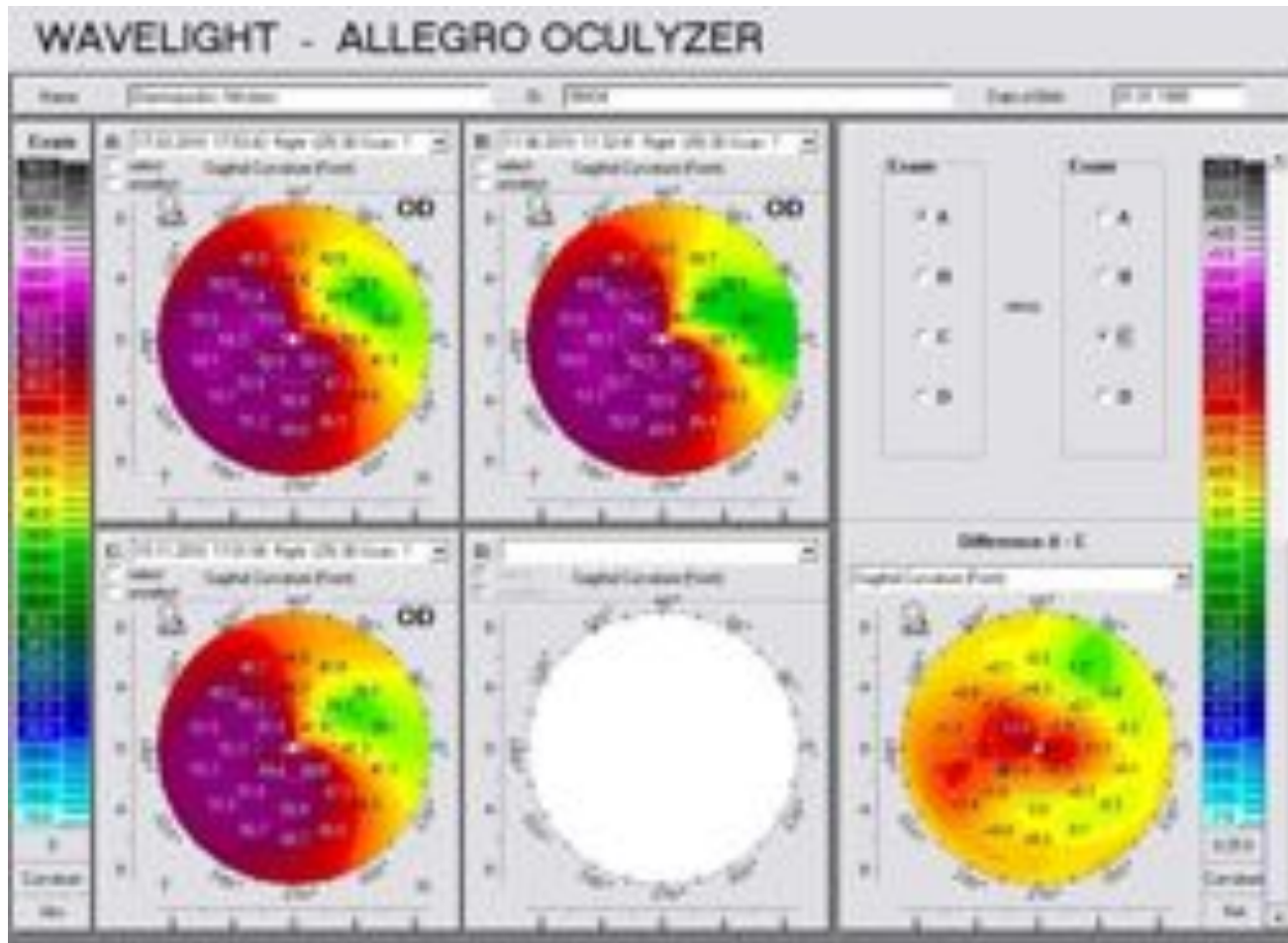
Procedure

Hypotonic ribo, as pachymetry  
after epithelial removal 390  $\mu\text{m}$



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# Serial OD



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OS

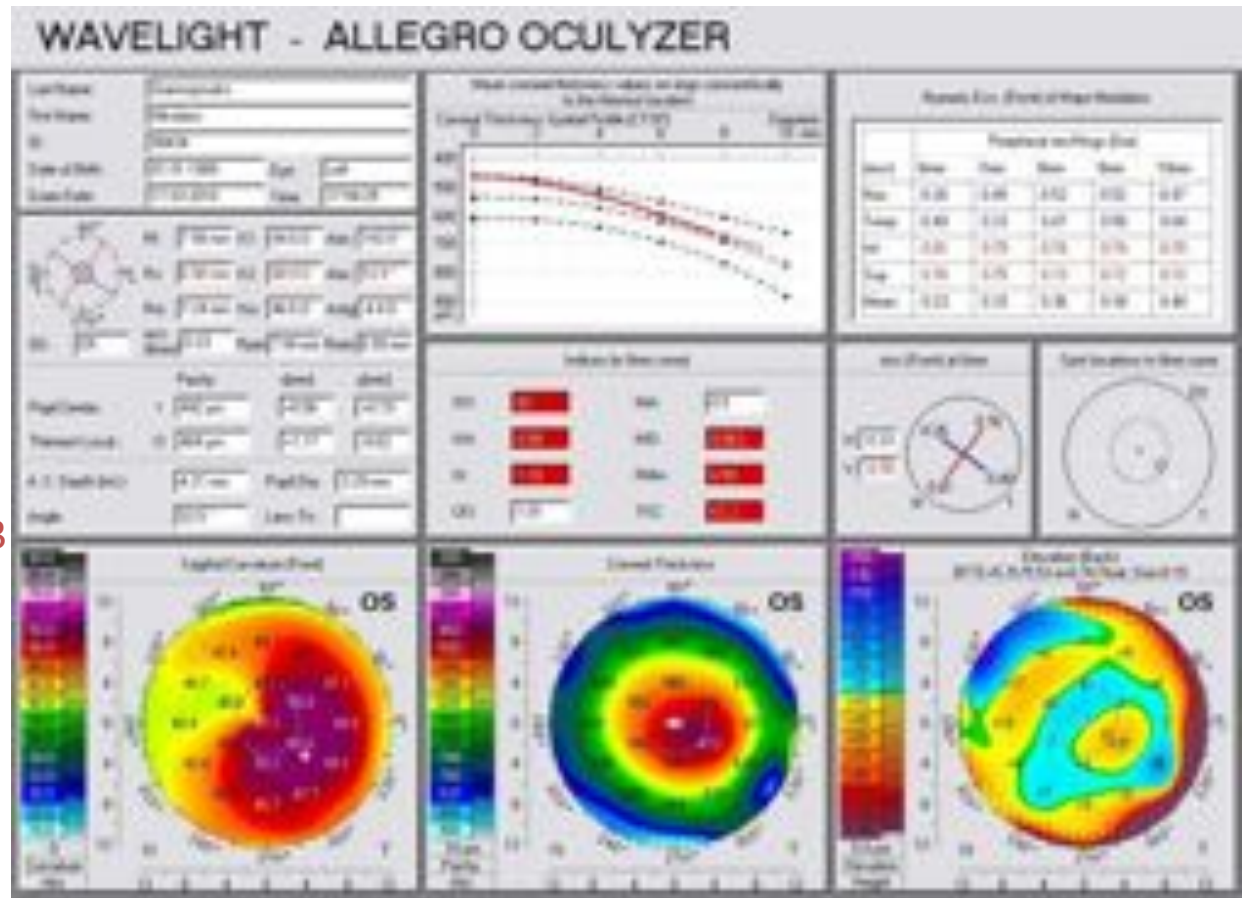
CCT 450  $\mu\text{m}$

VAs 2/10

BCVA 6/10

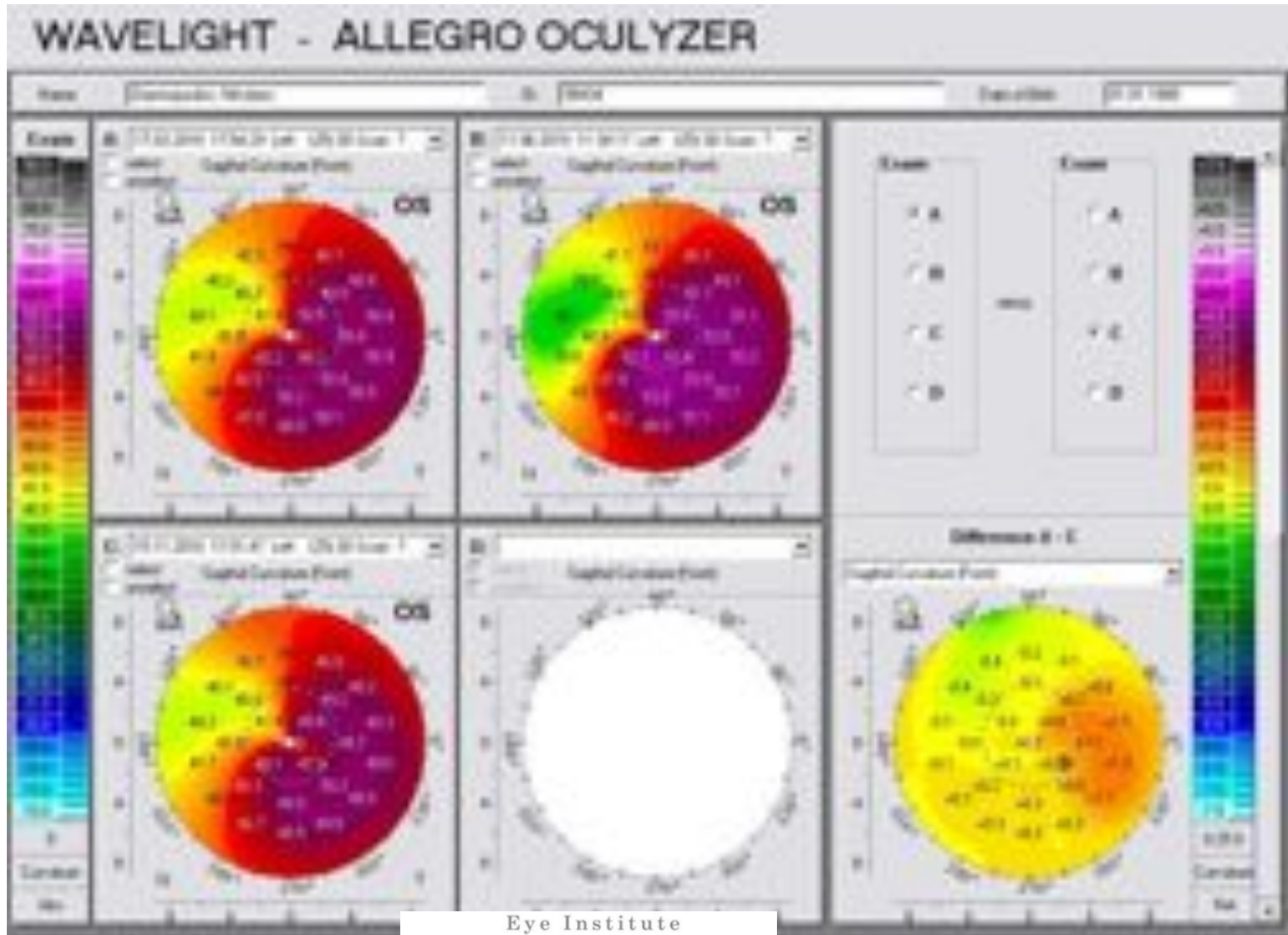
Pach post epith removal : 403

Standard protocol



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# OS compare



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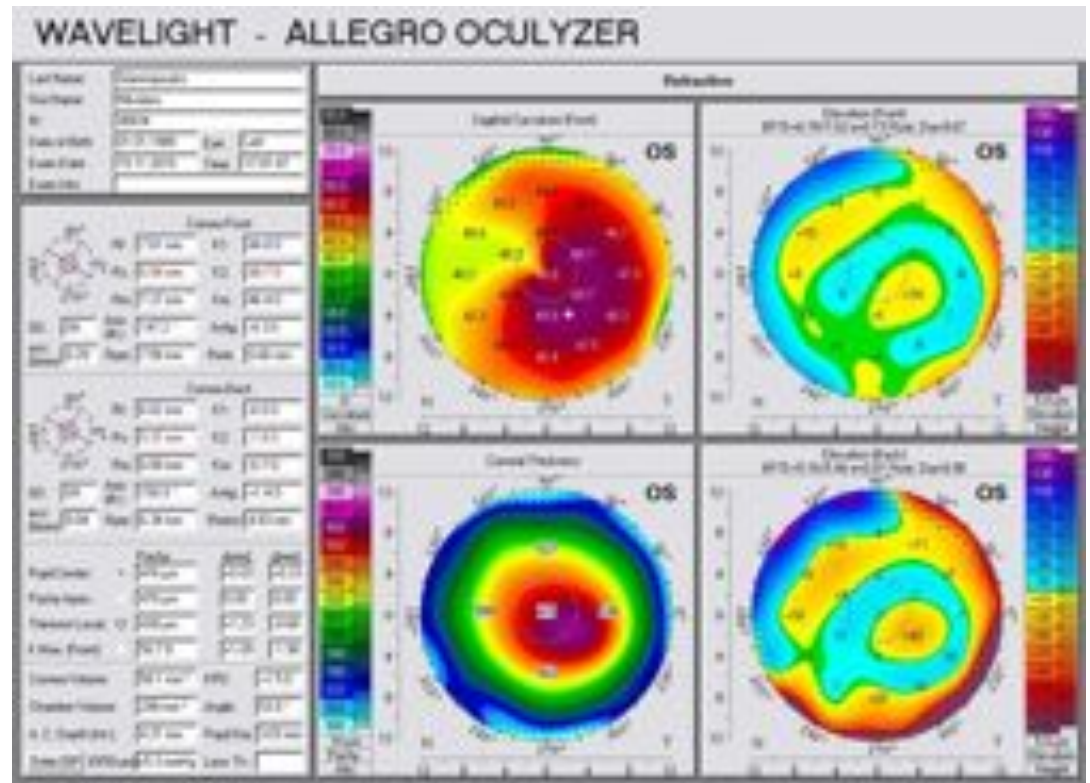
## OS results

As with OD, similar result

Improved optics

10/10+ with -1.00 KC CL

Planned for PRK

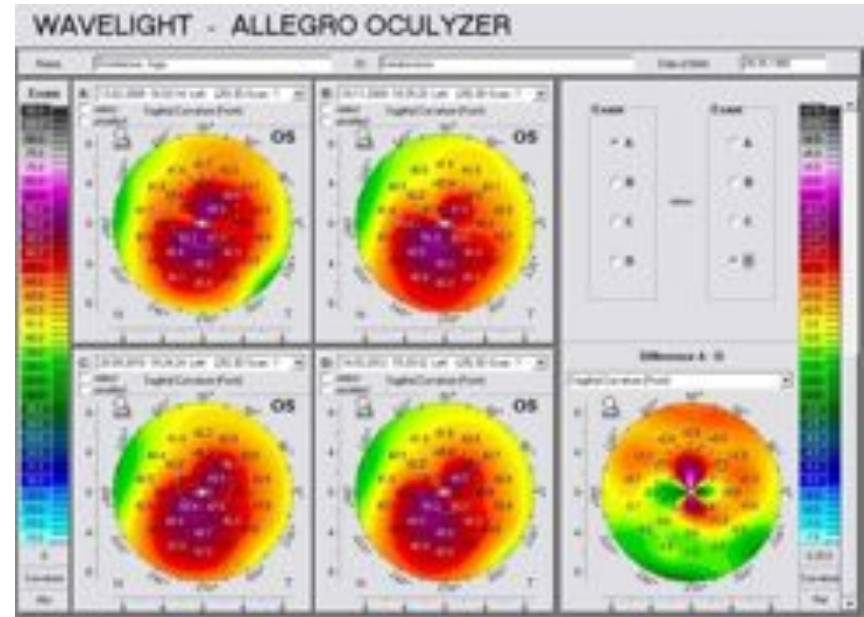
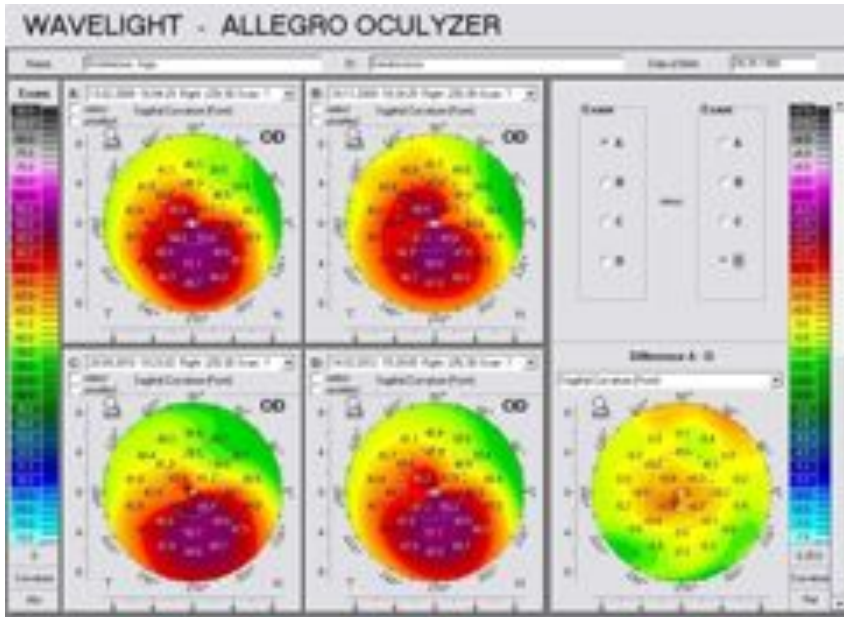


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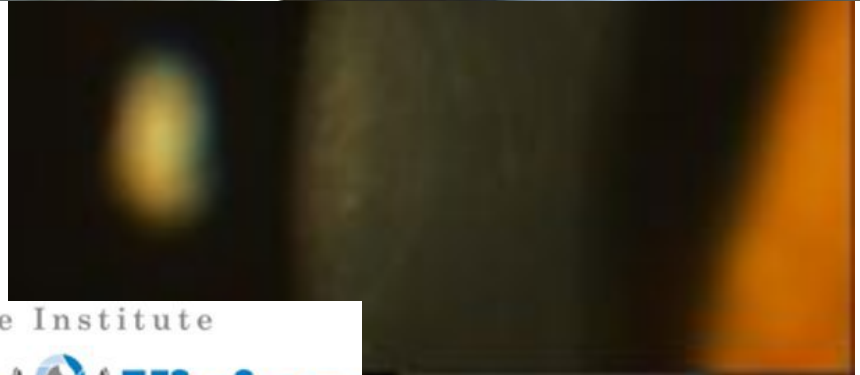
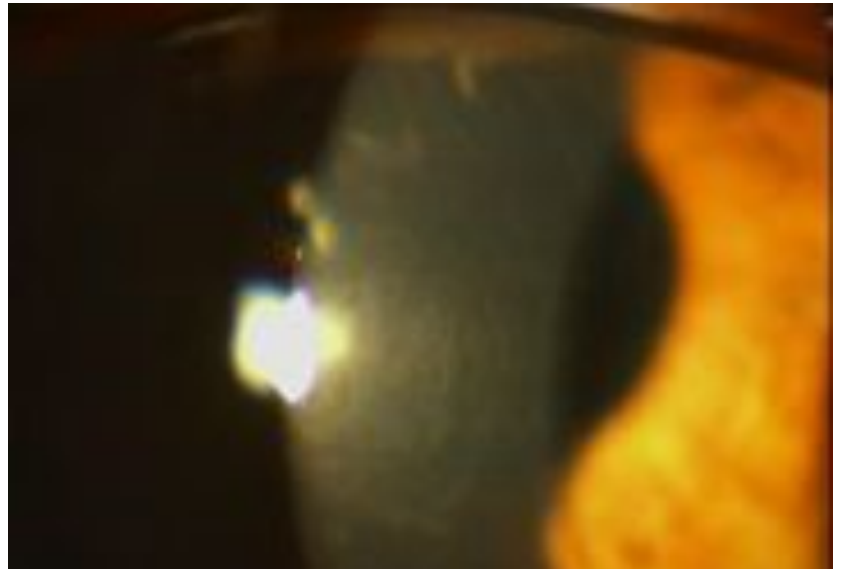
# I.O. (F), 22 yo

2007  
OD 4/10 w -11.50/-3.50x30  
Topo inferior KC

2007  
OS 5/10 w -10.50/-3.00x135  
Topo inf KC OS>OD



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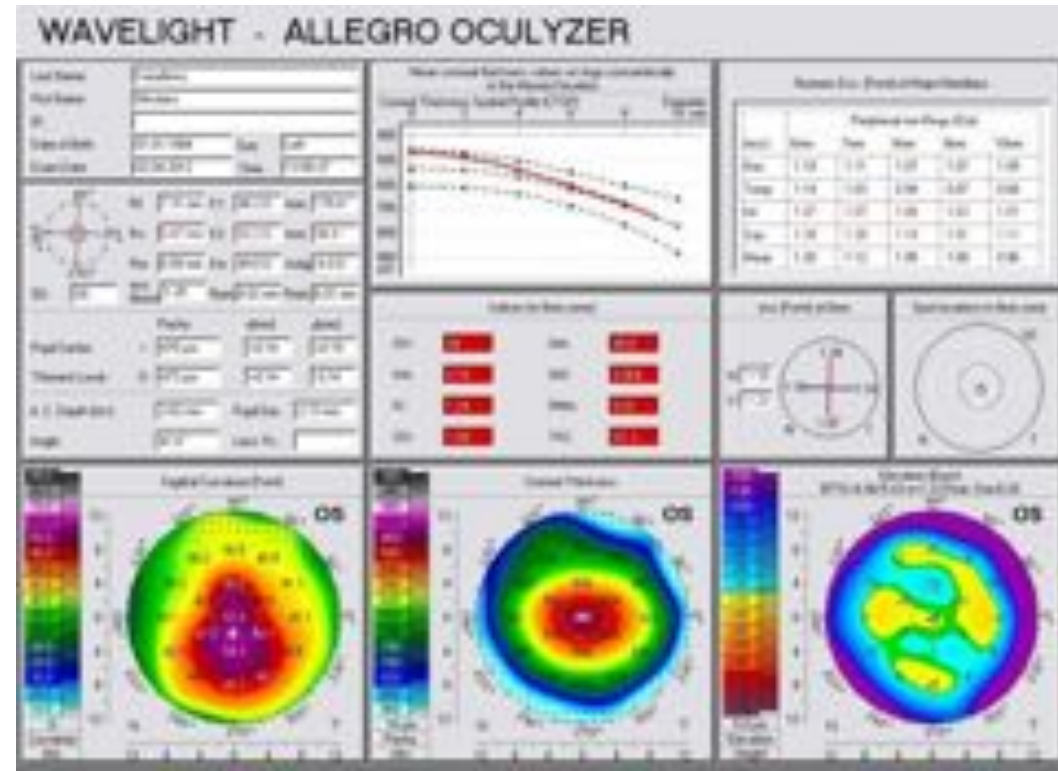
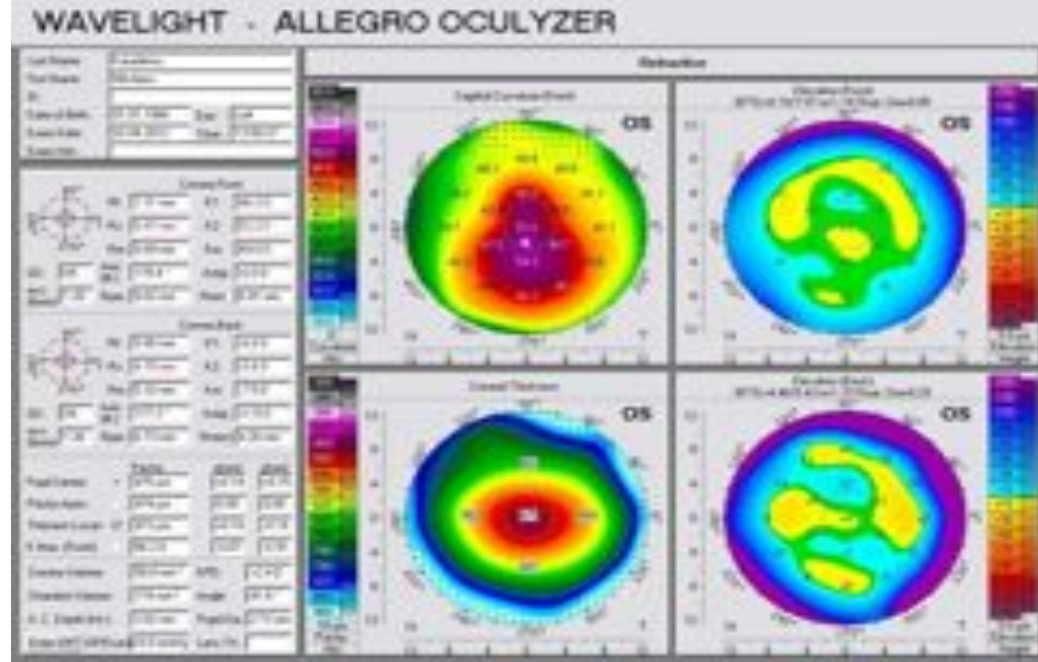
K.N, male, 28 yo,

KC OS > OD

OS

VAs 3/10

VAc 6/10 (-4.75/-4.25 x 15 )



## K.N. OS

### Procedure

CXL only (standard protocol), due to

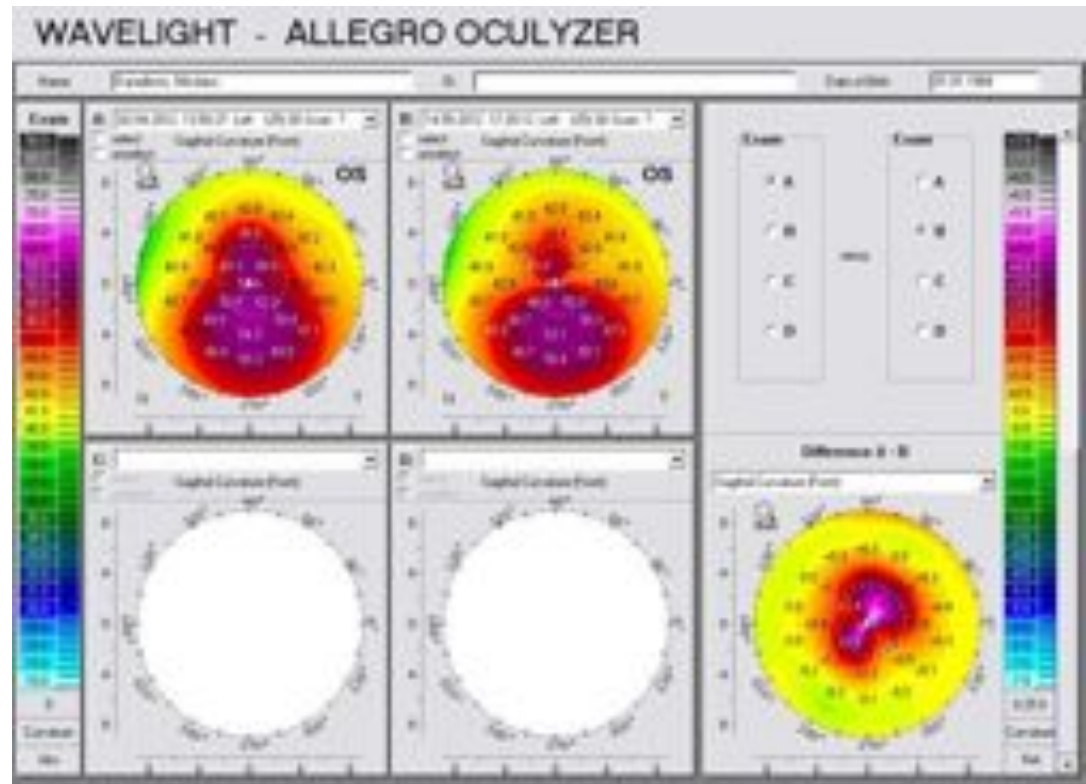
- thin corneas and
- high refractive error to treat with PRK

... initially planned for 2ry ICL

CCT 467 microns

Epithelium 62 microns

To our surprise, ... by just doing ONLY CXL, vision improved to 10/10 unaided, because of the effect of CXL shrinkage on central cornea, that had a great impact on eye's optics.

