

# Topo-aberrometric, refractive and pachymetric analysis of Keratoconics eyes undergoing CXL

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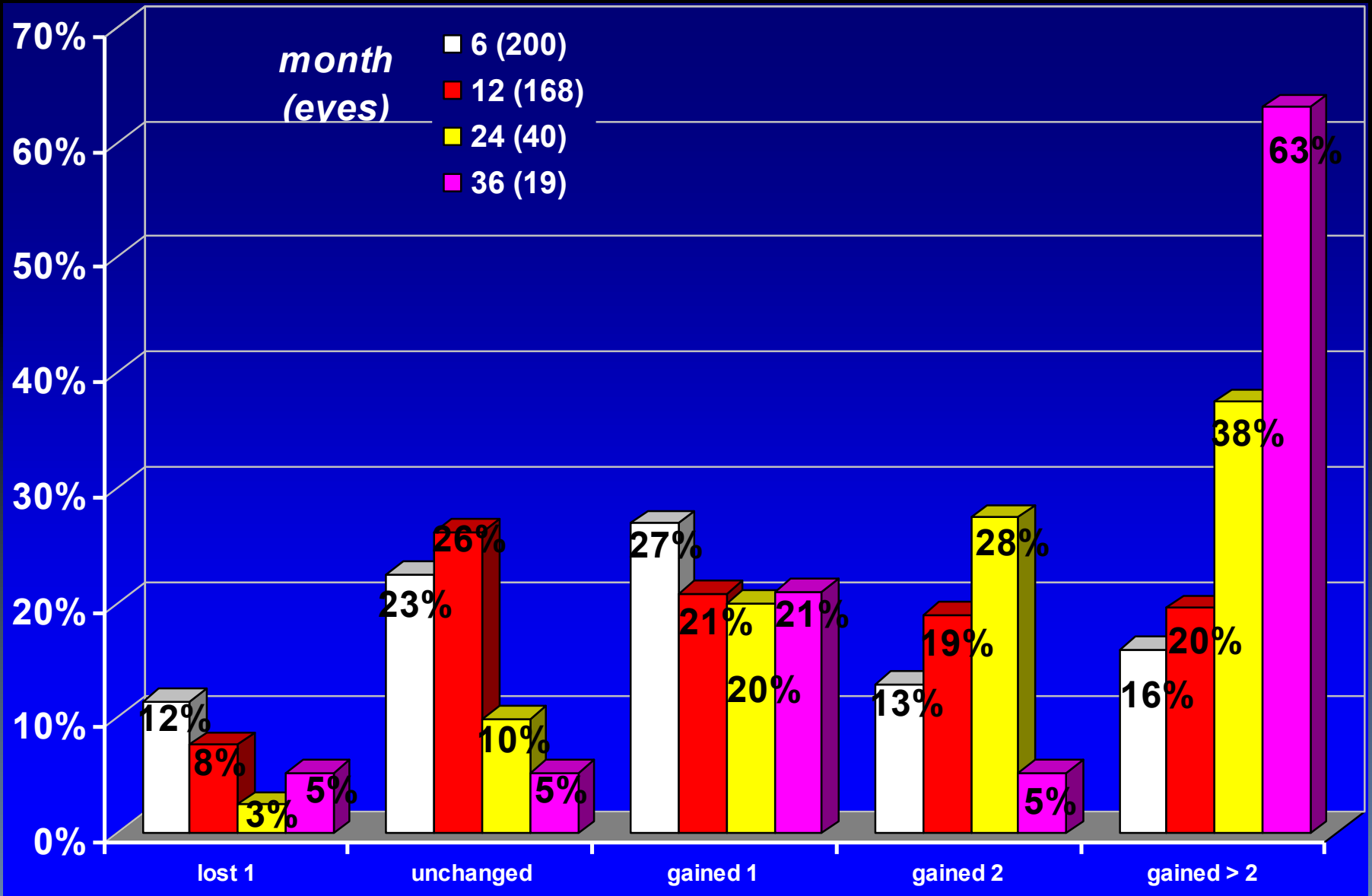
# Cross-linking (CXL) technique

- **2% Pilocarpine** drops (protection of lens and retina)
  - The light reaching the internal structures of the eye is decreased by the square of the reduction of the pupil diameter
    - (For example : a 6-mm pupil = 36 units, a 4-mm pupil = 16 units, 2-mm pupil = 4 units)
- Antipain meds 30 min before CXL.
- Oxybuprocaine hydrochloride 0.2% + Lidocaine 5 min before CXL.