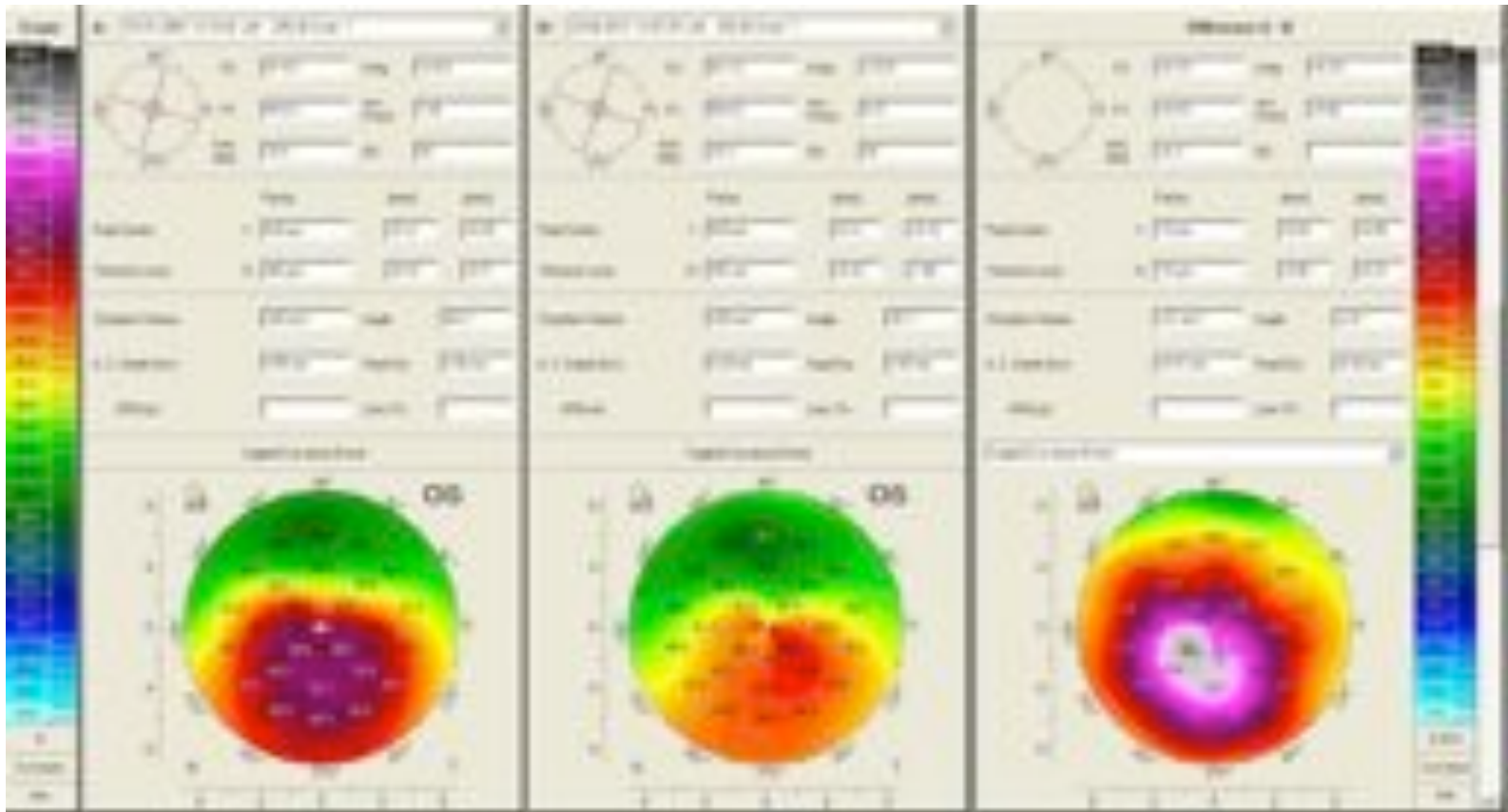


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# Is CXL a refractive procedure?

Most investigators speak of “disease reversal” when flattening occurs after CXL in ectasia

- This is a simple 3mW CXL-alone case from **2005**
- No scar developed, Now 2013 has Flattened 12D!!!



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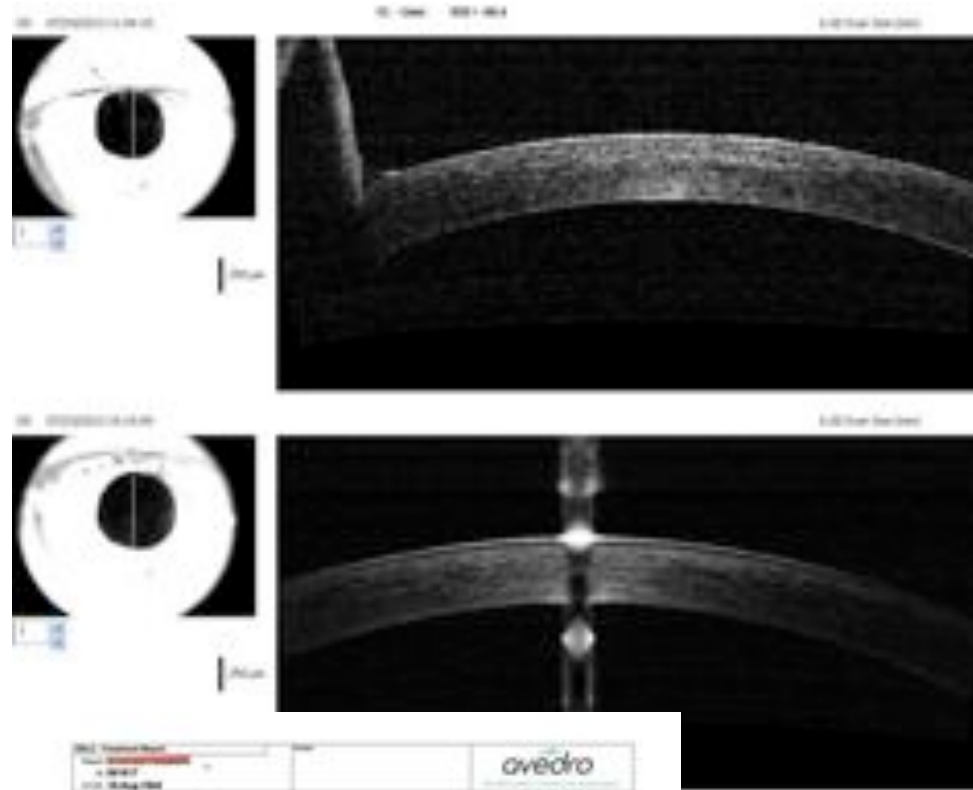
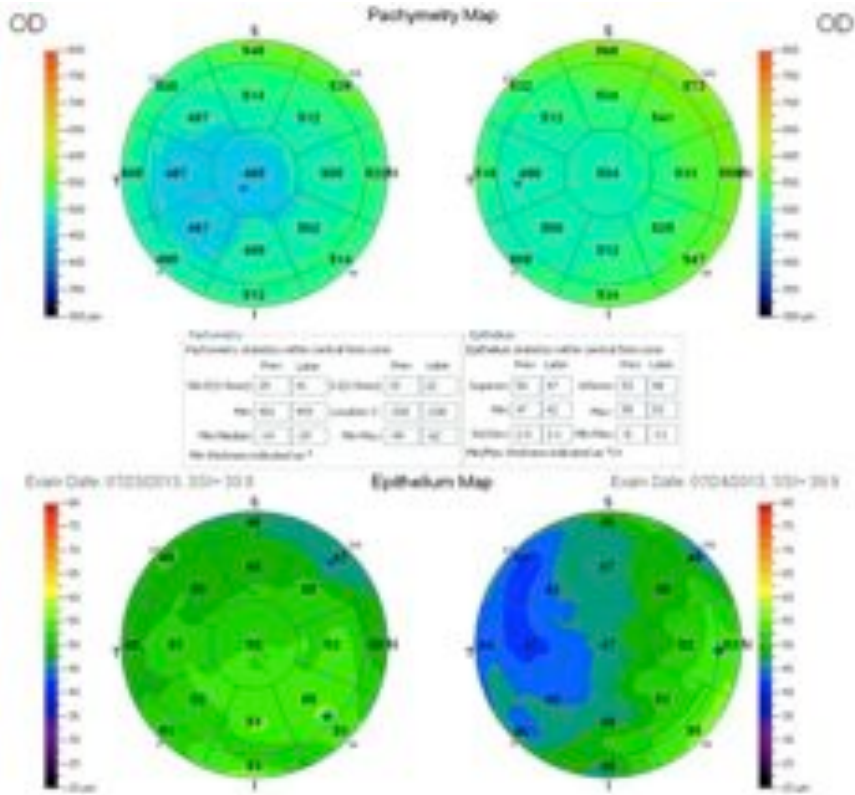
Novel Avedro KXL-II Device  
Riboflavin penetration captured  
by Build –in Scheimpflug image



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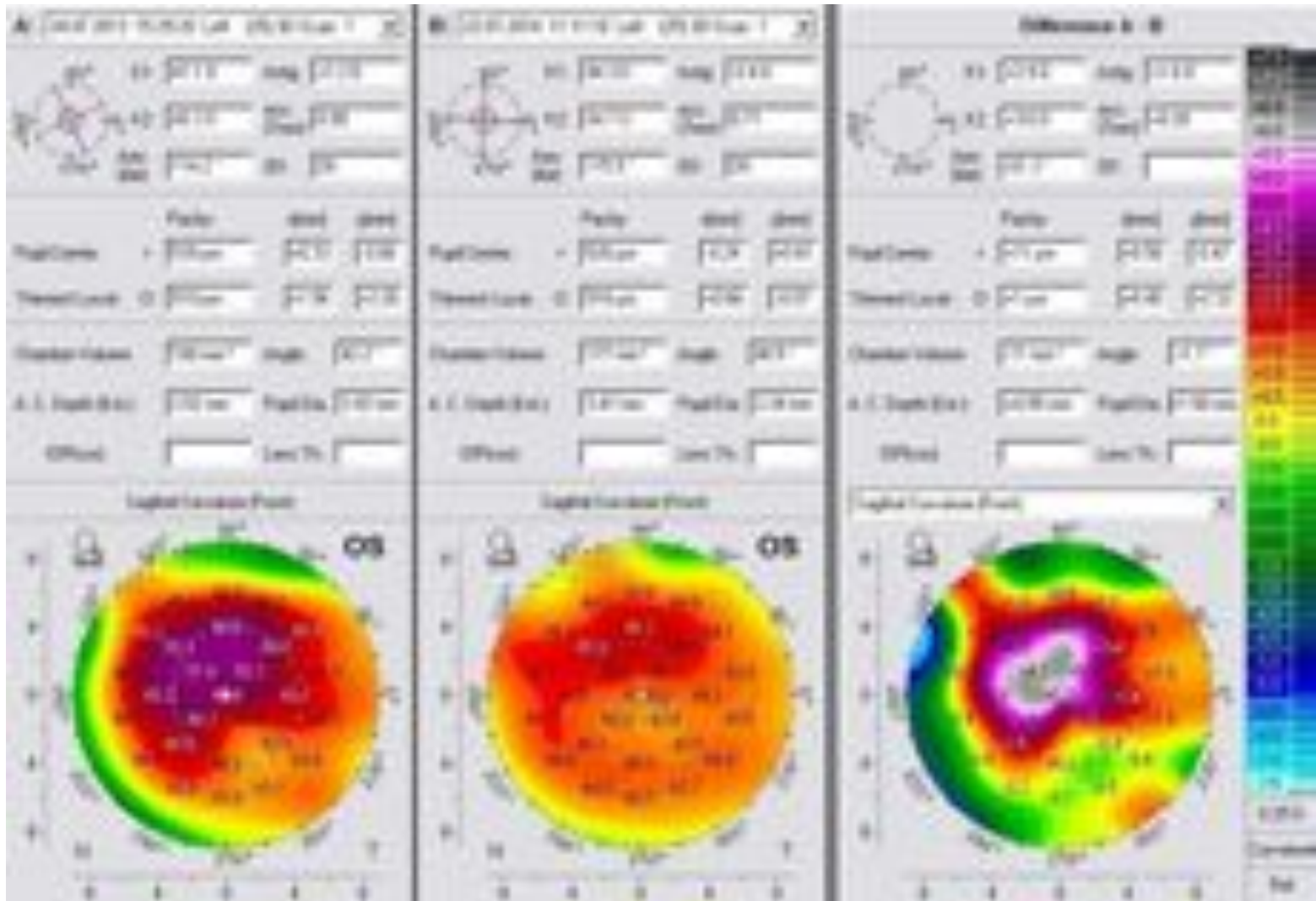
# Myopic profile central 4mm OZ transepi

4min Paracel+6min VibexXtra



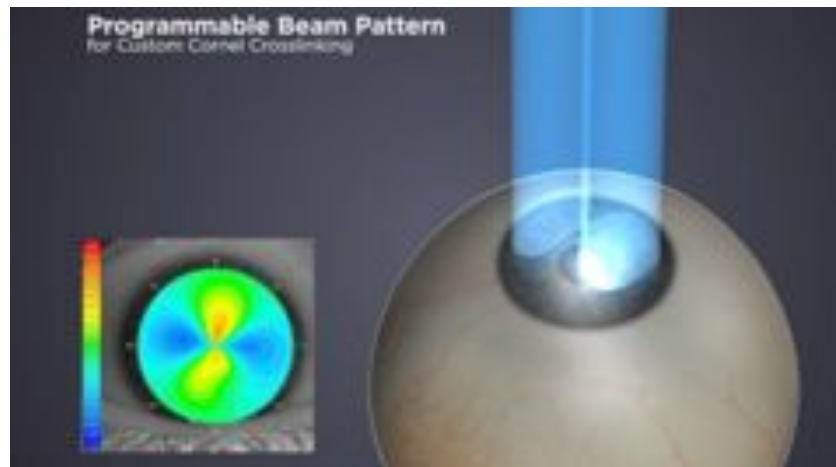
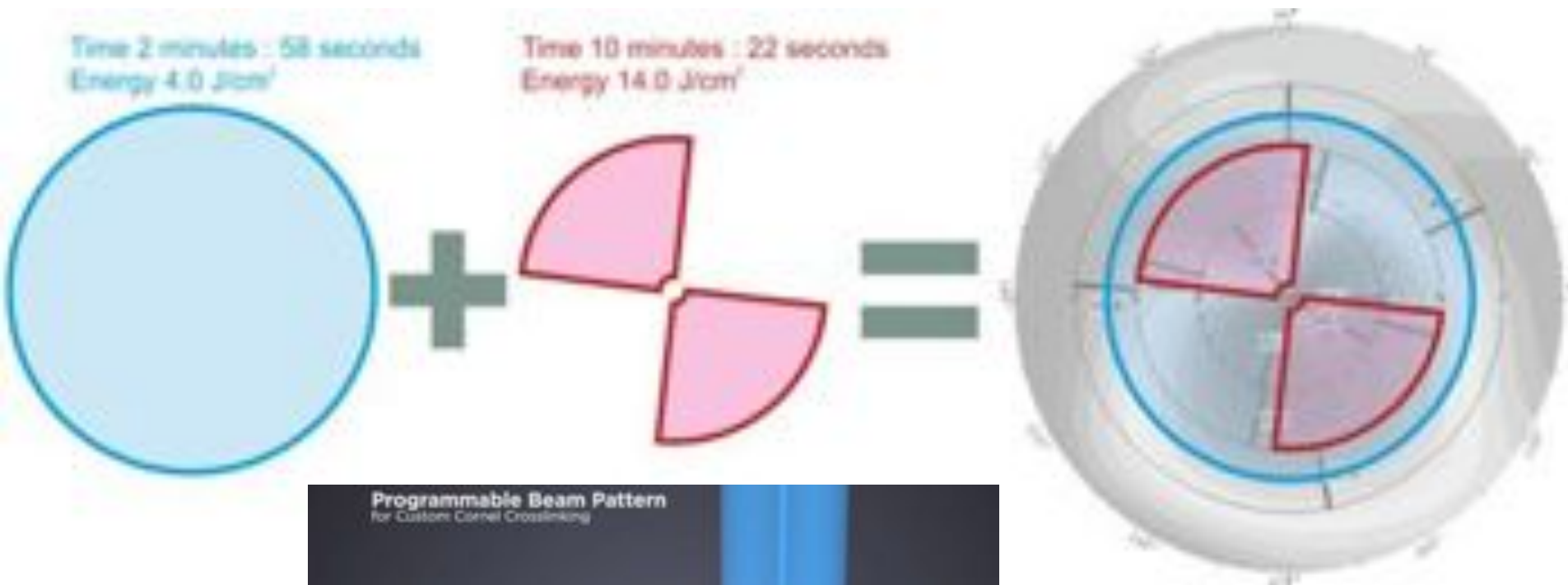
Time	Min	Max	Avg	StDev	Min	Max	Avg	StDev
1	300	500	400	50	300	500	400	50
2	300	500	400	50	300	500	400	50
3	300	500	400	50	300	500	400	50
4	300	500	400	50	300	500	400	50
5	300	500	400	50	300	500	400	50
6	300	500	400	50	300	500	400	50
7	300	500	400	50	300	500	400	50
8	300	500	400	50	300	500	400	50
9	300	500	400	50	300	500	400	50
10	300	500	400	50	300	500	400	50

# PiXL custom topo-assisted 7 months



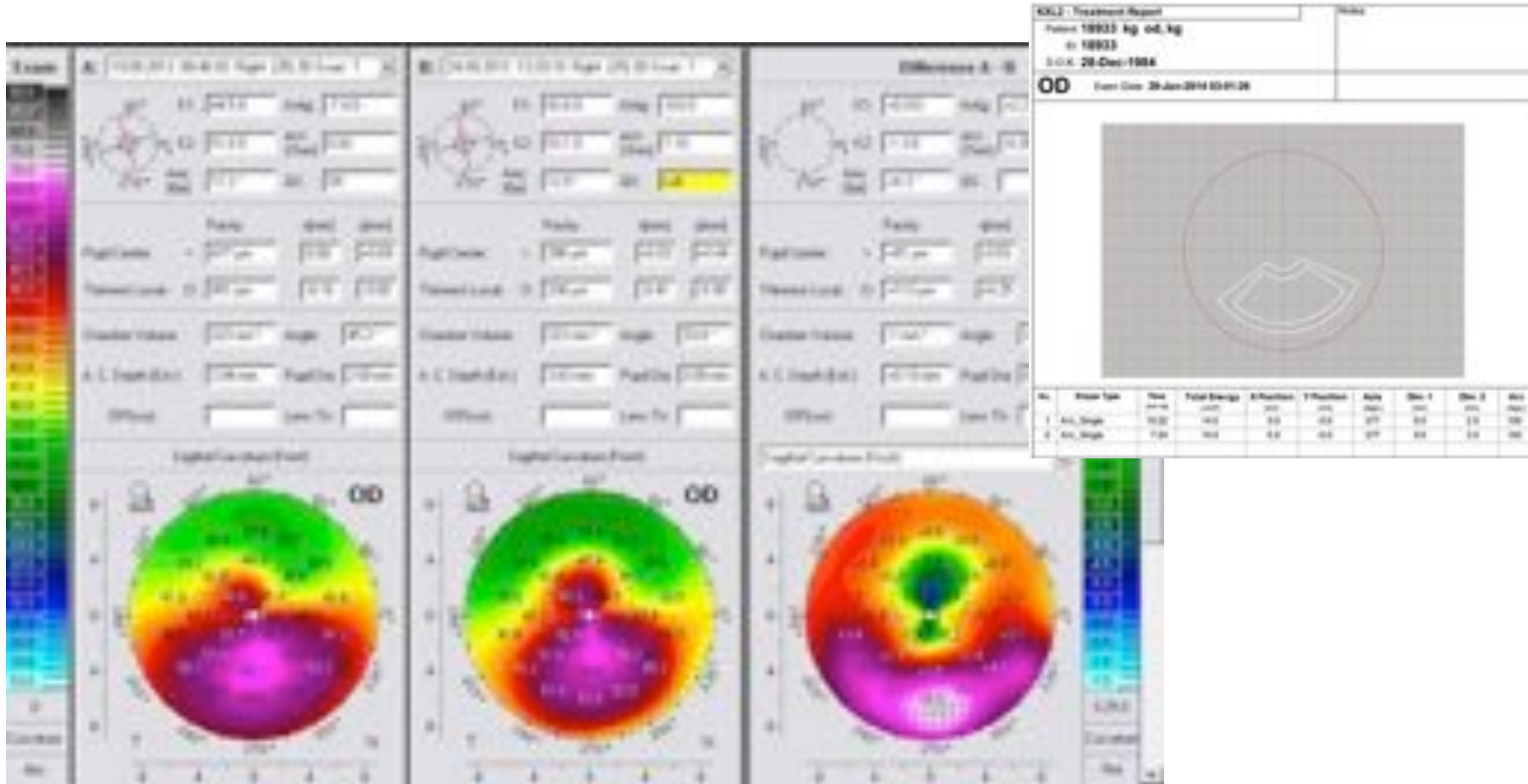
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# 8 month topography-customised tran-epithelial CXL treatment



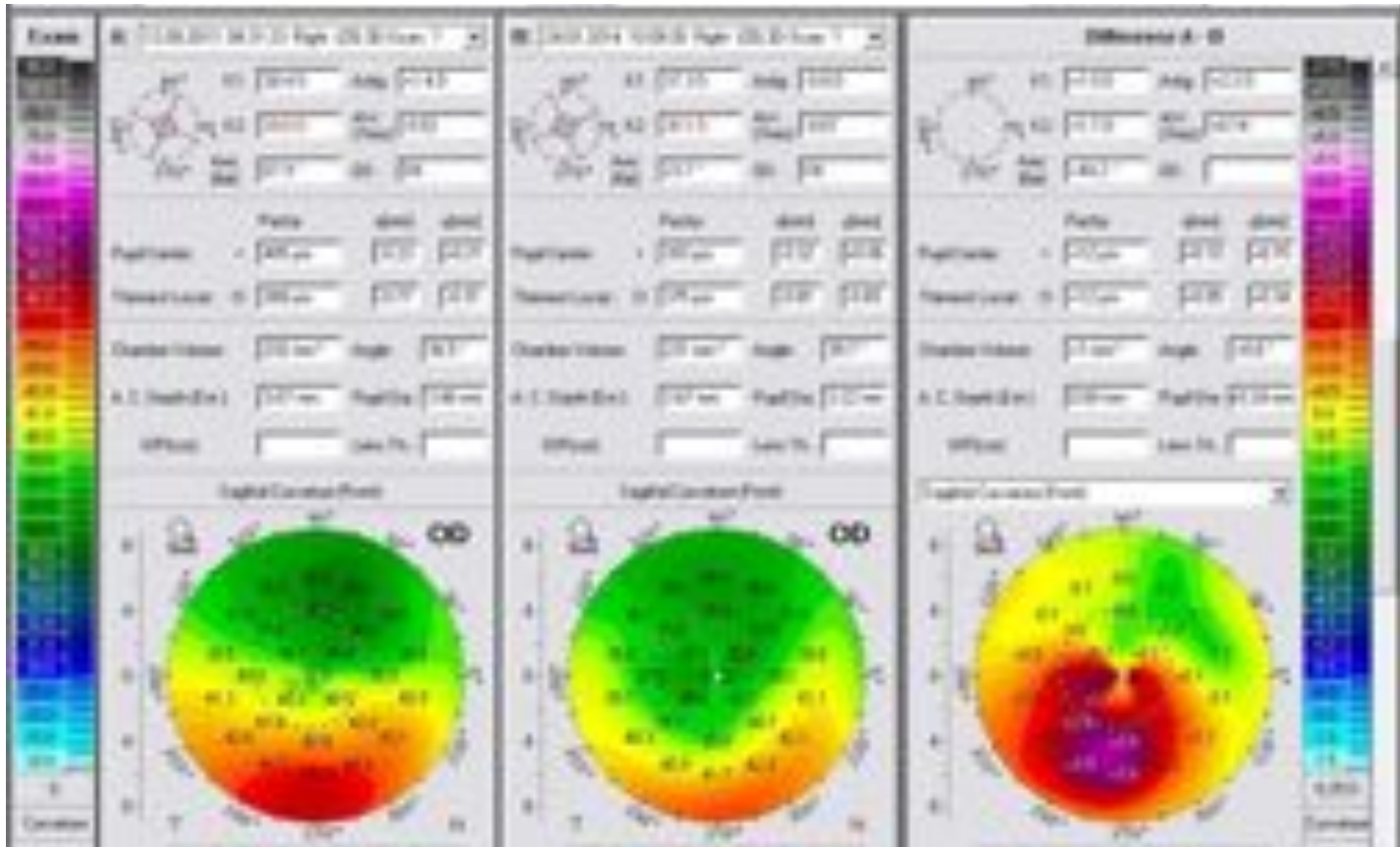
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# Customized CXL for KCN!



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KCN s/p Athens Protocol in 2006 residual cone and cylinder  
3 months after PiXL it **appears to work in CXL corneas as well**



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II.

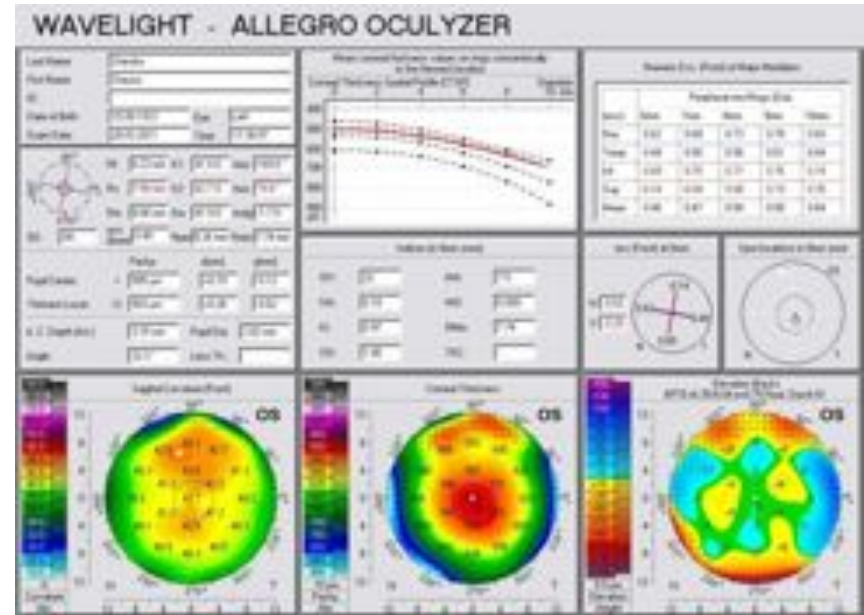
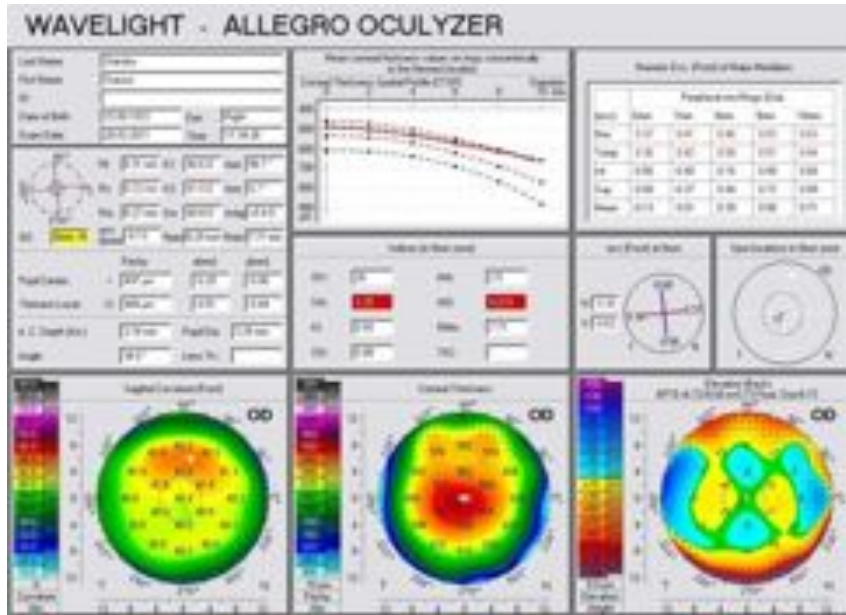
Αντιμετώπιση κερατόκωνου με  
συνδυασμό διασύνδεσης  
κολλαγόνου (CXL) + PRK

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# S.S, (m), 39 yo

OD , FFKC  
CCT 454  $\mu\text{m}$   
-4.00

OS, FFKC  
CCT 503  $\mu\text{m}$   
-4.00/ -0.75 x 15

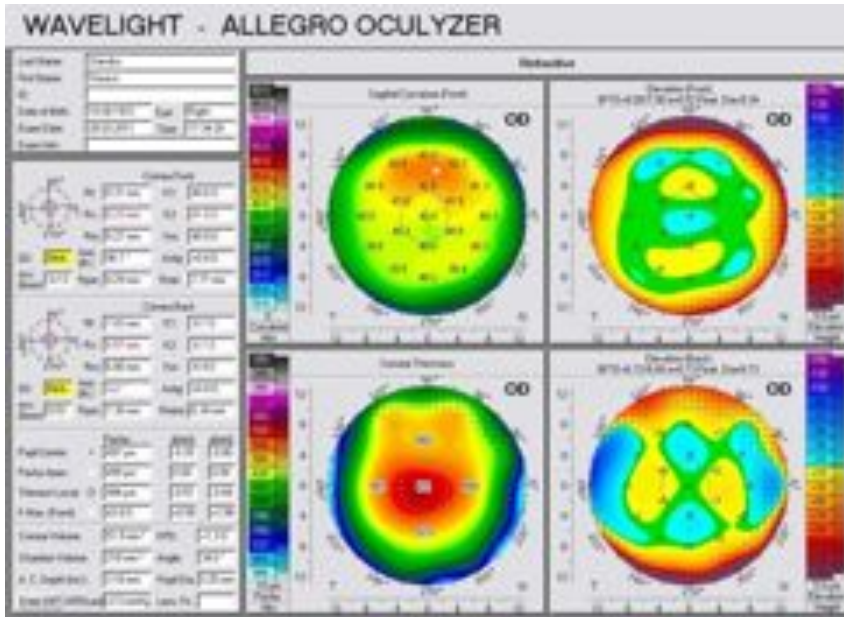


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S.S.

**OD PRK + 15 min CXL**  
**Full correction -4.00**

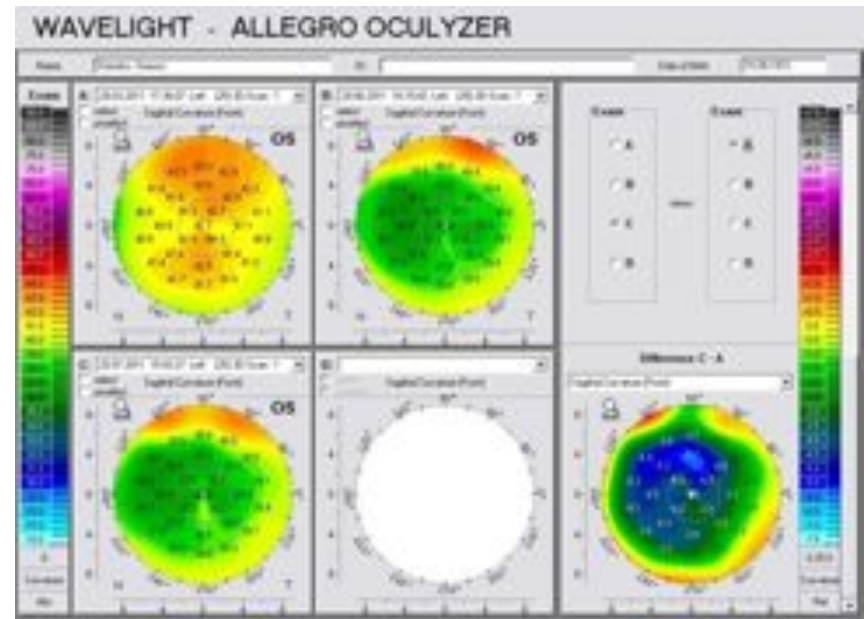
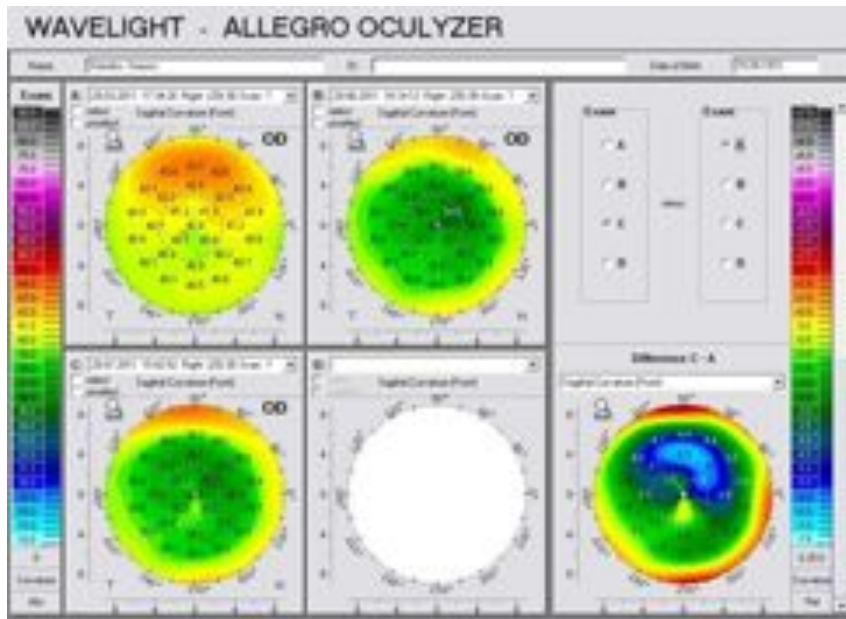
**OS PRK + CXL 15 min**  
**Full correction -4.00/-0.75 x 180**



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OD 3 months  
VAs 12/10 plano

OS 3 months  
VAs 12/10 plano



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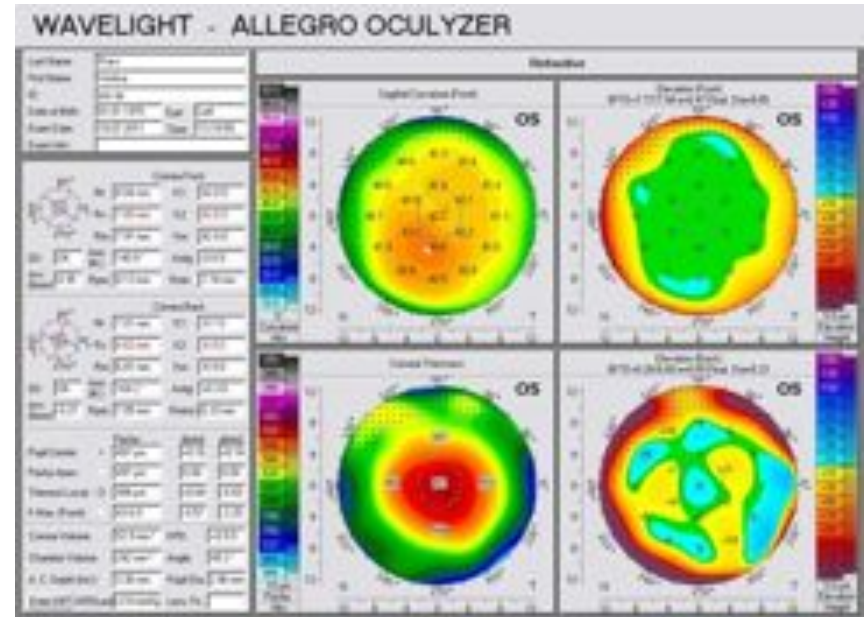
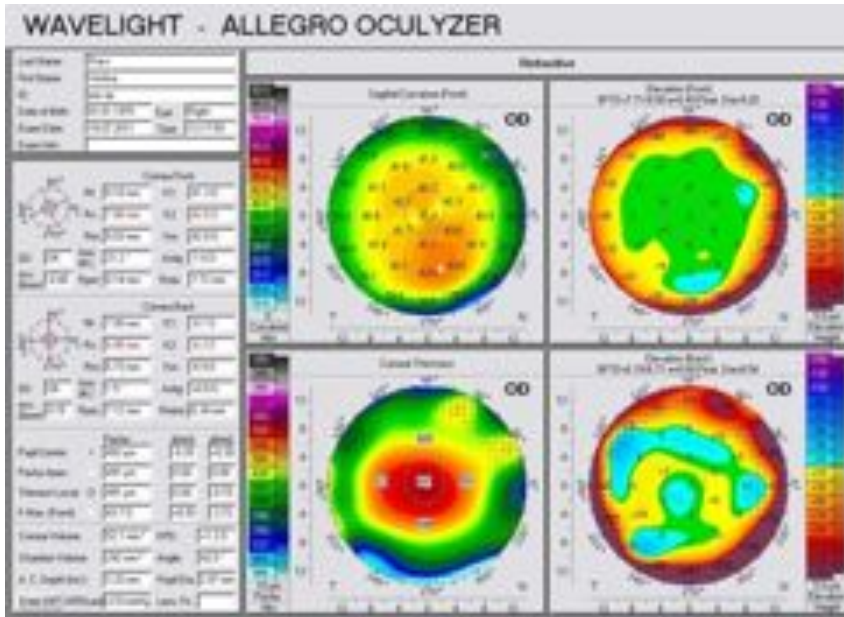
# P.X.

OD (4/12 post breast feeding)

**PRK** no nomogram **-1.75/-1.00x30** + **MMC 10 sec** + **full CXL**

OS (4/12 post breast feeding)

**PRK** no nomogram **-2.50/-1.00x153** + **MMC 10 sec** + **full CXL**

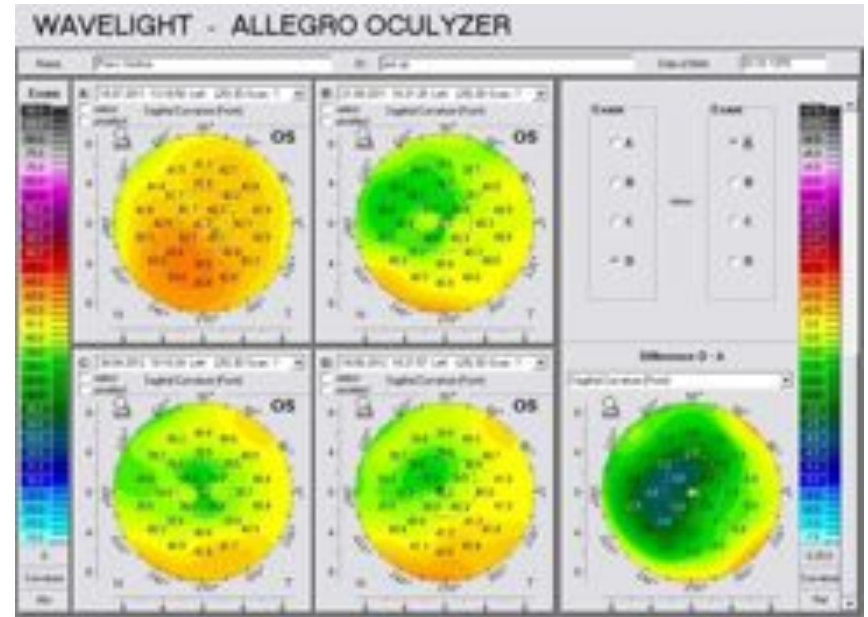
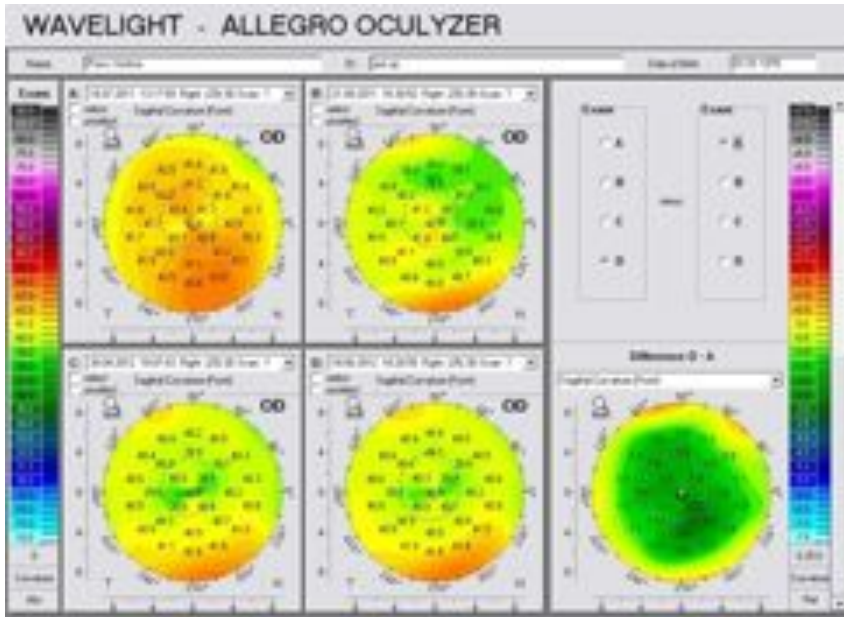


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# 1 yr postop

**OD VAs 10/10**

**OS VAs 10/10**



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Π.Π., (f), 27 yo

OD moderate KC

VA 8/10 s

BCVA 8/10 -0.50 /-1.50 x 130

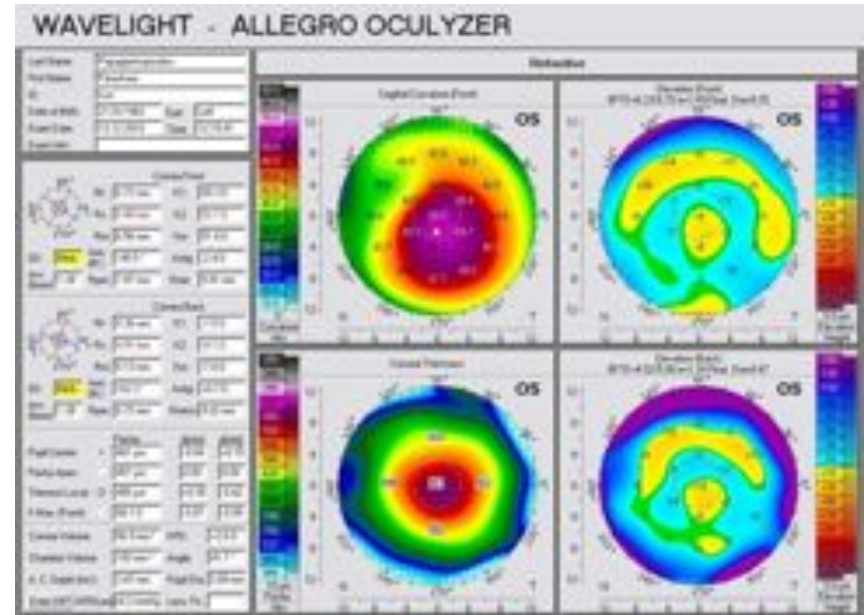
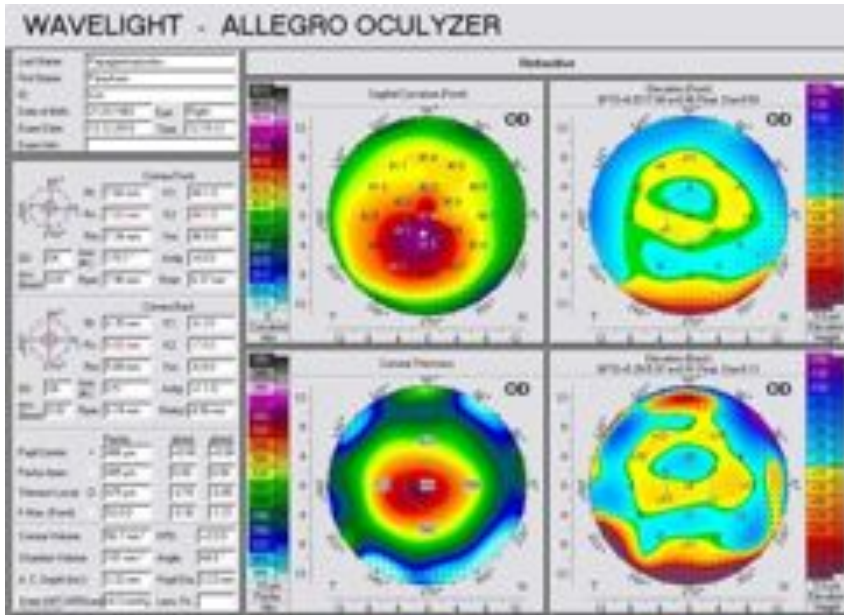
CCT 452  $\mu\text{m}$

OS advanced KC

VA 3/10 s

BCVA 7/10 c -1.00/-1.75x120

CCT 400  $\mu\text{m}$

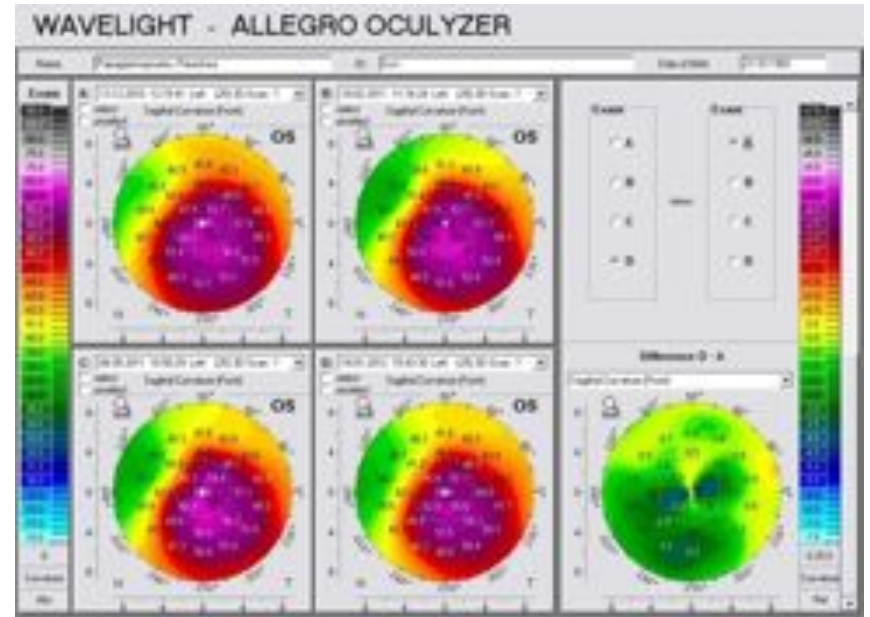
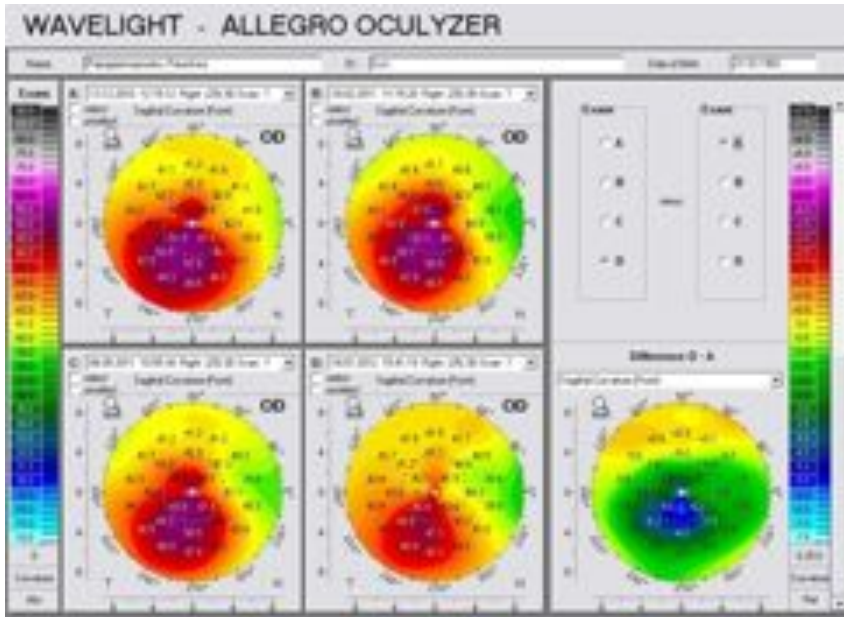