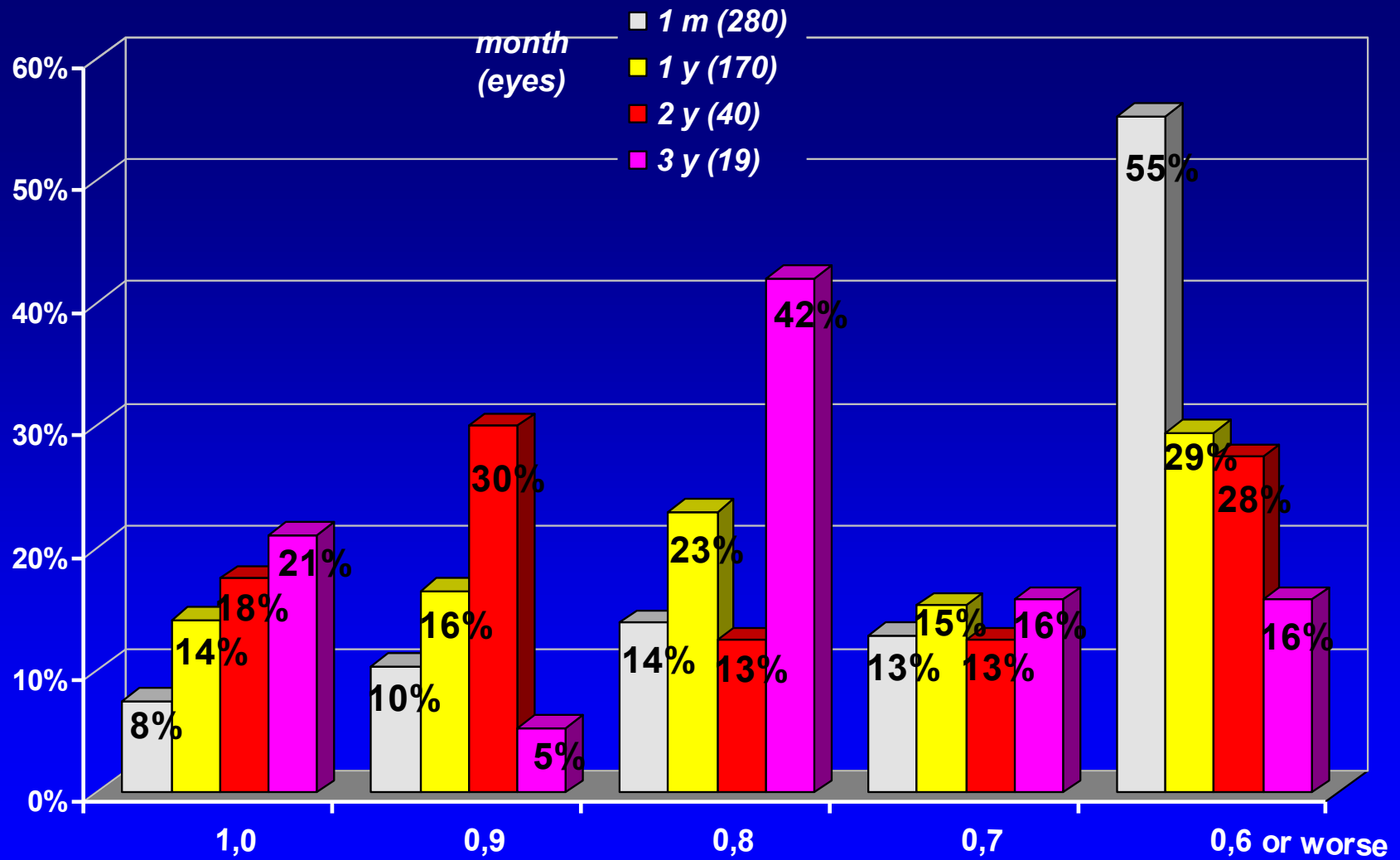
# Demographic

- 545 treated eyes
- Preop.evaluated eyes:344
  - 28 pediatric;
  - 21 ectatic (lasik,prk,intacs);
  - 3 PMD
- age@OP      average    30 years (from 10 to 67)
- sex          female      27,1% or 95 eyes
- male        72,4% or 254 eyes
- pre SR equiv: mean -3,95 D ± 4,35 D (from -24,75 to 5,50)
- pre SR sph:    mean -2,49 D ± 4,20 D (from -23,00 to 6,00)
- pre SR cyl:    mean -2,92 D ± 1,97 D (from -10,00 to 0,00)