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Π.Π

**OD PRK+CXL**  
**-0.25/-0.50x150**  
Postop  
VAs 10/10 plano

**OS PRK+CXL**  
**-0.50/-1.00x110**  
Postop  
VAs 7/10  
NI c -0.75/-0.75x150



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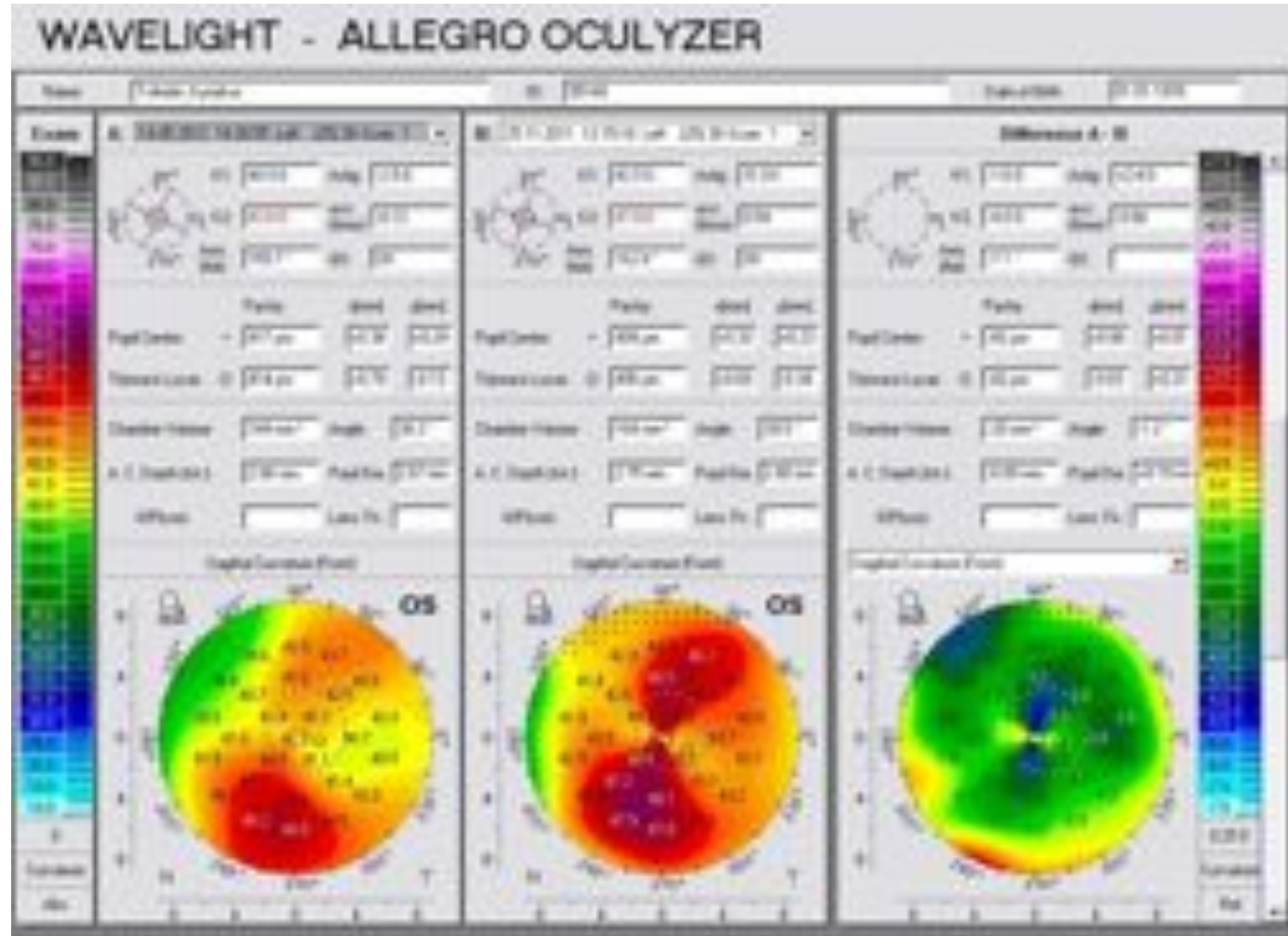


postop

VA s 10/10 +2

A/R +0.75/-2.25x148

Subj +0.25 / -0.50 x 85



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# V.A, (f), 23 yo

OD advanced KC

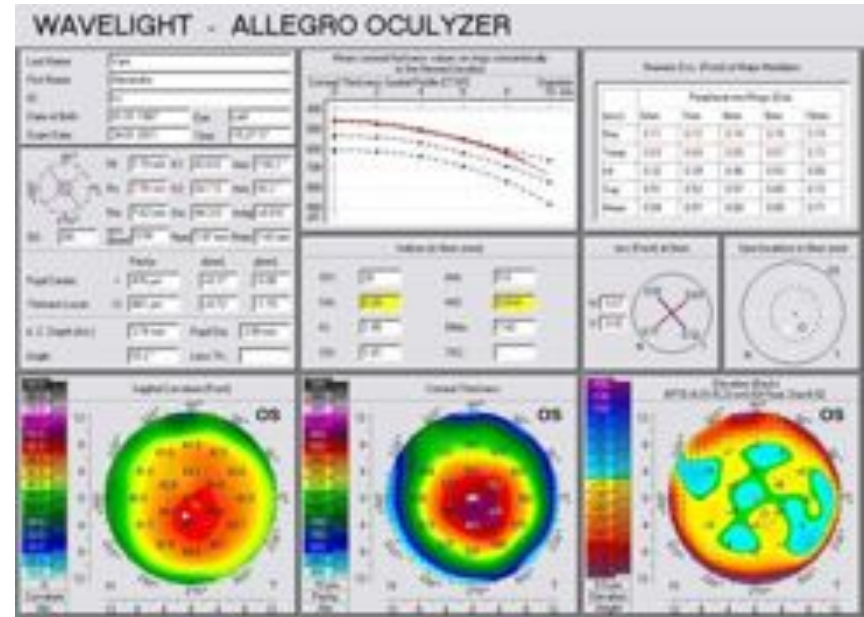
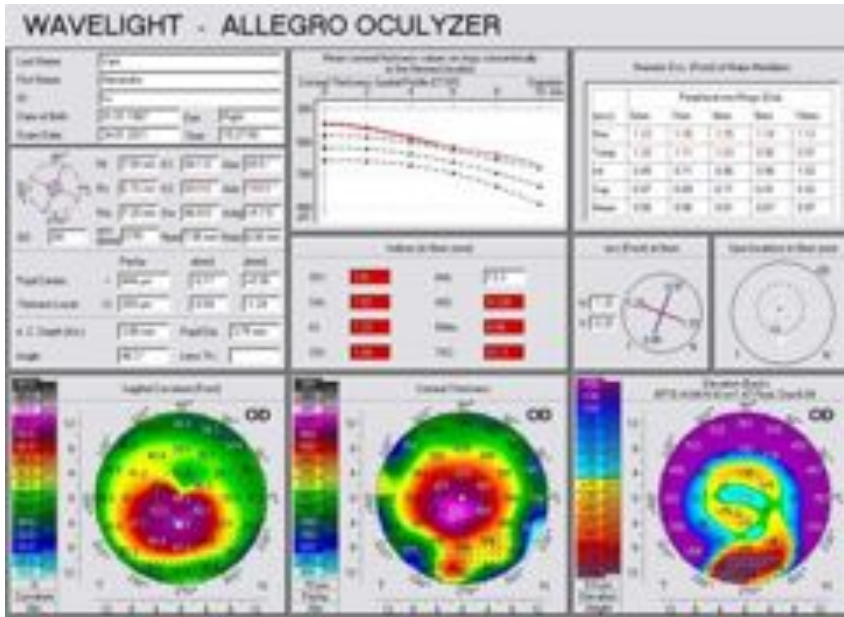
VAs CF

VA c +0.25/-4.75 x 70 5/10

OS moderate KC

VAs 2/10

VAc -1.25/-1.75x110 10/10



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## OD

CCT with epith 431

CCT s epith 387

CXL

Combination hypotonic + isotonic ribo

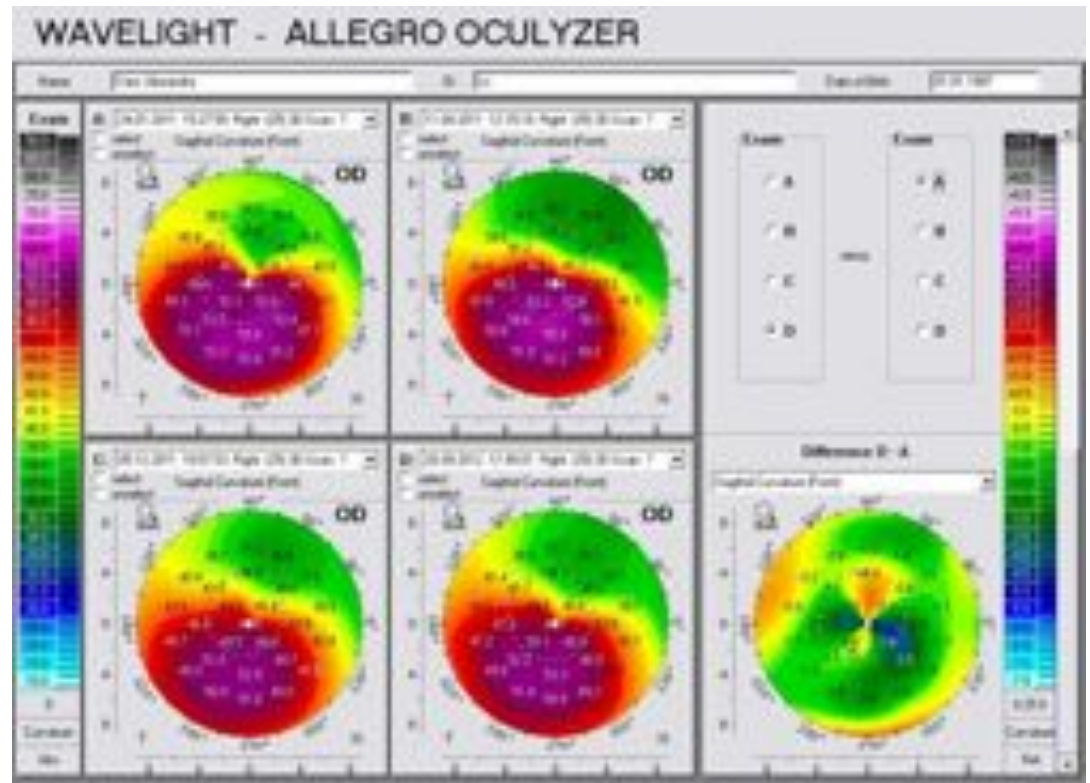
MMC 14 sec

PRK +0.25 / -2.50 x 75

POSTOP

VAs 6/10

VAc 7/10 with -1.50/-1.50x70



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**OS**

CCT epith 458

CCT s epith 407

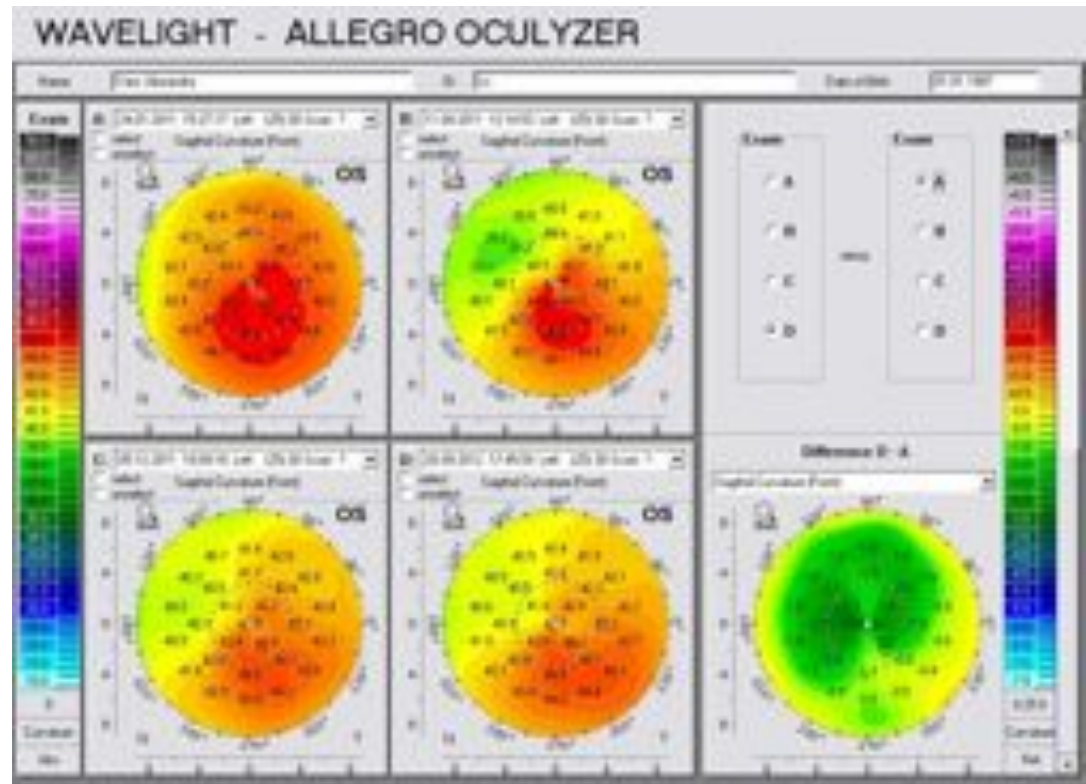
CXL Isotonic Ribo

MMC 12 sec

PRK -0.75/-1.50 x 110

POSTOP

VAs 10/10



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# Κ.Π, (m), 30 yo

OD advanced KC

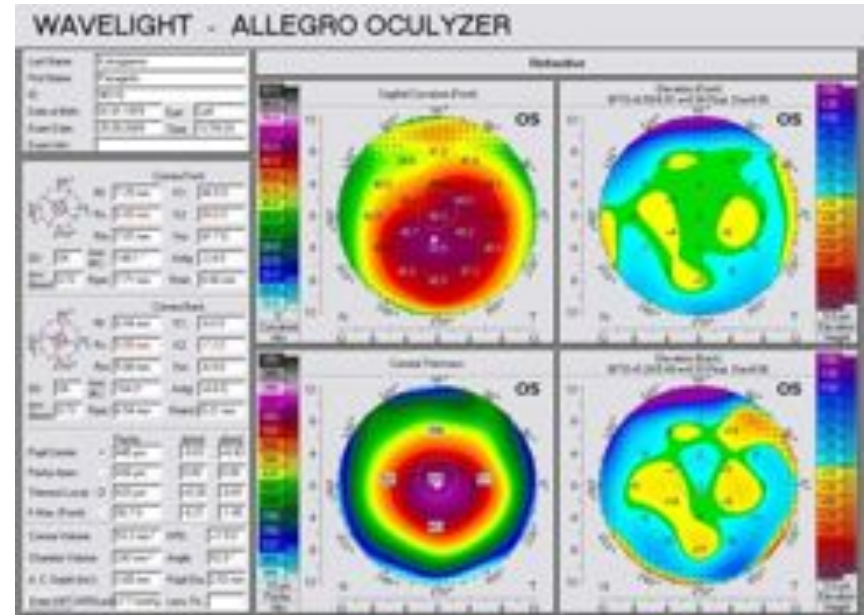
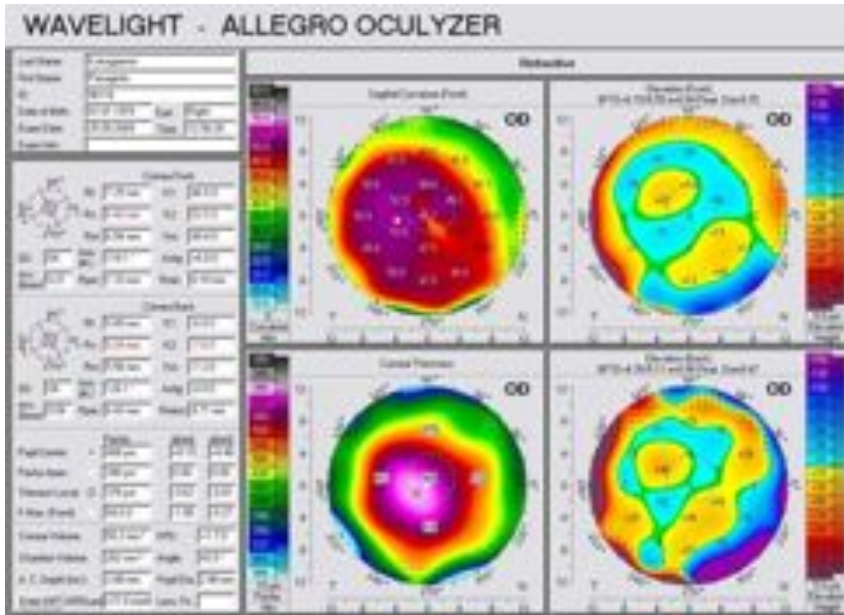
VAs 1/10

VAc -3.00/-2.00x120 8/10

OS moderate KC

VA s 3/10

BCVA 10/10 with -2.50/-1.00 x 145



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**OD**

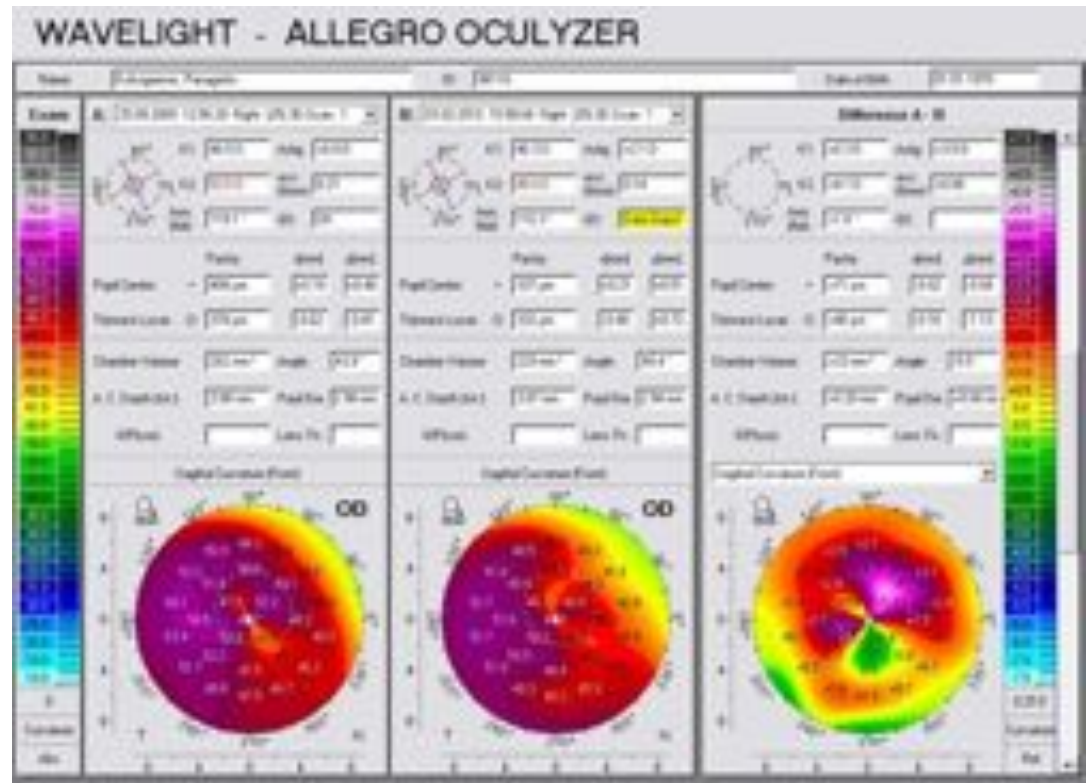
CCT 437  $\mu\text{m}$

CXL +PRK

-2.25/-1.25x120

POSTOP

VAs 6/10



Eye Institute

OS

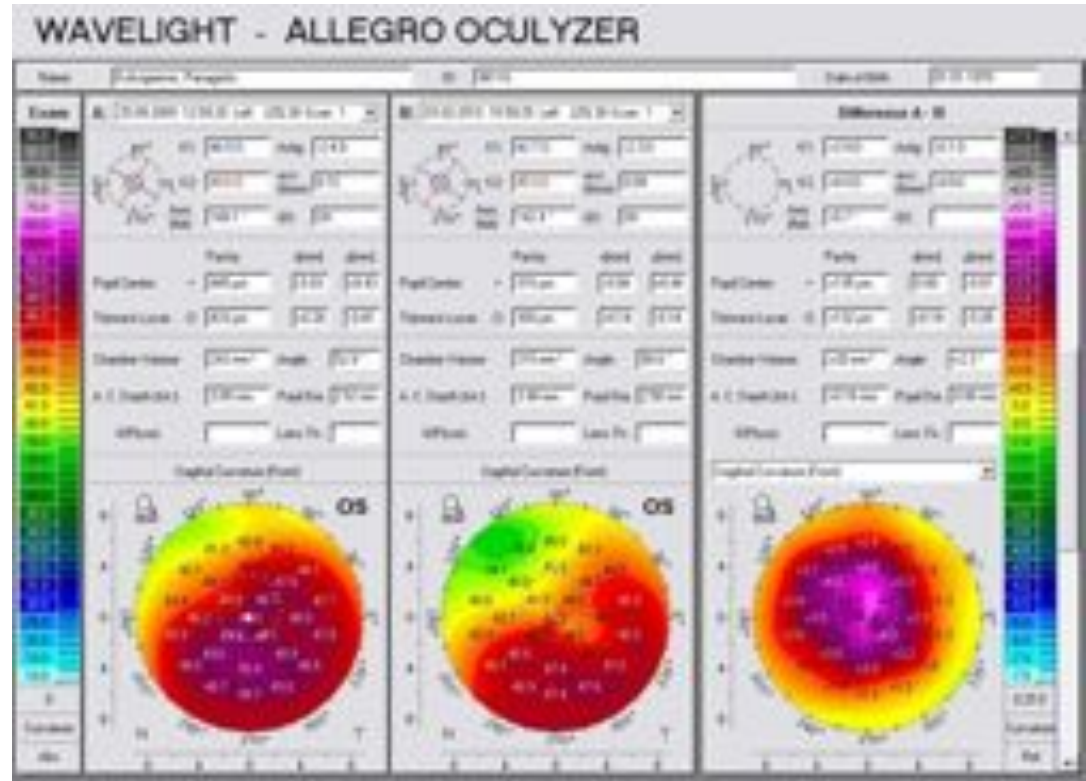
CCT 436  $\mu\text{m}$

-2.75/-0.75 x 150

PRK + CXL

POSTOP

VAs 8/10



Eye Institute



OD PRK + 30 min CXL

-3.50/-0.75 x 170

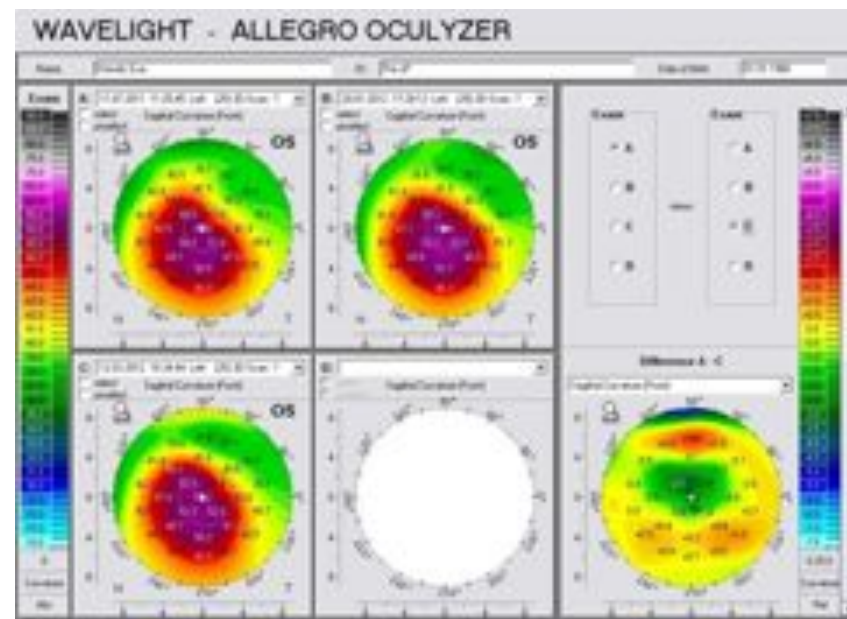
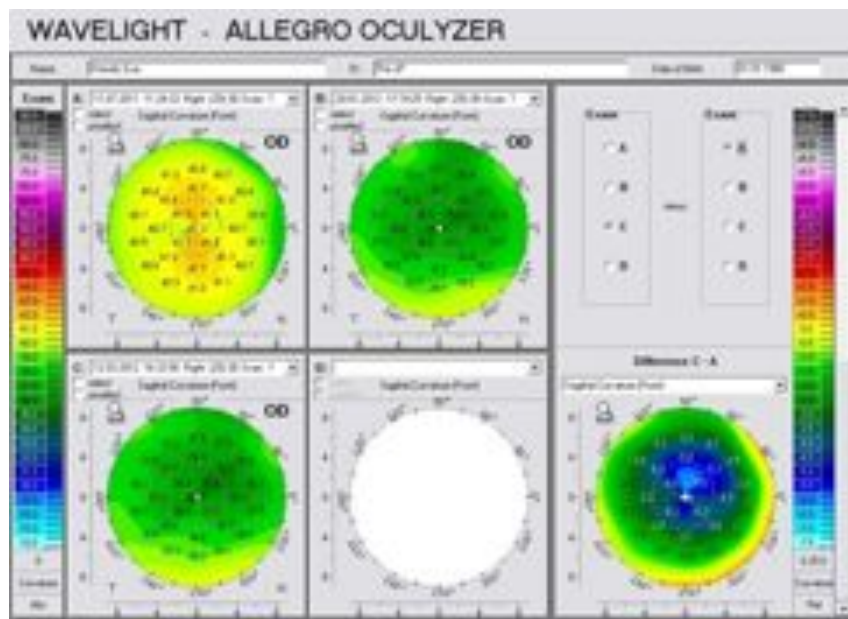
Postop

12/10 s plano

OS CXL only

Plan for ICL

Stable after CXL



Eye Institute

# KK,(f), 43 yo

OD -6.25/-0.25 x 28

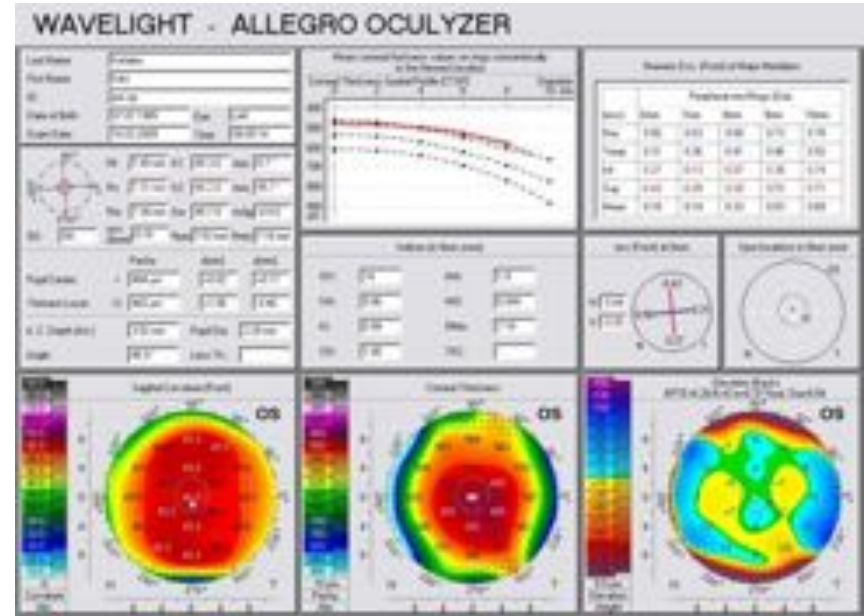
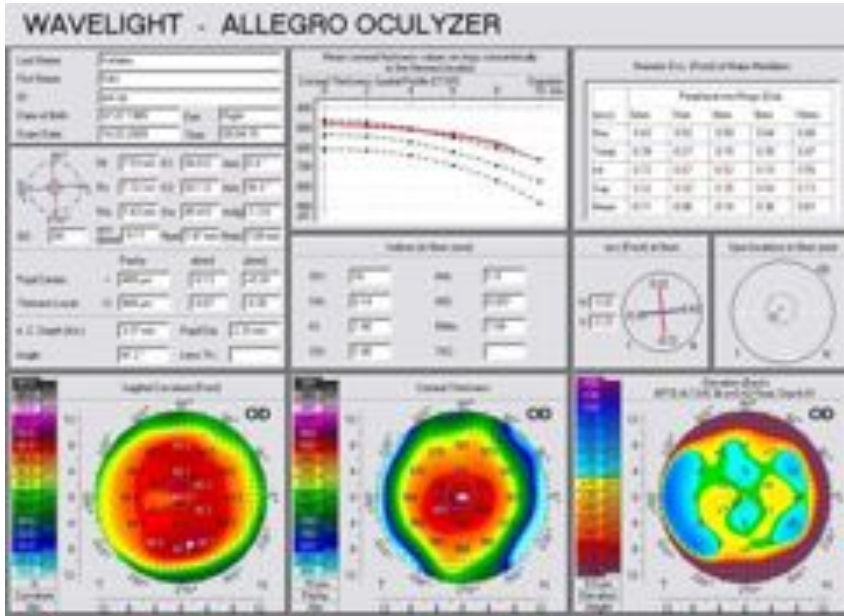
Subclinical KC

CCT 493

OS -7.00/-0.50 x 20

Subclinical KC

CCT 486



Eye Institute

# KK

OD -4.25/-0.75 x 30 (monovision) OZ 6 mm

**PRK + ribo (30 min)**

Postop

10/10 (-0.75/-0.75x170)

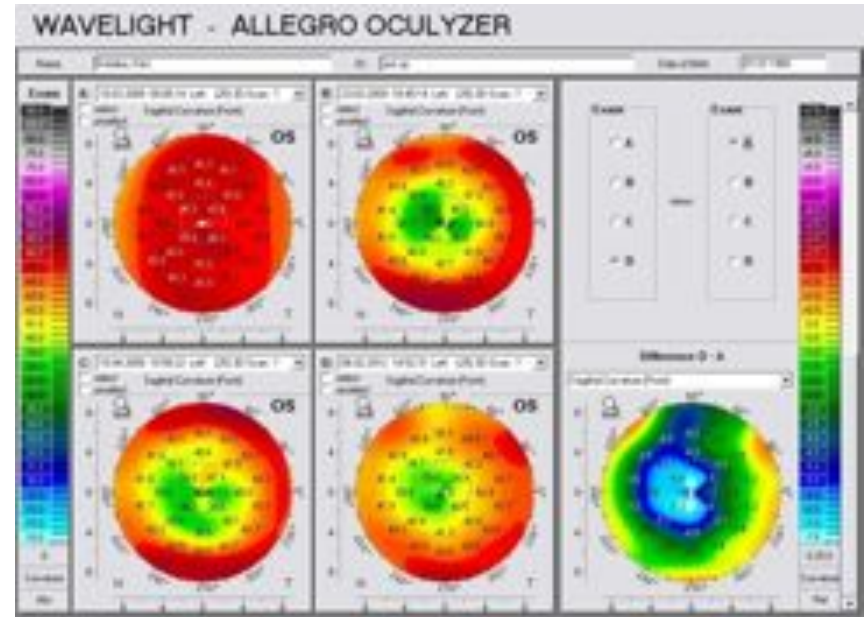
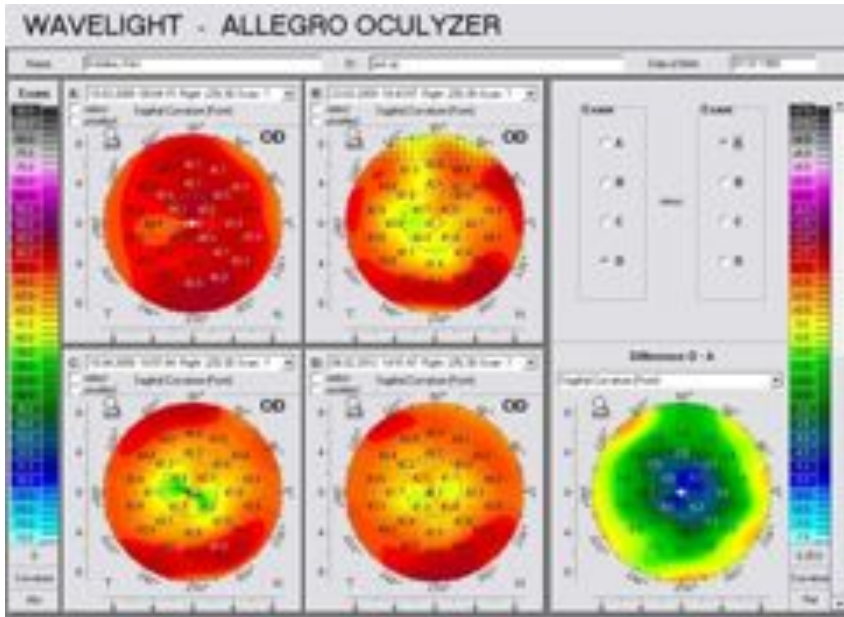
Bin J1

OS -6.50/-0.75 x 20 OZ 6 mm

**PRK + ribo (30 min)**

Postop

12/10



Eye Institute

# M.E, (m), 34 yo

c/o unstable refraction, continuous change Rx glasses

OD 7/10 s

9/10 c +1.25 / -2.75 x 28

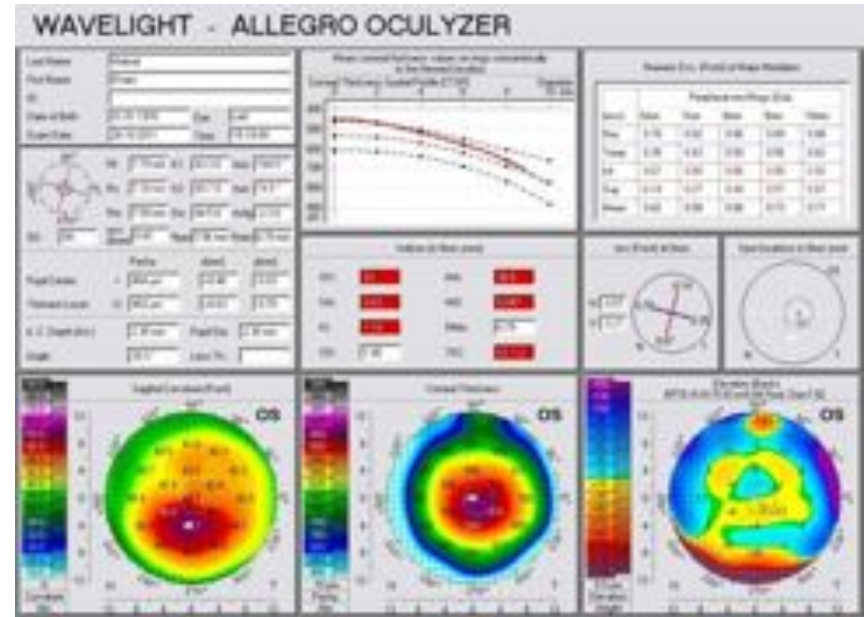
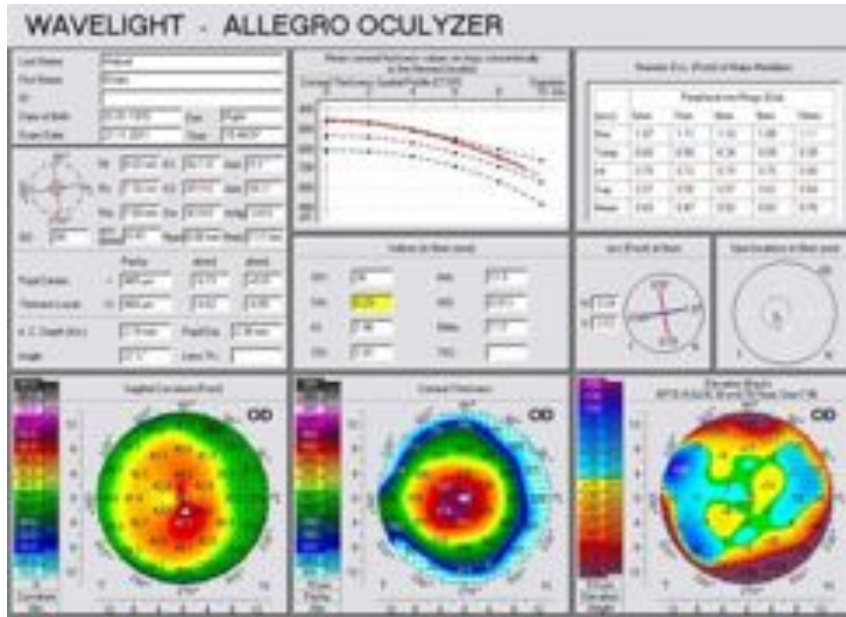
CCT 467  $\mu\text{m}$

**NOT suitable for ICL, as AC depth 2.18**

OS 7/10 s

9/10- with +1.75 / -1.75 x 140

CCT 467  $\mu\text{m}$



Eye Institute

# M.E.

OD

**PTK 50  $\mu\text{m}$  / OZ 7.00/AZ 8.90**

**PRK +1.00 / -2.50 x 30 (max depth 39  $\mu\text{m}$ ,  
central 23  $\mu\text{m}$ )**

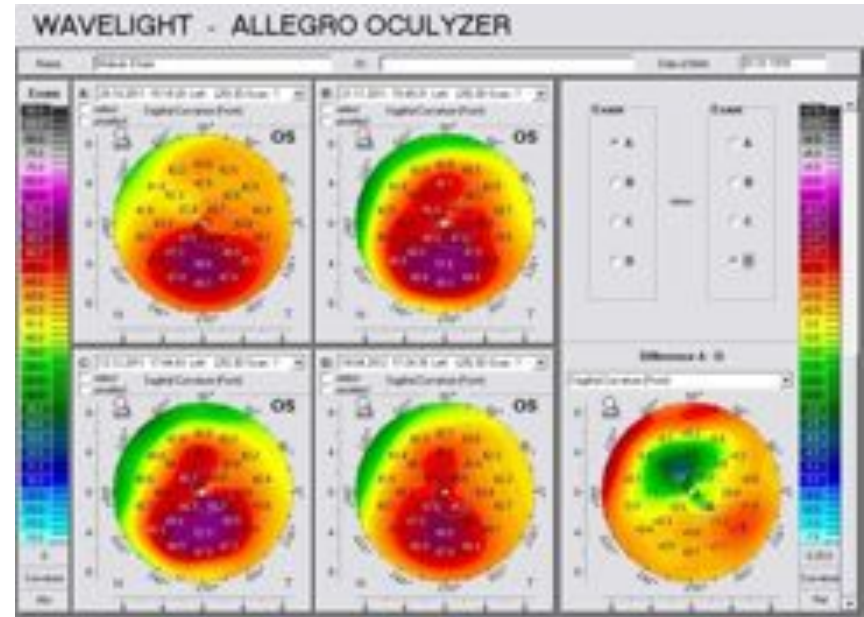
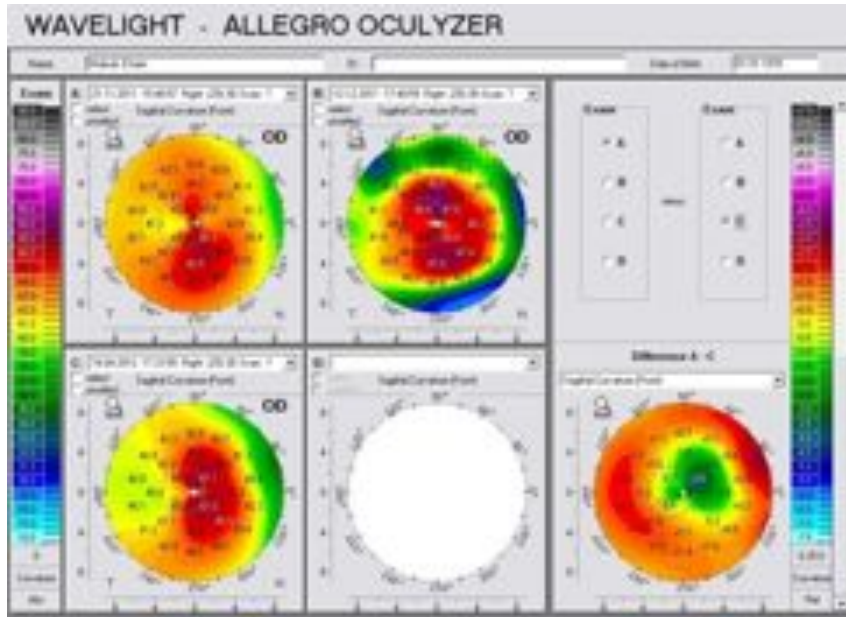
**CXL 1 hour + MMC 12 sec**

OS

**PTK 50  $\mu\text{m}$  / OZ 7.00 / AZ 8.90**

**PRK +1.25 / -1.75 x 140 (max 28  $\mu\text{m}$   
periphery, 8  $\mu\text{m}$  central)**

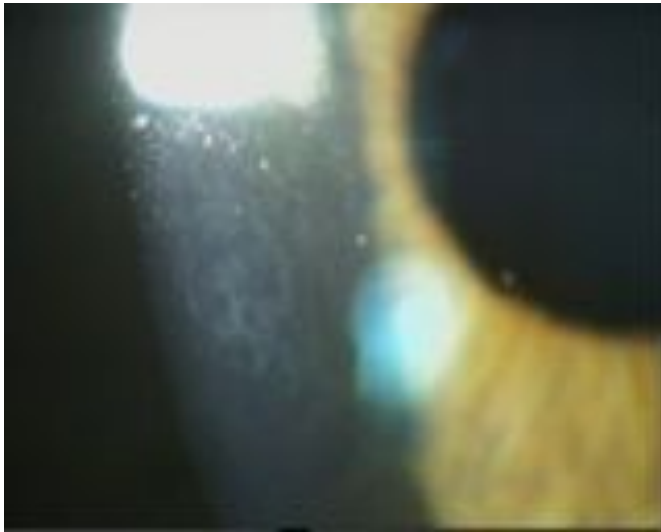
**CXL (stand. Protocol) 1 hour – No MMC**



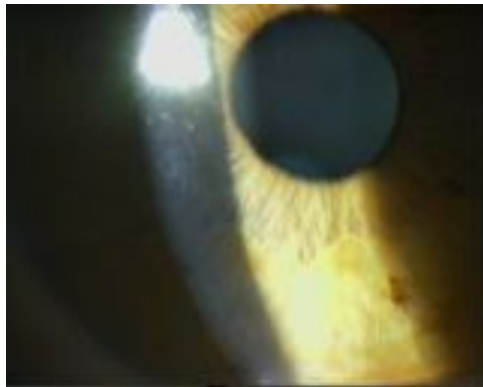
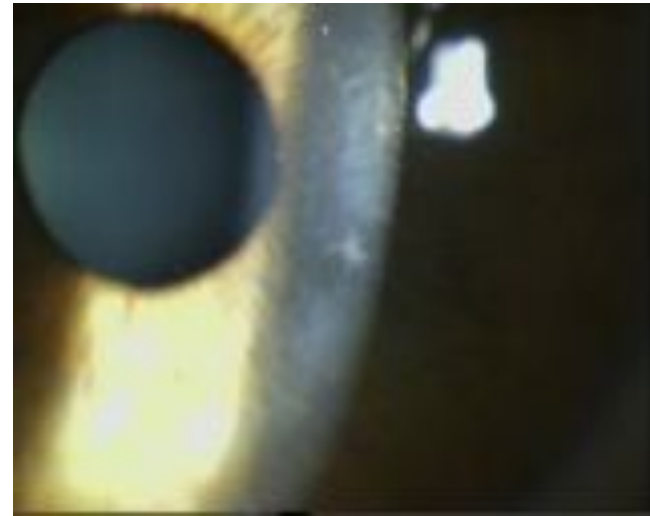
Eye Institute

# M.E, postop 12 m.

OD VAs 10/10+



OS VAs 10/10 s



Eye Institute

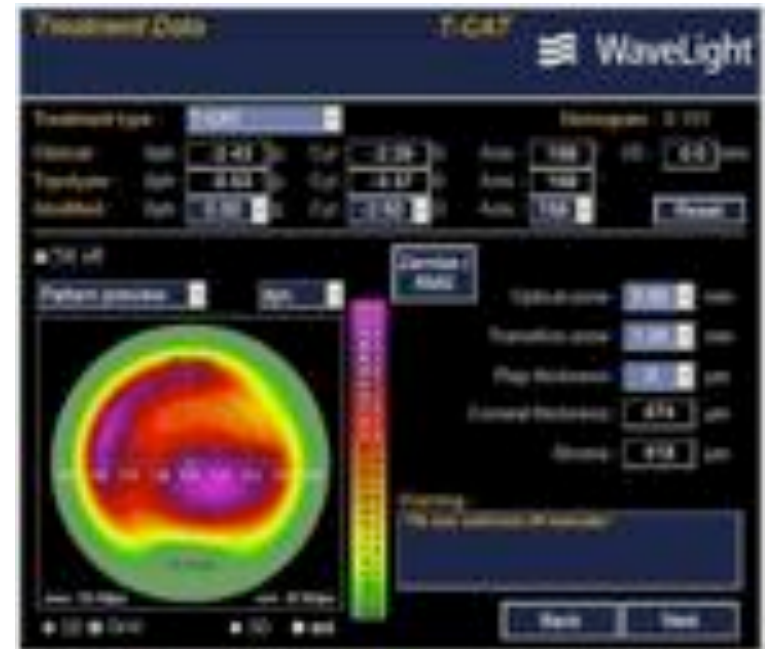
# Topo-guided partial PRK

- 1-Topolyzer:Placido disc topography
- 2-Pentacam (Oculus)
- 3-Pentacam HD (oculyzer II)-Refractive suite
- 4-Vario (placido disc +pupil sensor+iris recognition+limbal landmarks recognition)



WaveLight® FS200  
Femtosecond Laser

WaveLight® EX500  
Excimer Laser



WaveLight® Refractive Suite



# The Athens Protocol 4 steps:

same day PTK > topoPRK > MMC > CXL (6mW/cm<sup>2</sup> x 15 min)

1- PTK

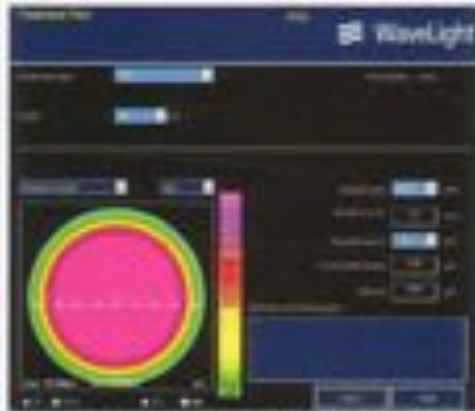


Figure 4.1: Epithelium removed with 50 mHz PTK

2- topo  
-guided  
PRK

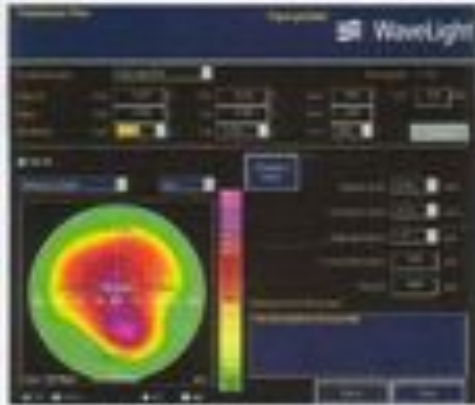


Figure 4.2: TIC at treatment zone



Figure 4.3: Topography-guided PRK to correct part of the refractive error (TICAT treatment plan) maximal thickness removed 50 microns

4-: CXL



3- 30" MMC

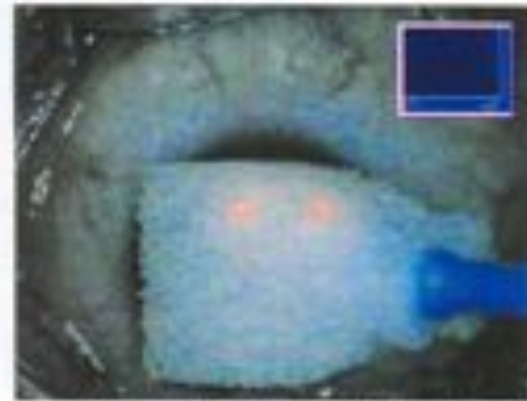


Figure 4.4: MMC solution (0.02%) for 20 seconds



Eye Institute

# The Athens Protocol 4 steps:

same day PTK > topoPRK > MMC > CXL (10mW/cm<sup>2</sup> x 10 min)

1- PTK



Figure 4.1: Epithelium removed with 50 microns PTK

2- topo  
-guided  
PRK

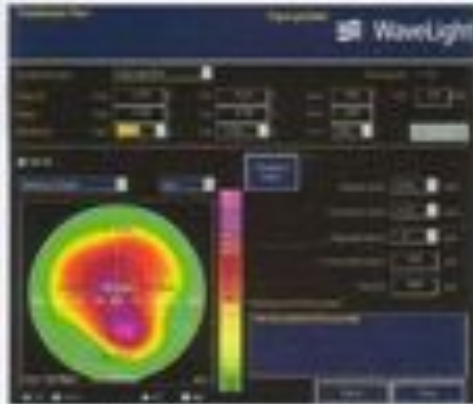


Figure 4.2: TIC at treatment plan



Figure 4.3: Topography-guided PRK to correct part of the refractive error (TICAT treatment plan) (maximal thickness removal 50 microns)

4-: CXL



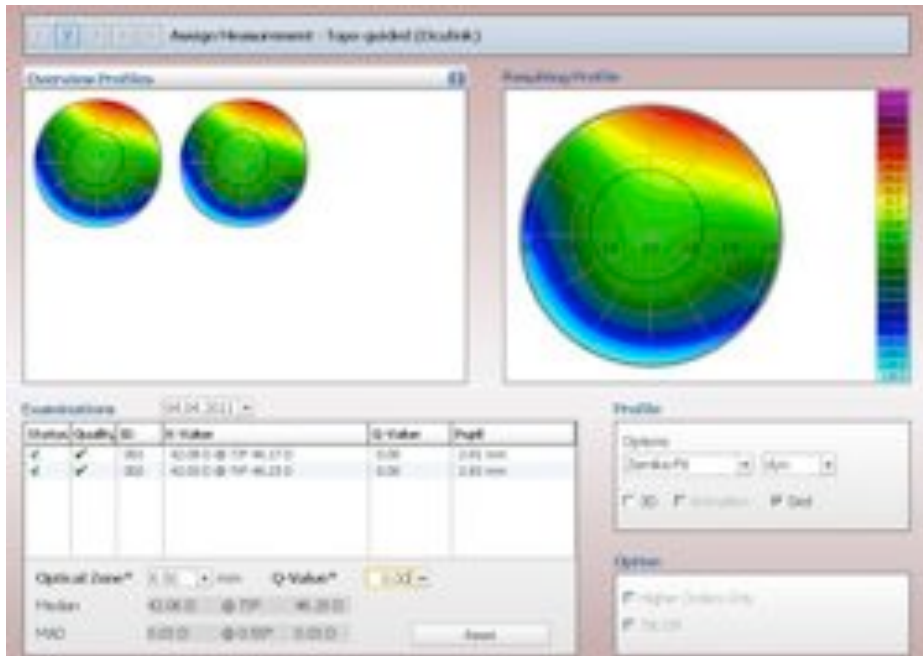
3- 30" MMC



Figure 4.4: MMC solution 0.02% for 20 seconds



# Step 2: Validate Pentacam and clinical refraction entry



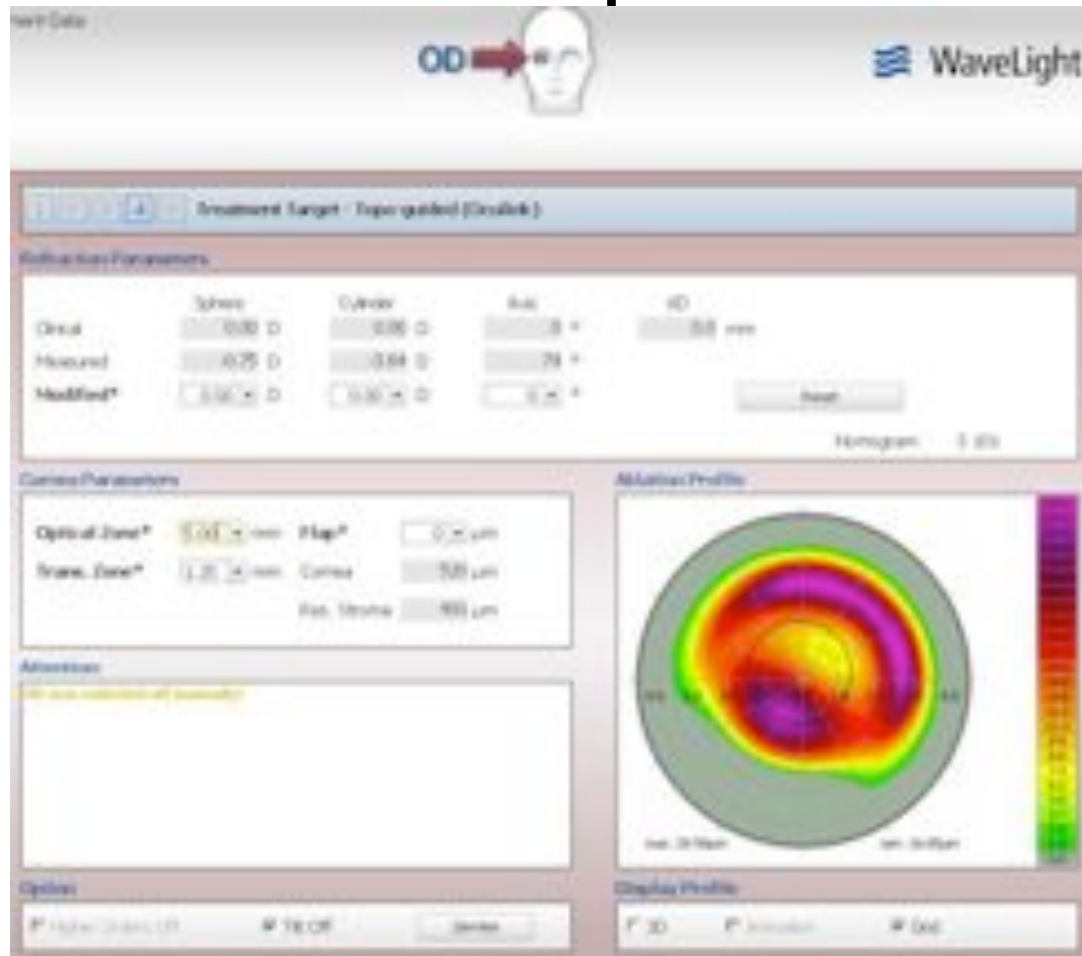
Eye Institute

Step 4: attempted Rx to 0, OZ to 5 or 5.5mm, cyl axis to match topo axis not refractive axis

The screenshot displays the WaveLight software interface for a laser eye procedure. At the top, it shows 'OD' with an arrow pointing to a head icon and the 'WaveLight' logo. Below this is a 'Treatment Target - Topoguided (Disabled)' section. The main area is divided into several panels:

- Refractive Parameters:** A table with columns for Sphero, Cylind, Axis, and ID. The values are: Sphero (0.00 D), Cylind (0.00 D), Axis (0°), and ID (5.5 mm). There are also 'Measured' and 'Modified' rows with similar values.
- Cornea Parameters:** Includes 'Optical Zone' (5.00 mm), 'Flap' (0 mm), 'Trans. Zone' (1.25 mm), 'Cornea' (500 μm), and 'Post. Strab.' (900 μm).
- Aberration Profile:** A circular topographic map showing wavefront aberrations with a color scale on the right.
- Options:** A section at the bottom left with checkboxes for 'F 20', 'F 30', and 'F 40'.