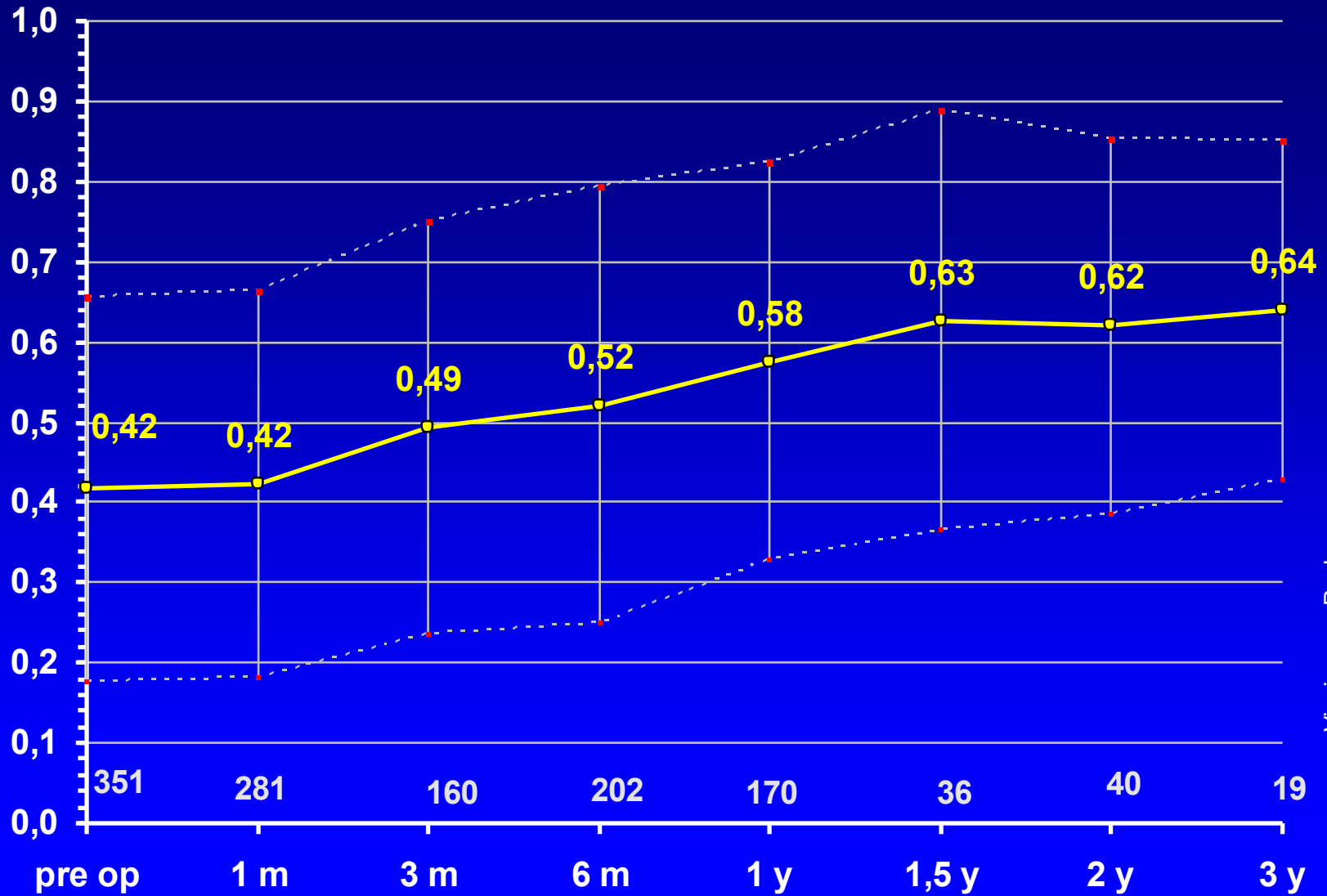
# Change in BSCVA - %“Safety”