# Step 4: OZ to 5 or 5.5mm, cyl axis to match topo axis

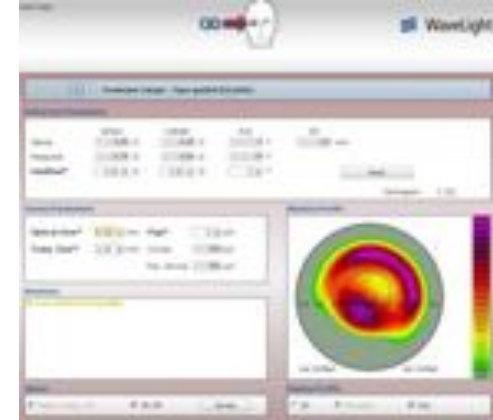


Eye Institute

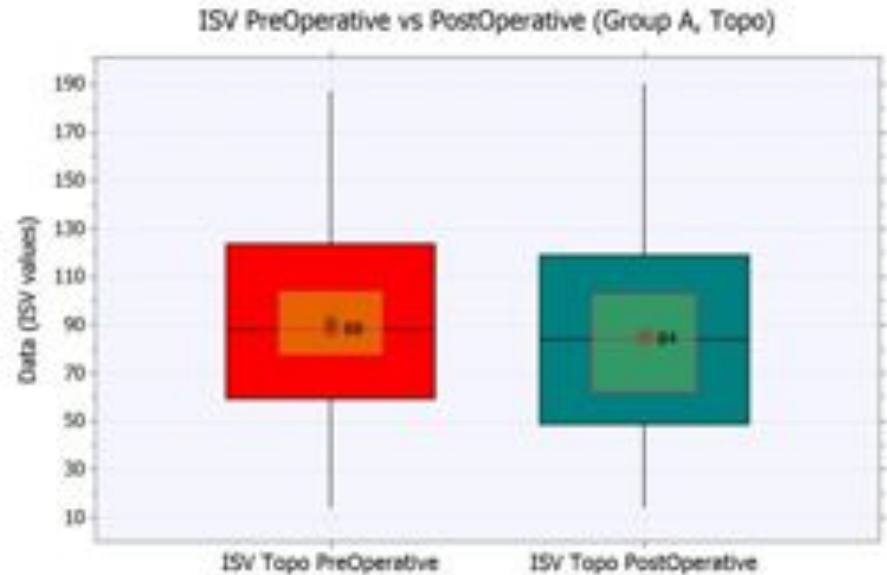
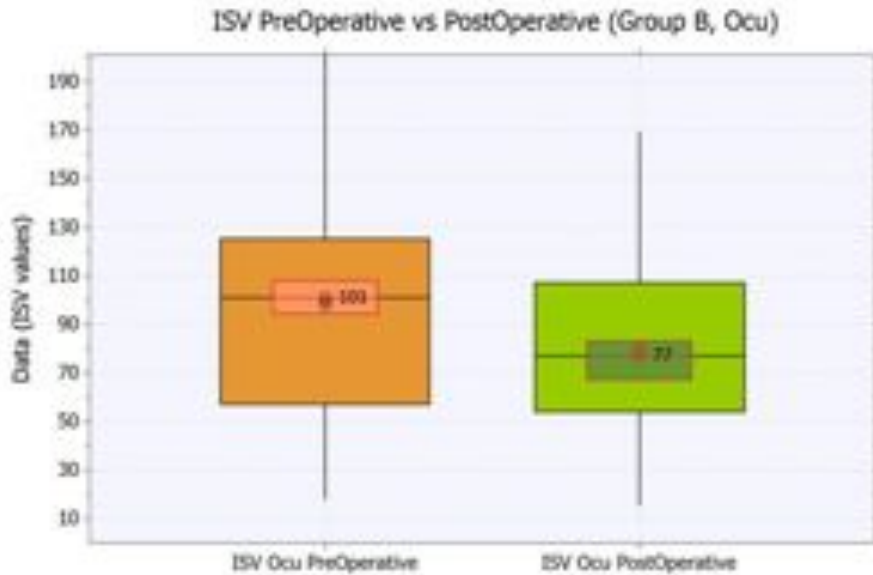
# Step 6: PTK treatment plan



Eye Institute

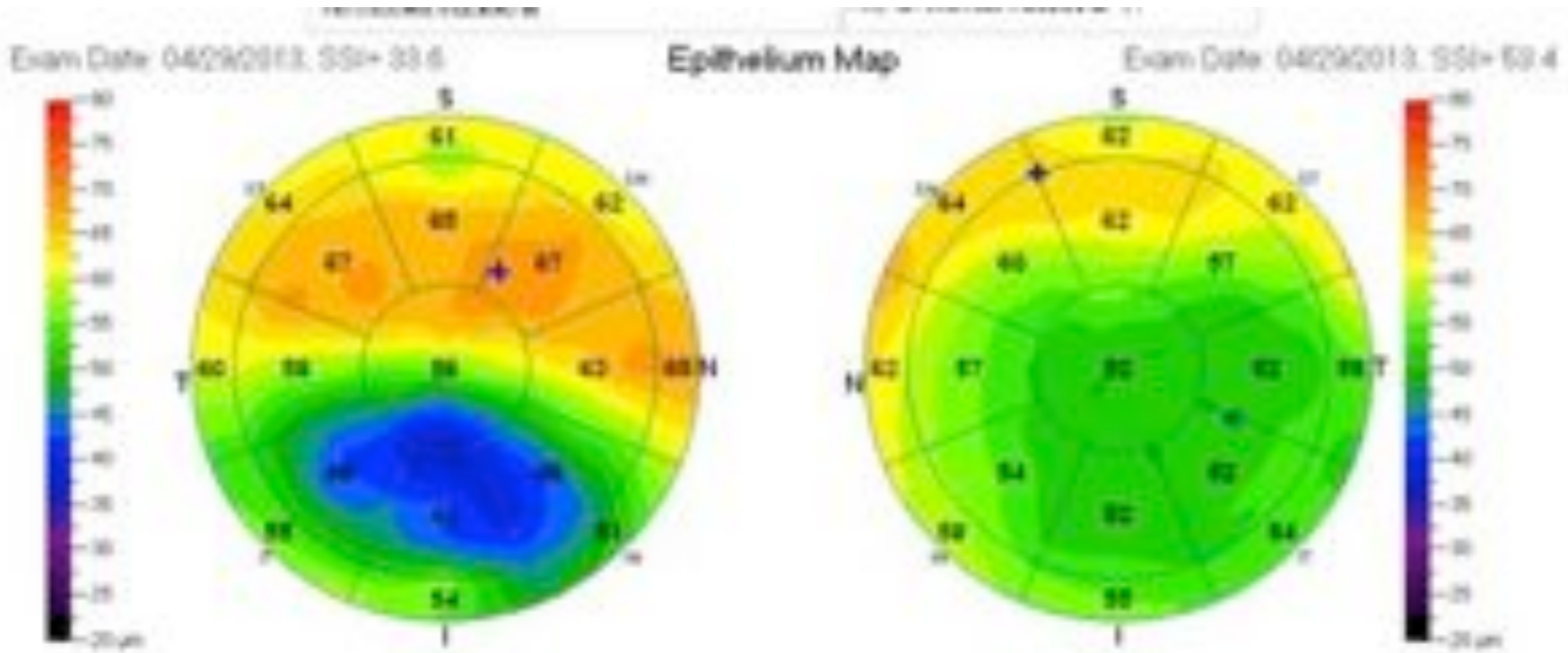


## Oculink Vs Topolink in Athens Protocol



Oculink (Pentacam driven)  
appeared more effective!

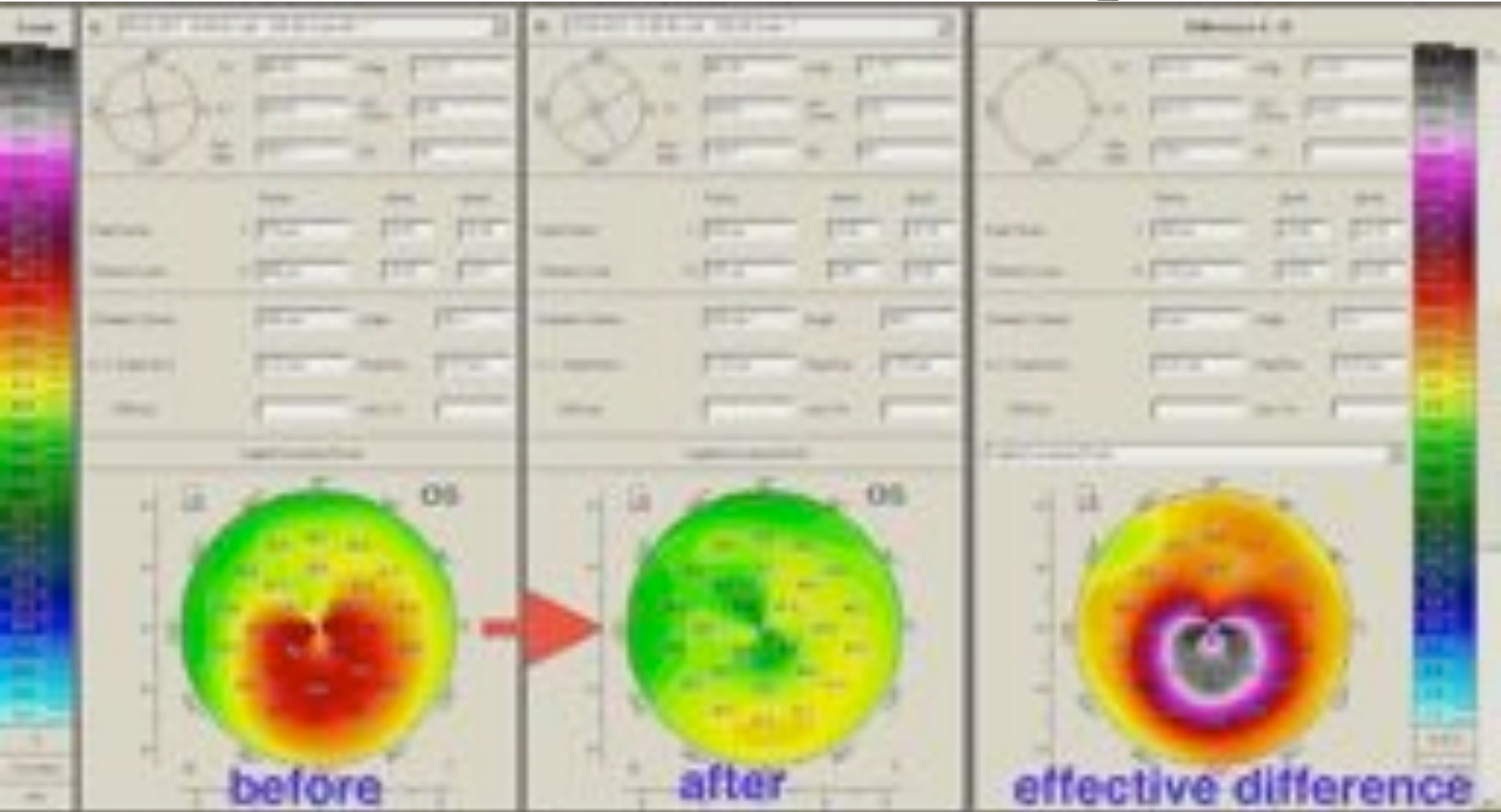
# Athens Protocol (topoPRK +CXL) KCN epithelial changes



before

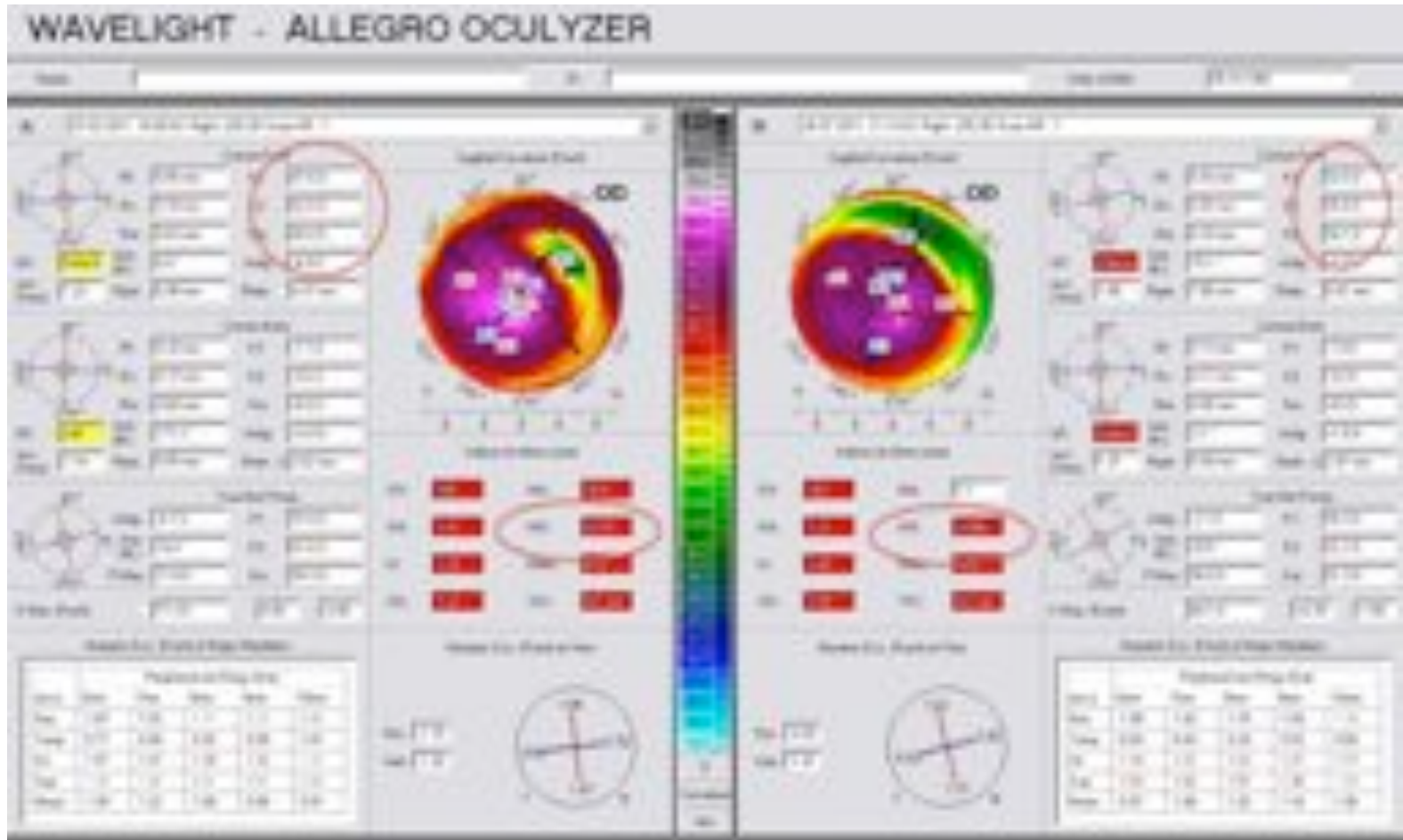
after

# Athens Protocol example



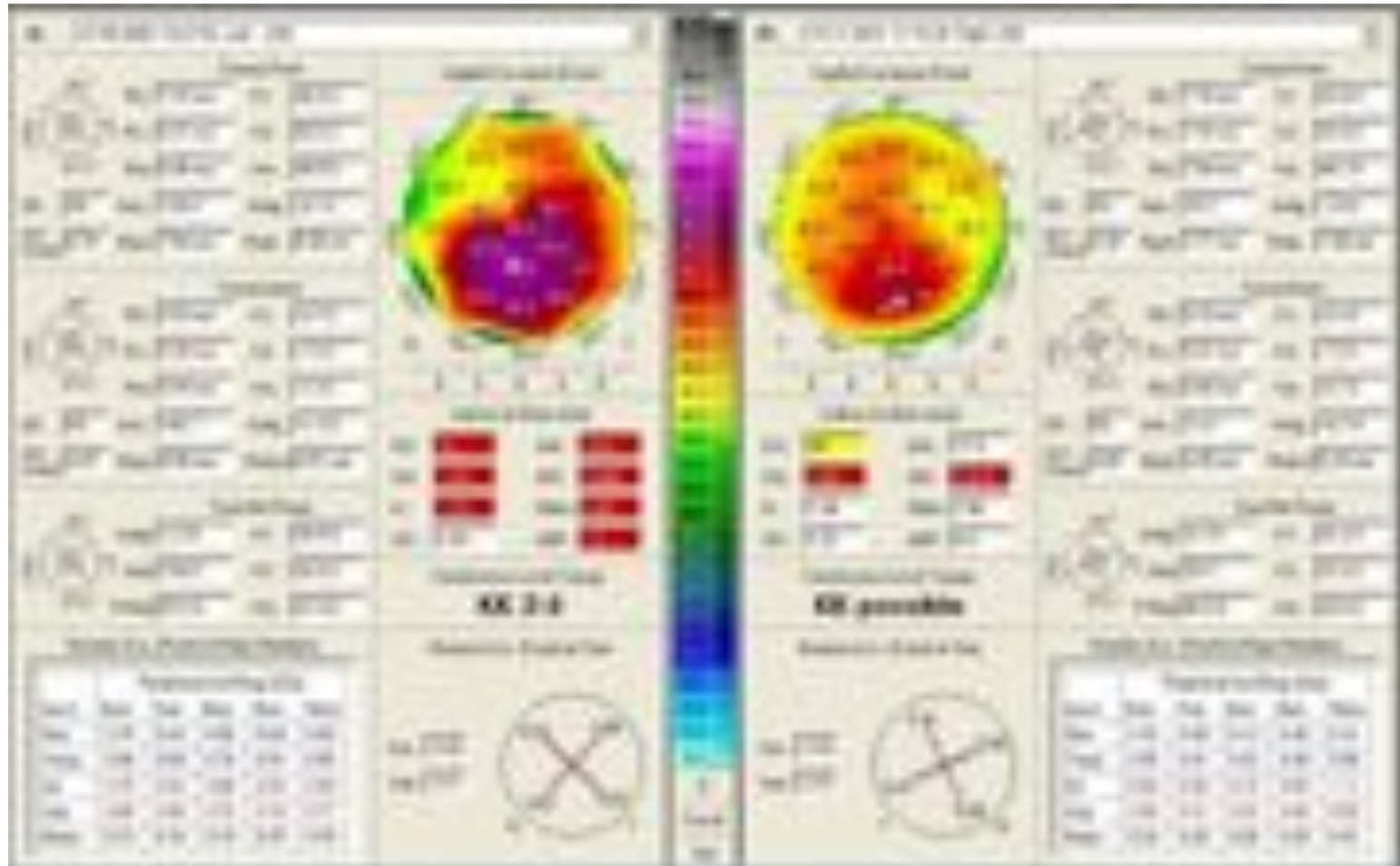
Eye Institute

# Topometric parameter improvement: IHD



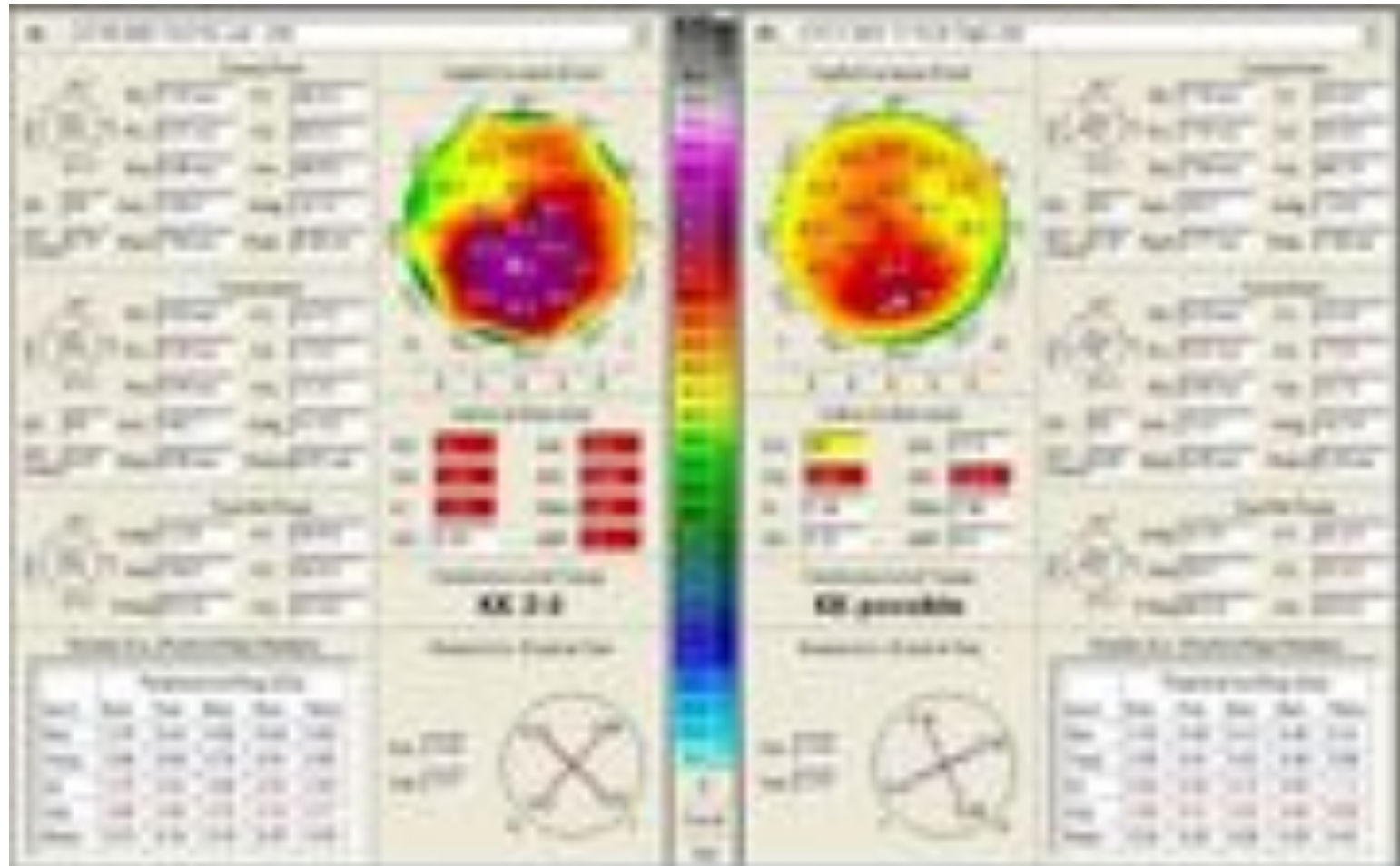
Eye Institute

Average K from 48.5 to 44  
Refraction -2.5-4.5@155 (20/70) to -1-1.5@10 (20/20)



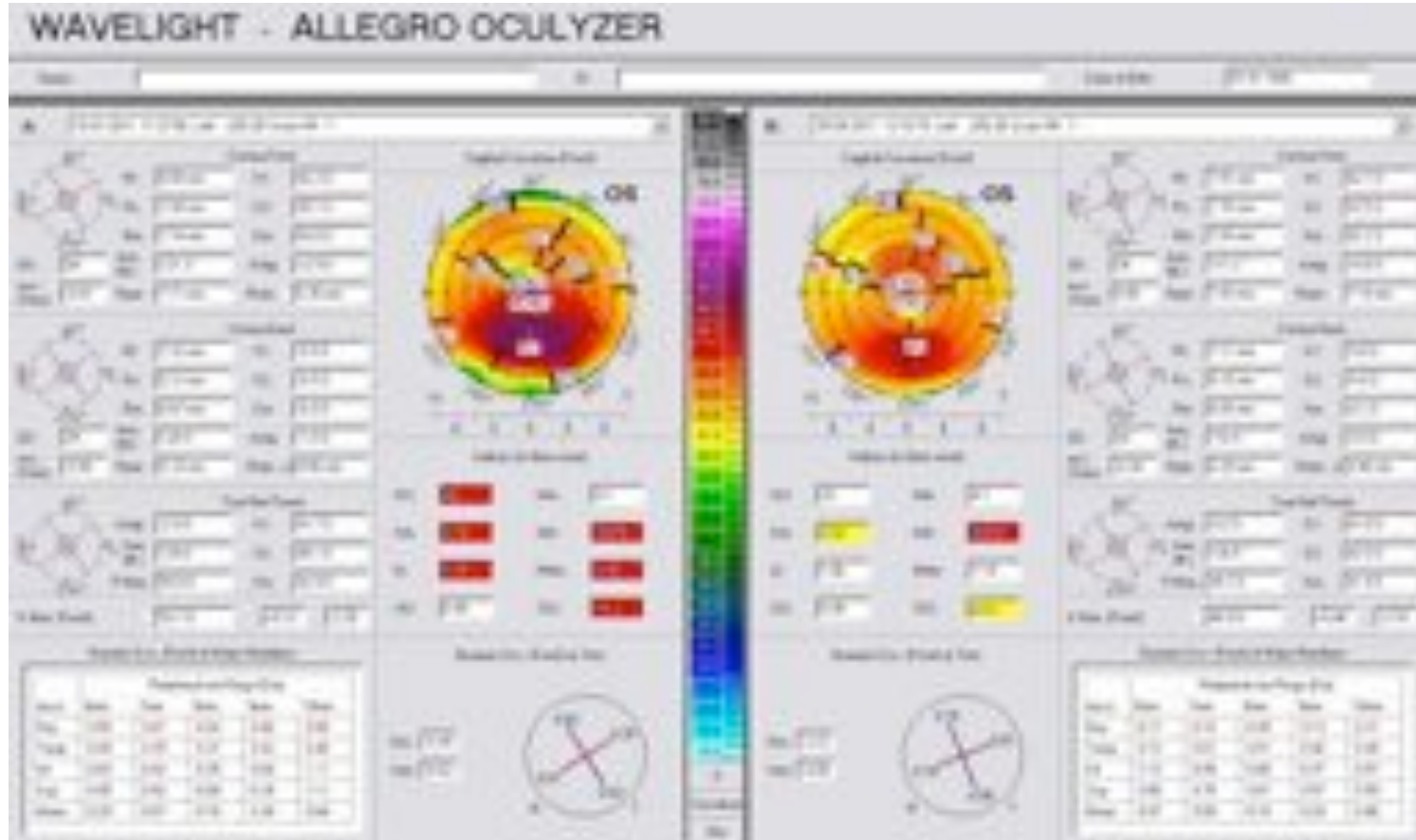
Eye Institute

Average K from 48.5 to 44  
Refraction -2.5-4.5@155 (20/70) to -1-1.5@10 (20/20)

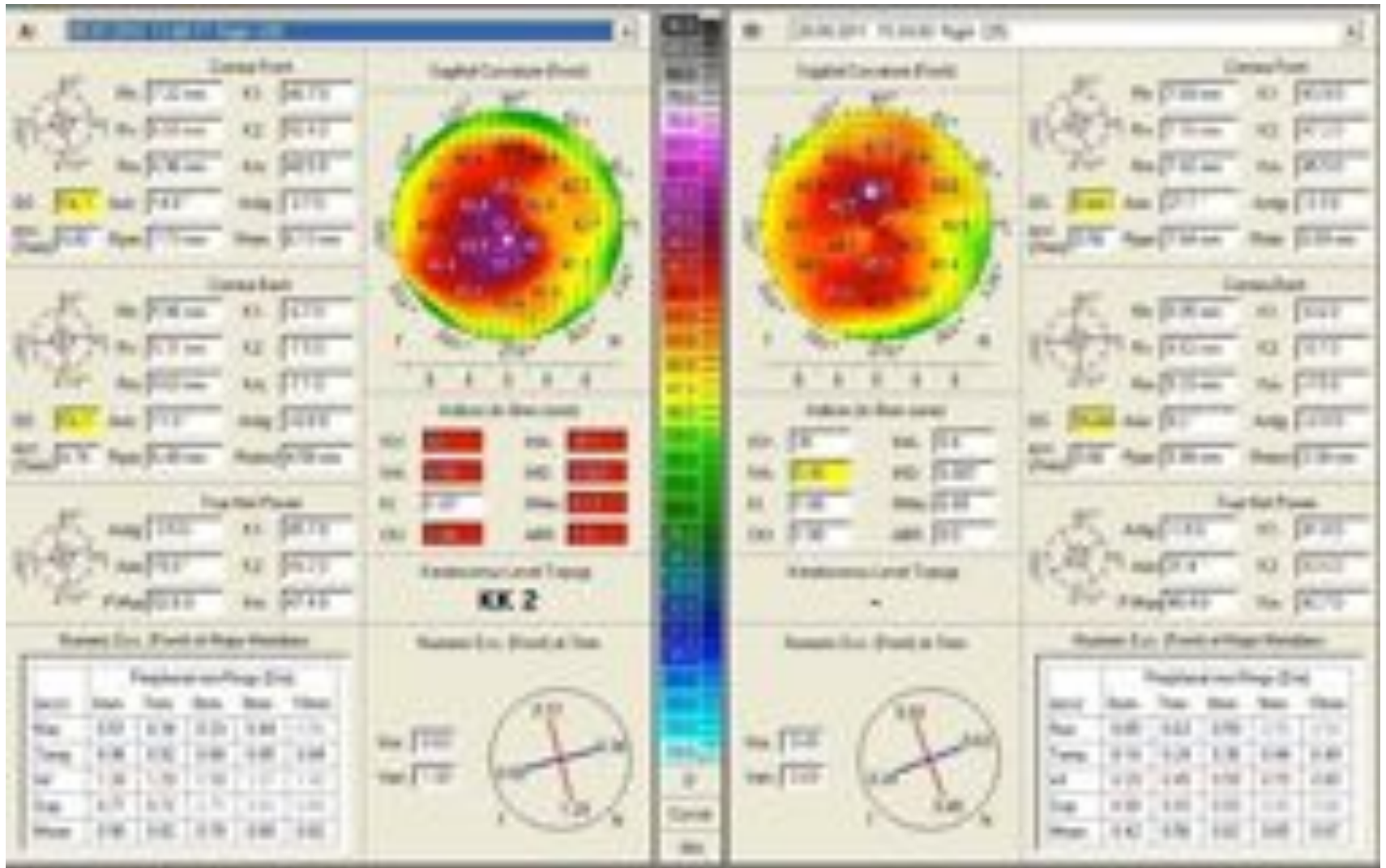


# Myopia induction!:

Refraction from +0.75-3.50@10 (20/60) to -0.75-0.75@170 (20/20) due to improvement of the topometric parameters



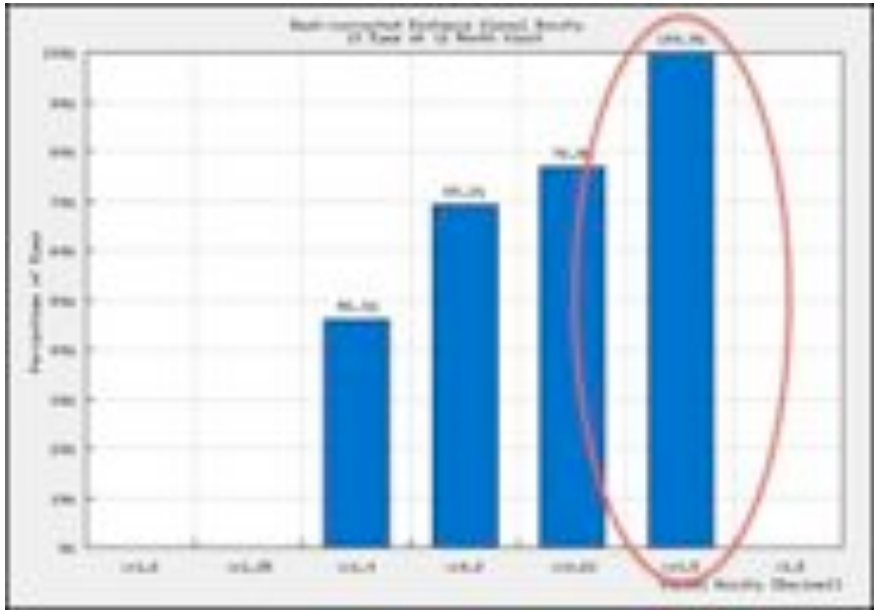
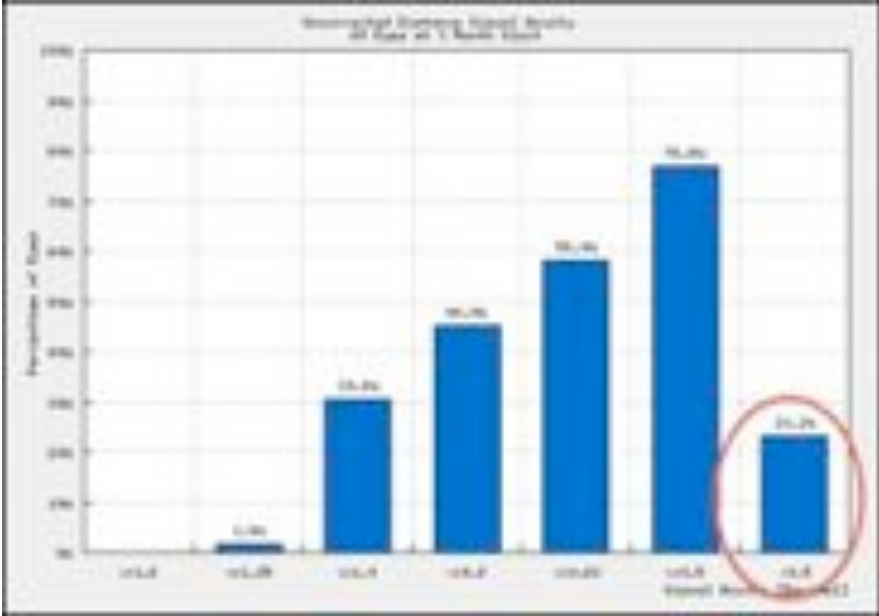
# 5 year follow up in a 15 y/o



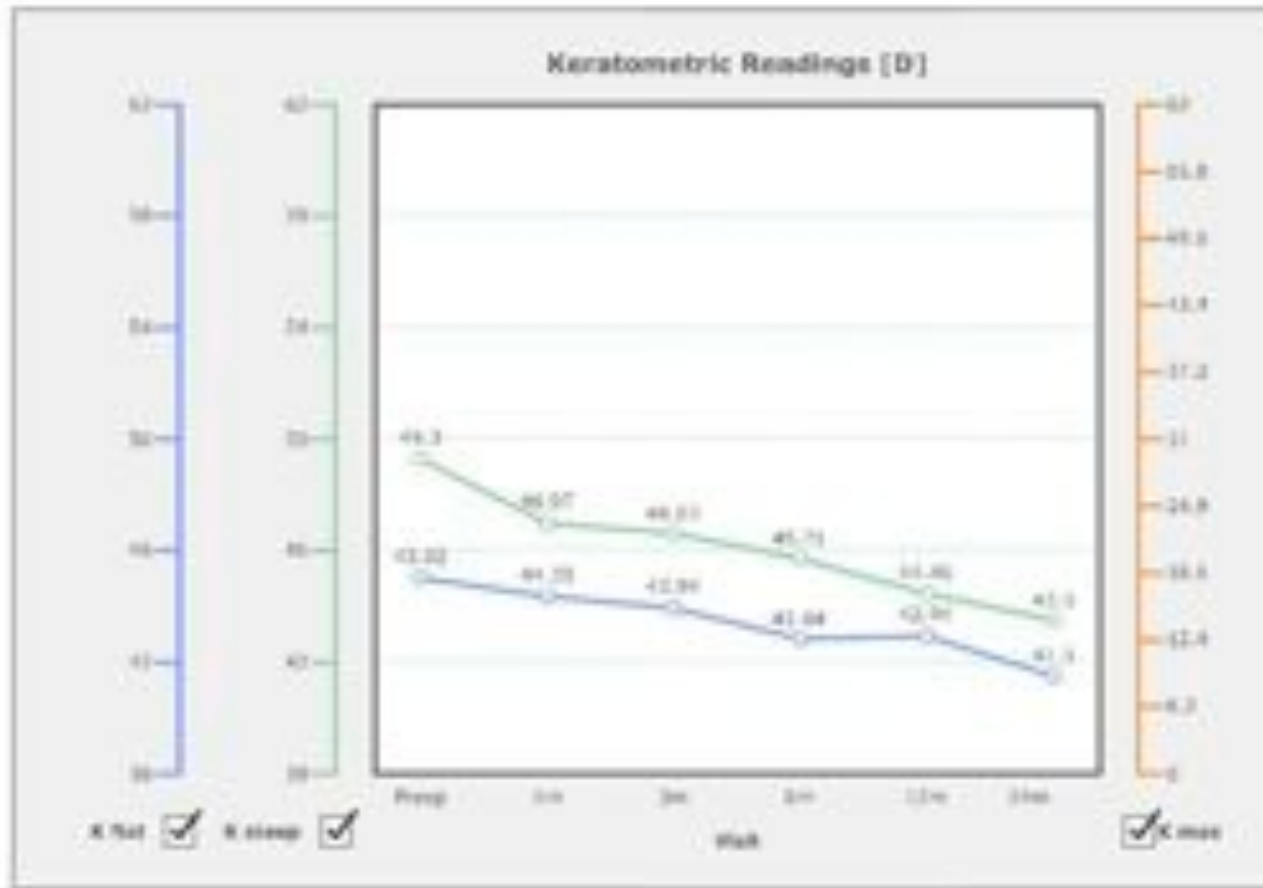
Eye Institute

# Athens Protocol:

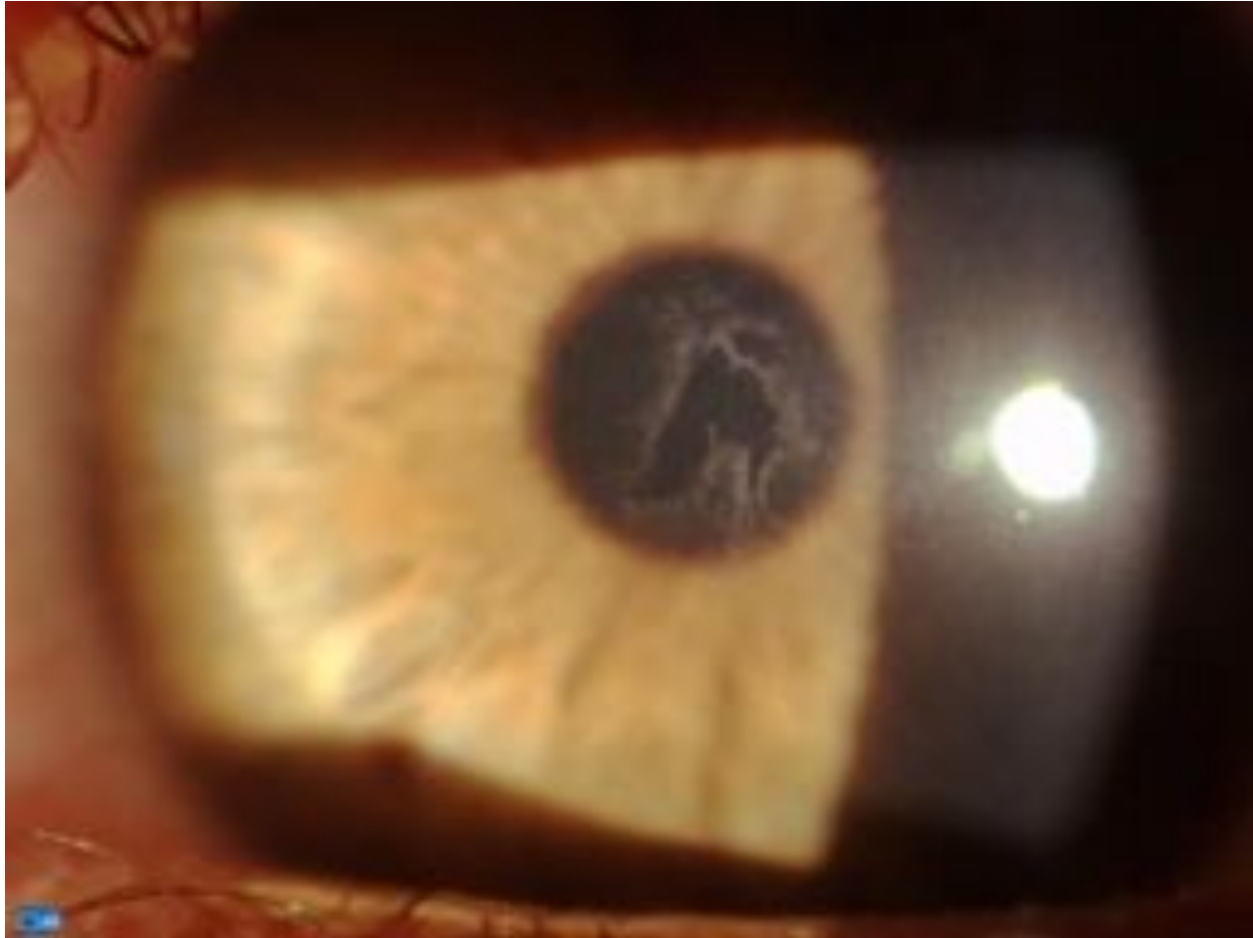
Some improvement in UCVA, dramatic improvement in BSCVA: 98% of cases at least 20/40!



# Athens Protocol: Keratometric change over 24 months, progressive flattening this finding makes challenging the prediction of refractive correction

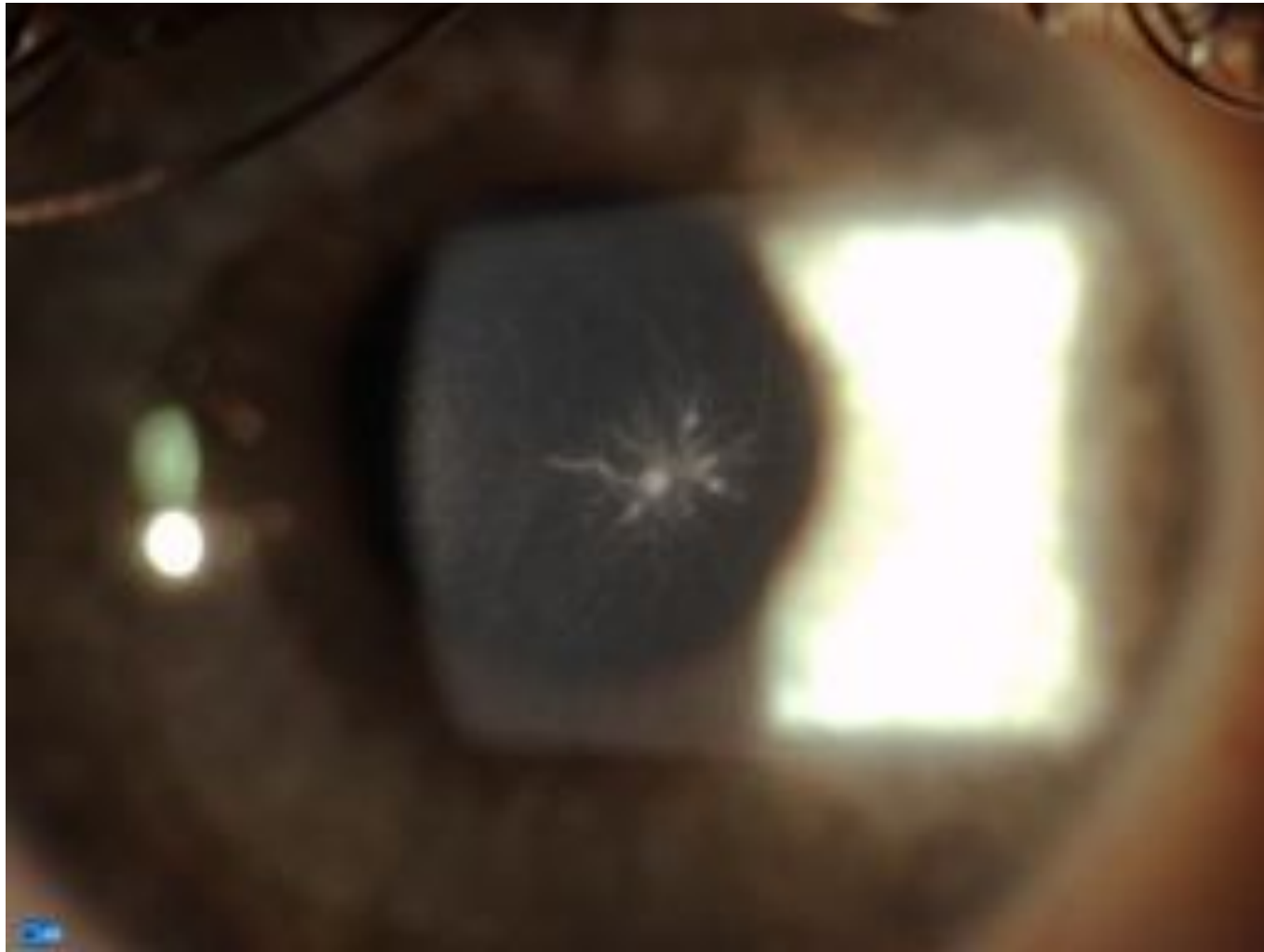


## Delayed epi-closure: day 5



Eye Institute

# Active epithelial surface after reepithelialization



Eye Institute

## Conclusions The Athens Protocol: topo-guided normalization and higher fluence CXL

- Not a refractive treatment-rather therapeutic
- The sphere refractive result may be unpredictable
- The improvement of BSCVA is **very predictable**
- **Synergistic** effect when combined with CXL
- Minor healing delays may dictate careful management
- No other current treatment can improve predictably tomometric cornea parameters with long follow-up

III.

Αντιμετώπιση κερατόκωνου με  
συνδυασμό διασύνδεσης  
κολλαγόνου (CXL) + ICL + DALK

# K.M, (f), 28 yo

OD KC

CCT 488

CL intolerant, glasses intolerant

VA s 7/10

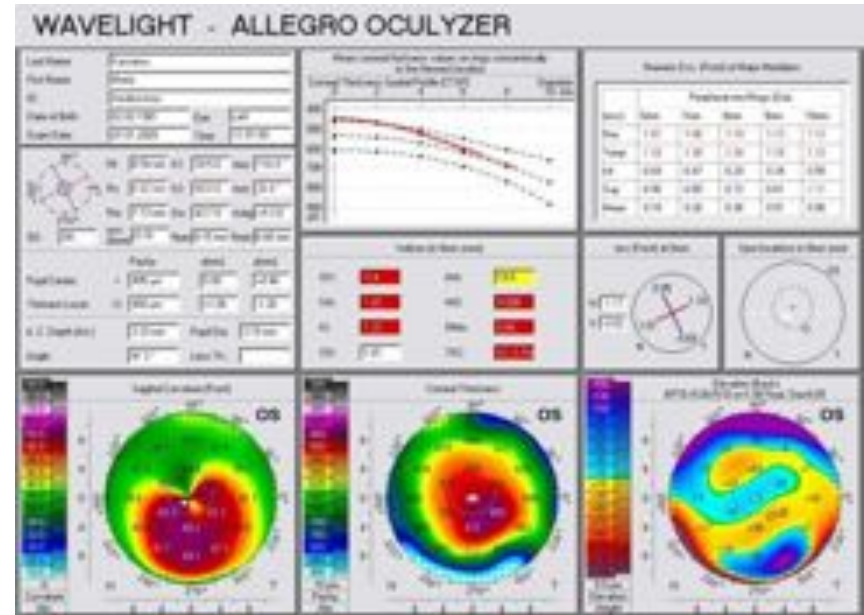
OS KC / PMCD

CCT 446, Vogt's striae

CL & gl intolerant

VA 1/10 w -0.50/-4.75 X 150

Underwent **CXL only** with excellent result

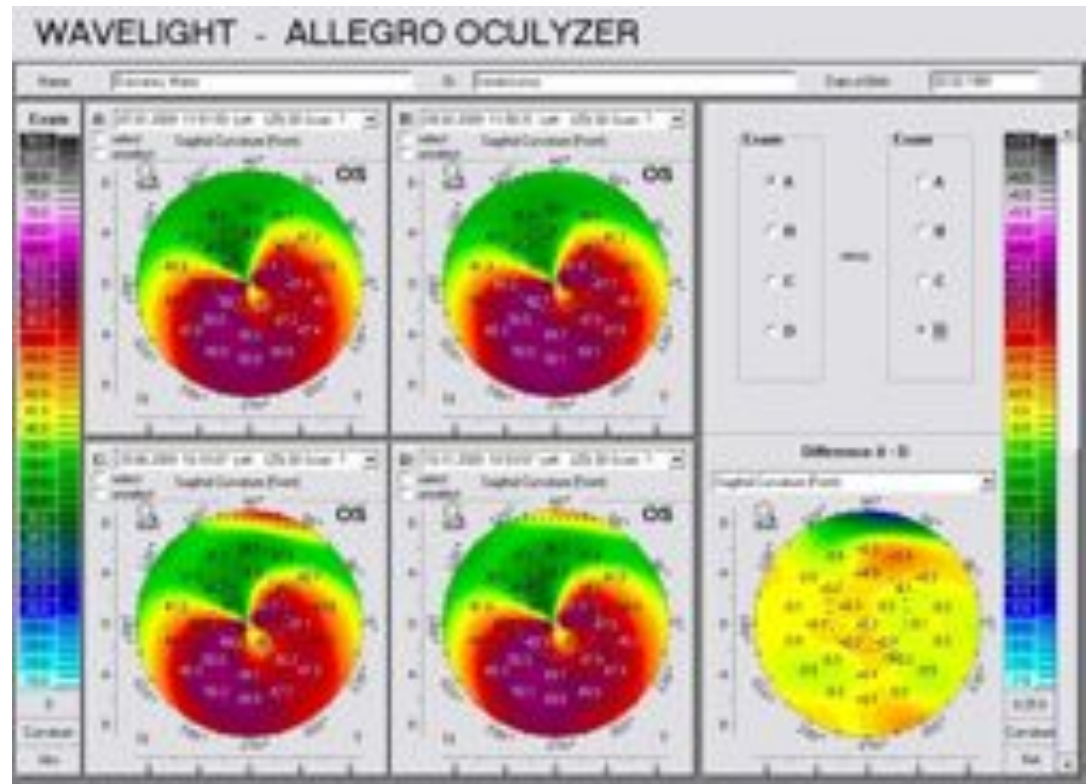


OS

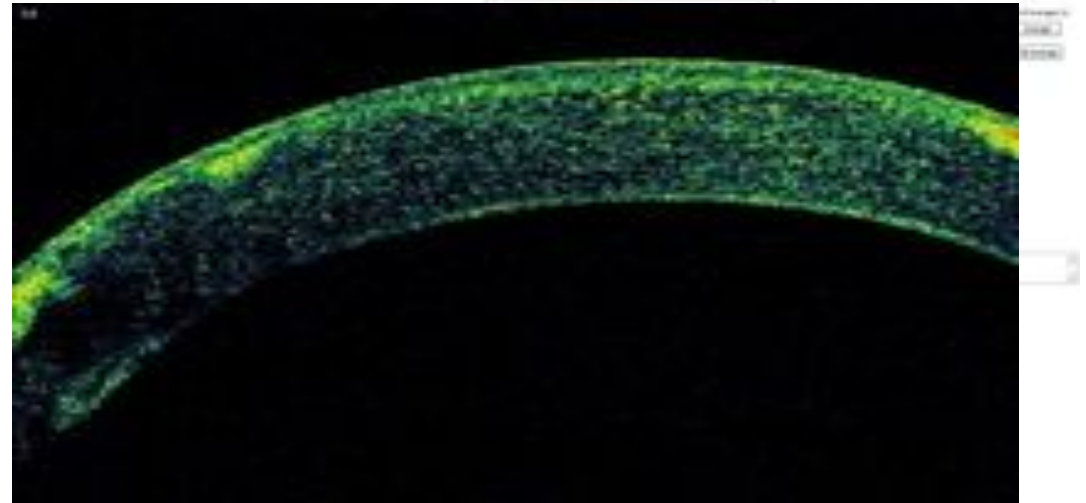
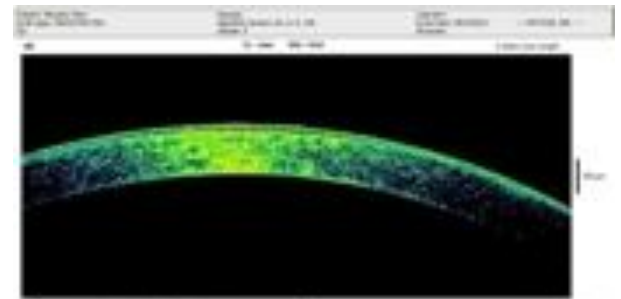
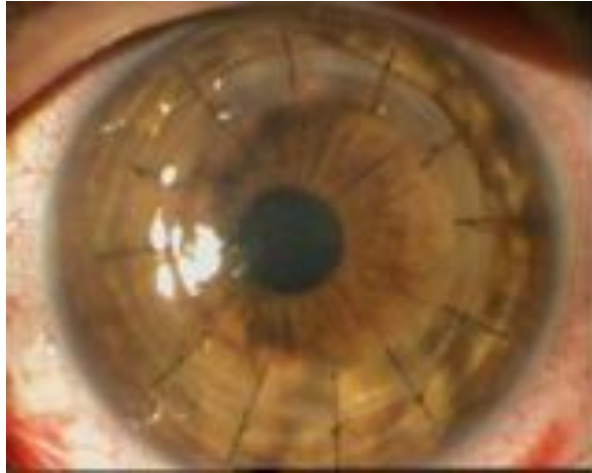
CXL standard protocol

Stable post CXL

Plan for DALK



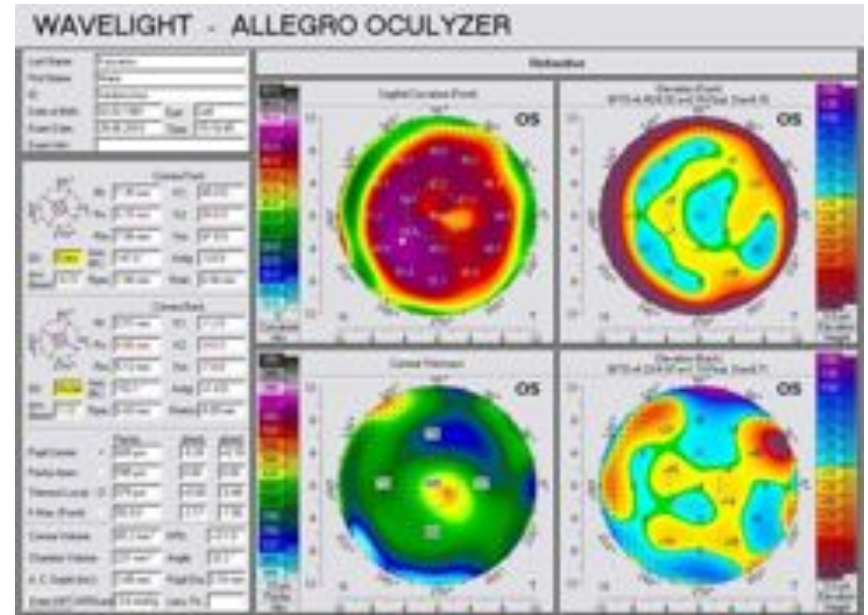
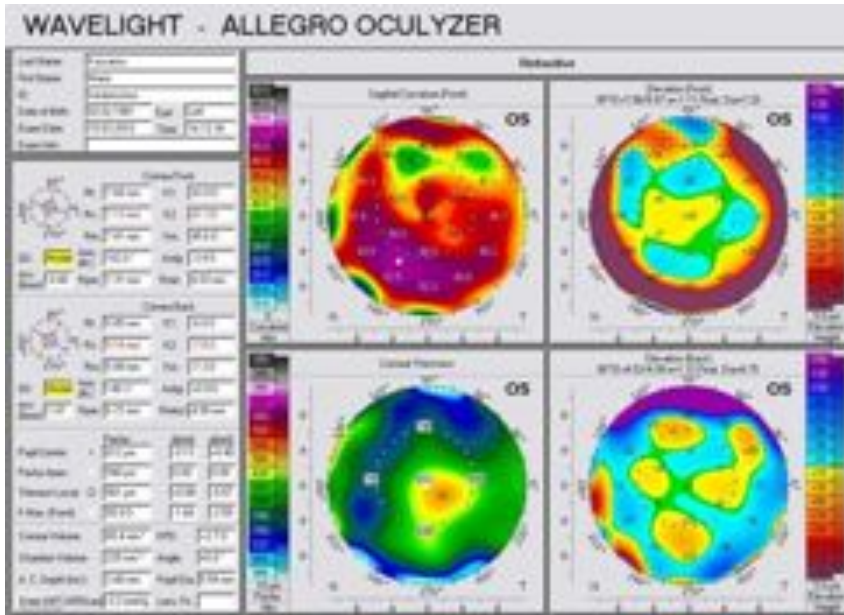
# DALK (OS)



# Post DALK (OS)

2m. Post DALK  
VAs 1/10  
Refr -7.50 / -6.50 x 146

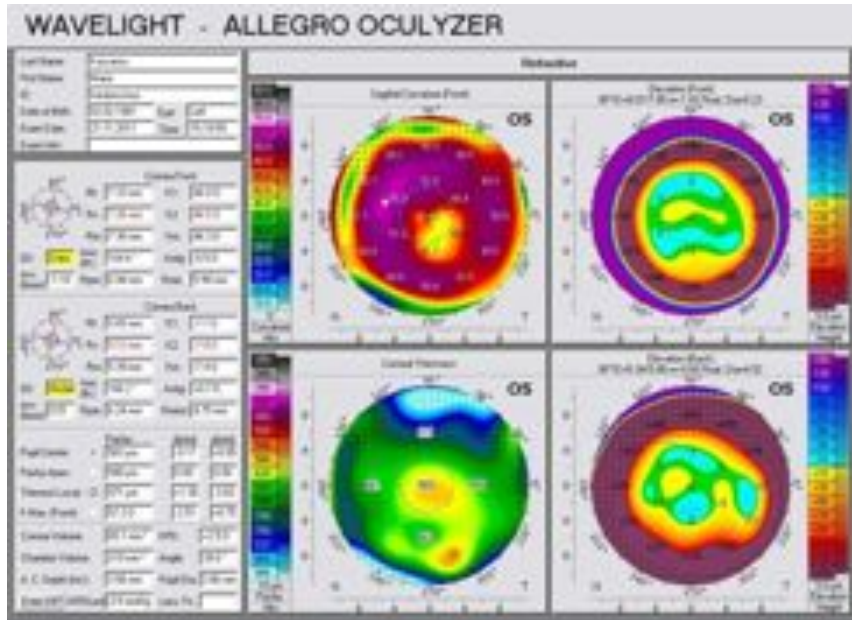
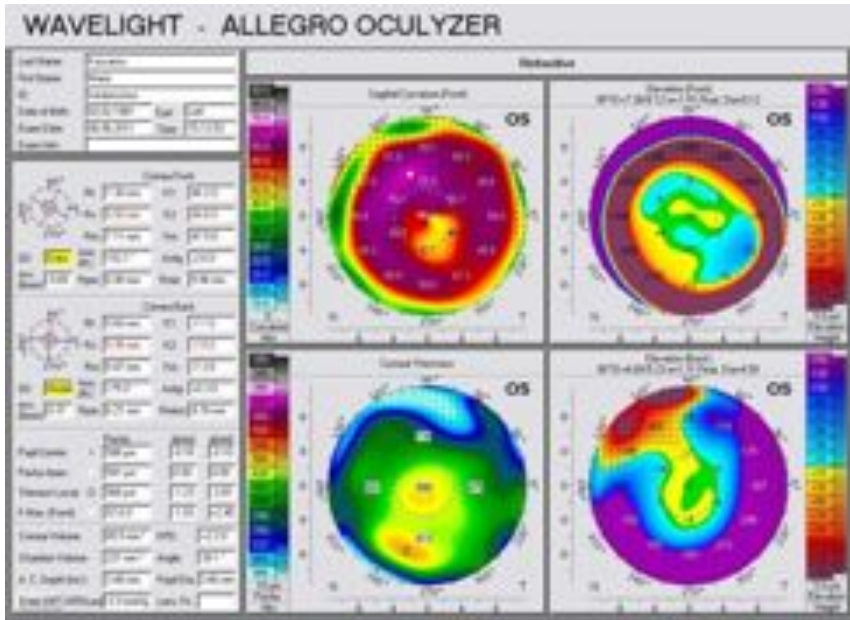
5m. Post DALK  
VAs CF  
Refr -11.75/-1.50 x 147



# Post DALK

1.5 yr post DALK

22 m. post DALK  
 Vas CF  
 Vac -10.75 / -3.75 x 115 5/10+



## OS T-ICL

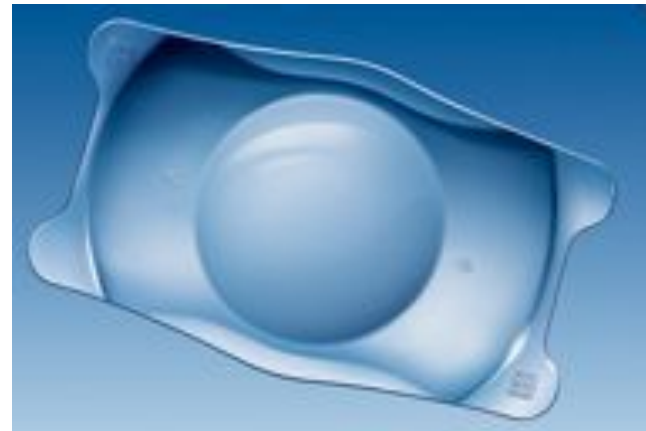
-15.5/+2.5/005

Toric ICL

Final refractive result

Vas 6/10+

Refr +0.25 / -1.00 x 140 no  
improvement

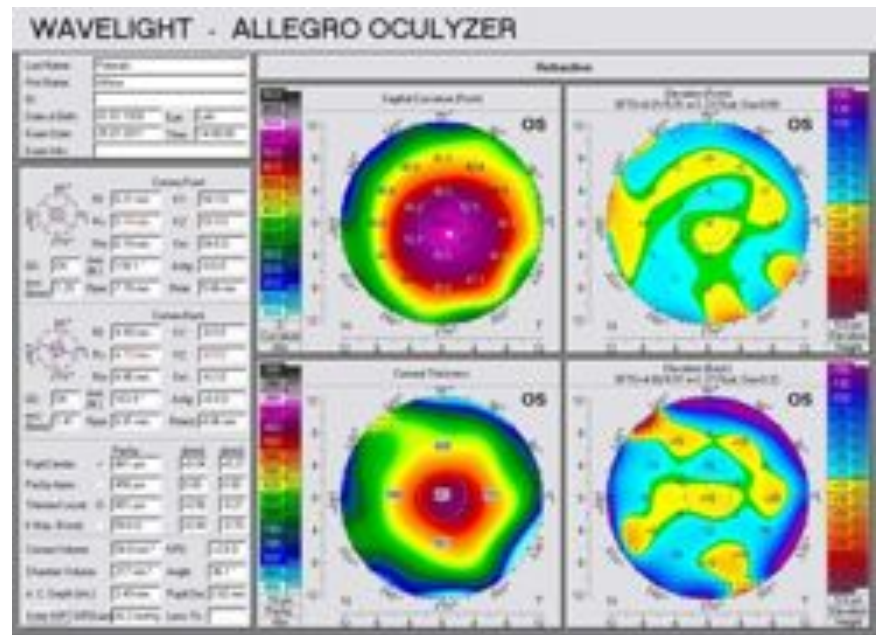


PA, (f), 33 yo

OS advanced central KC  
CCT 457

VAs CF

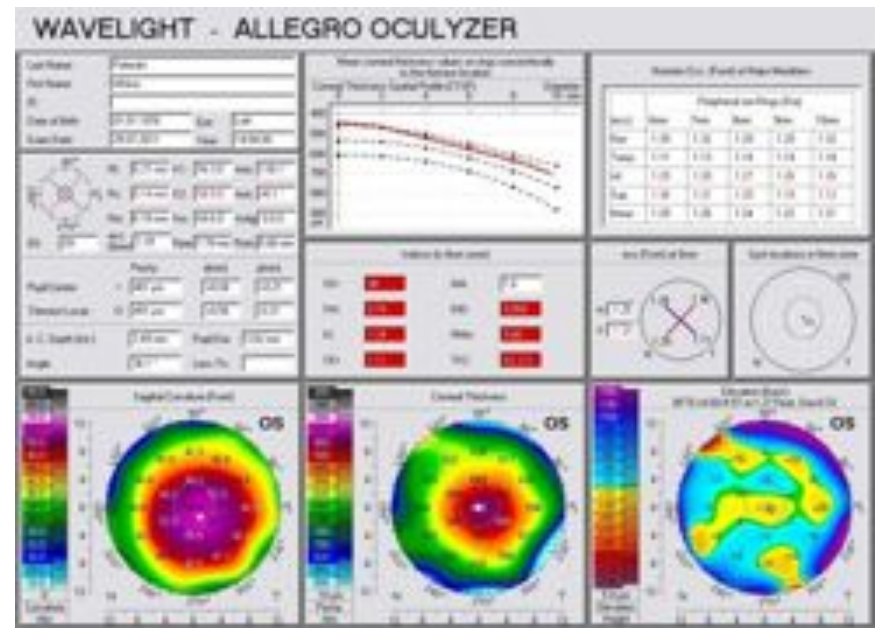
VAc -8.50/-0.50 x 10 7/10



Due to thin cornea + high refractive error

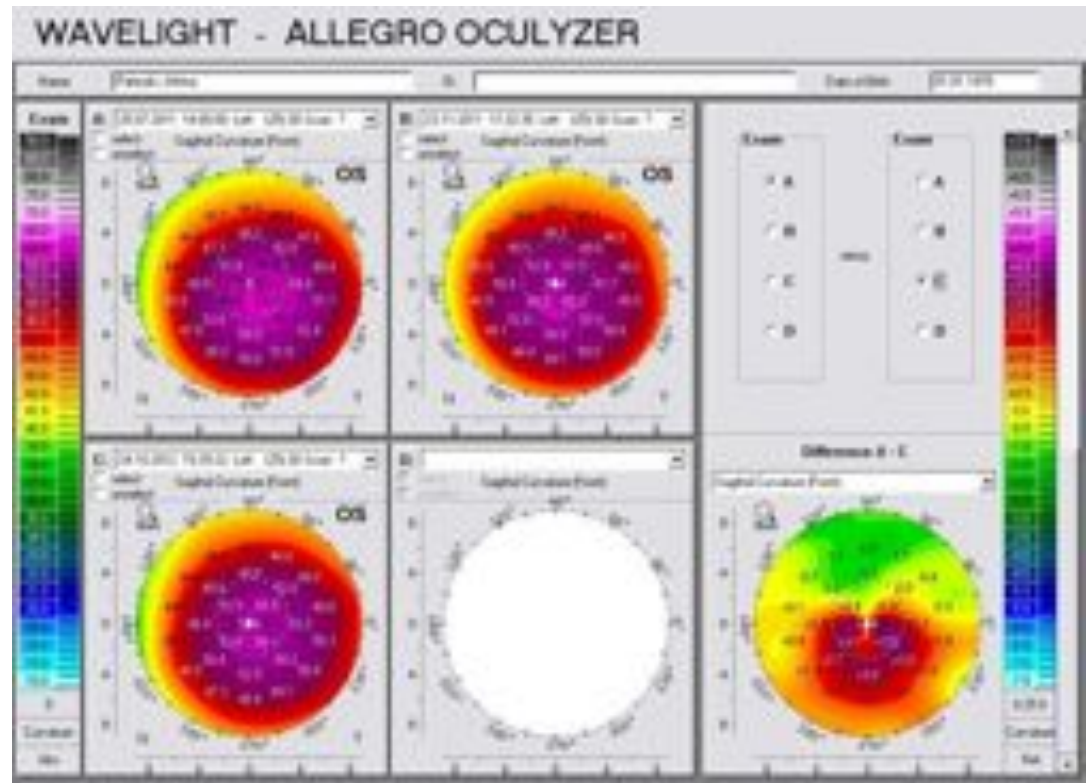
Decided upon

CXL only



## CXL result

Not real change to refraction



# ICL

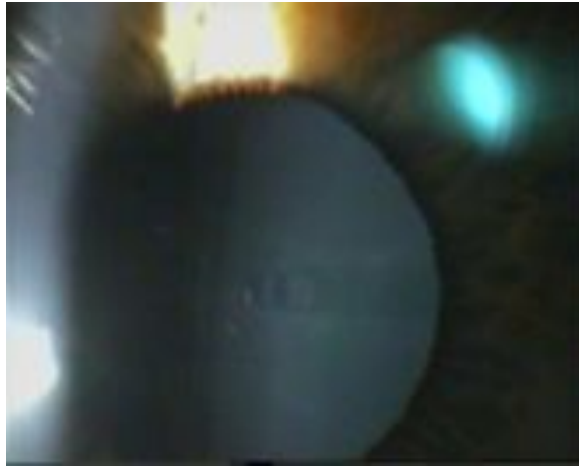
-8.00

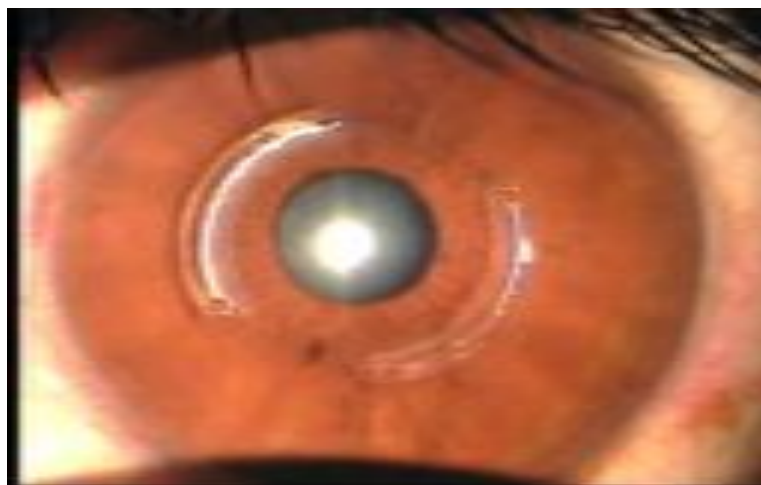
Diameter 12.6

1<sup>st</sup> postop day

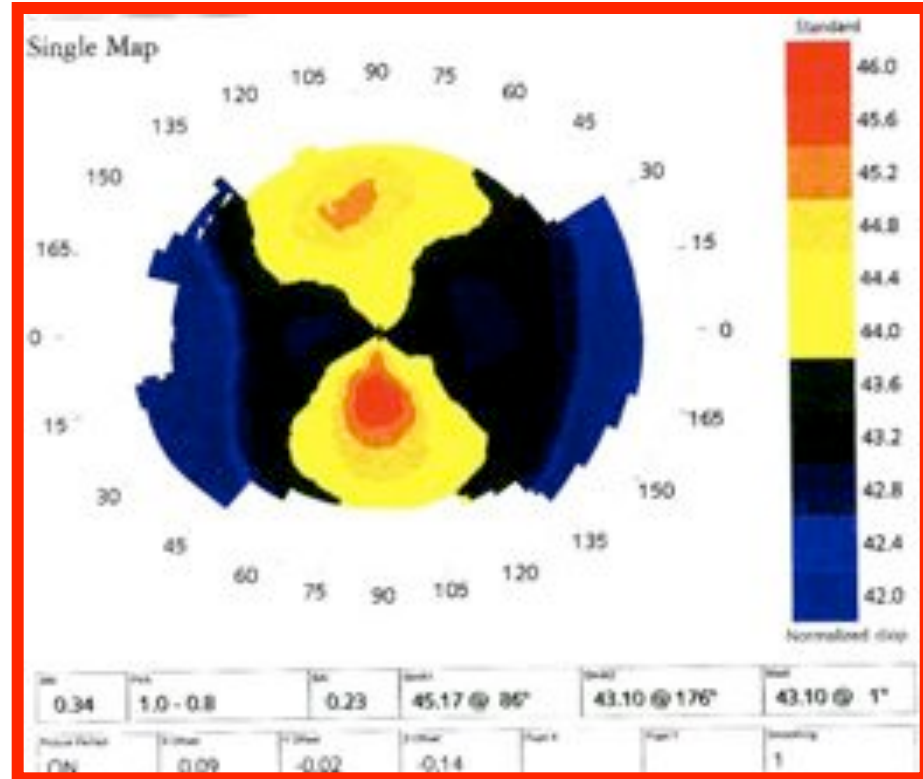
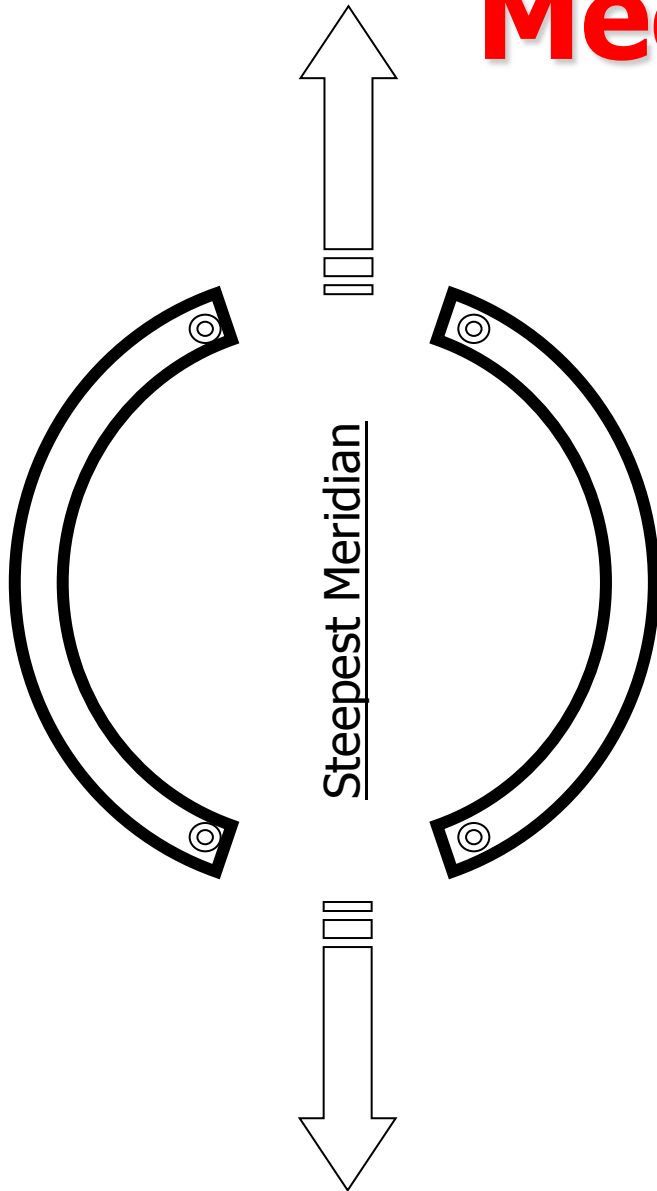
VAs 10/10

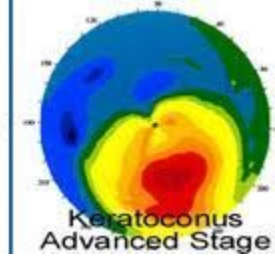
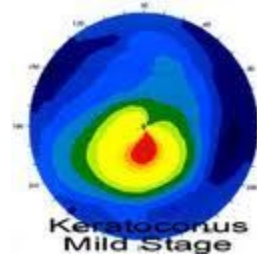
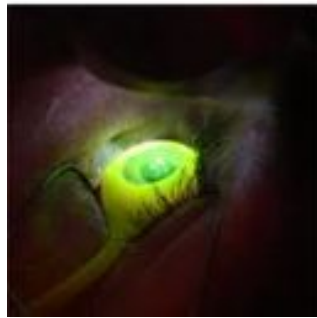
A/R -1.25 / -1.25 x 37





# Mechanism of Action





# Εξατομικευμένη

Διαθλαστική Χειρουργική στον  
Κερατόκωνο !!!

## Art & Science !!

Κ. Χ. Καραμπάτσας

MD, PhD, FEBO, MRCOphth, FRCS

Eye Institute