# BSCVA - %



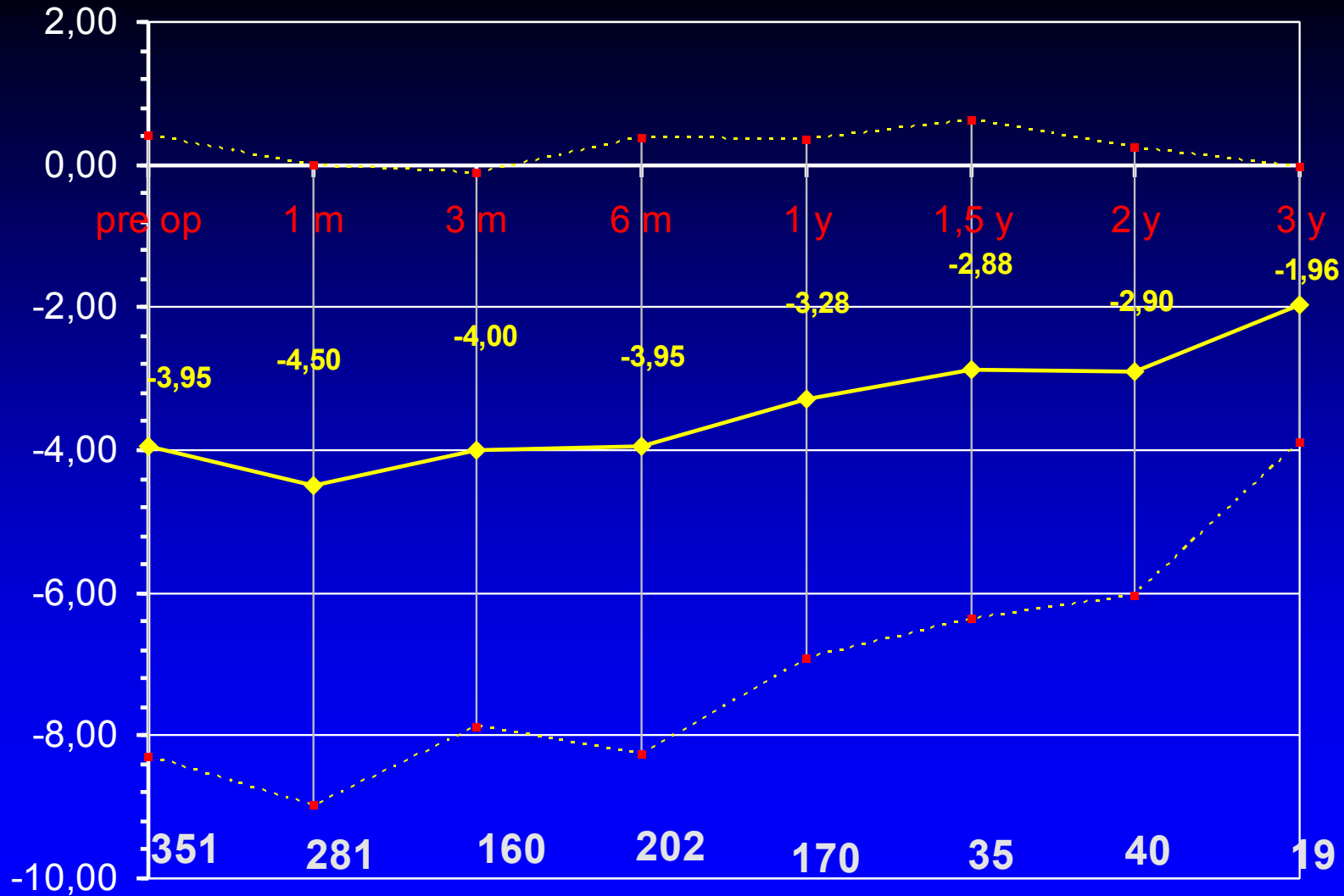
# BSCVA over time

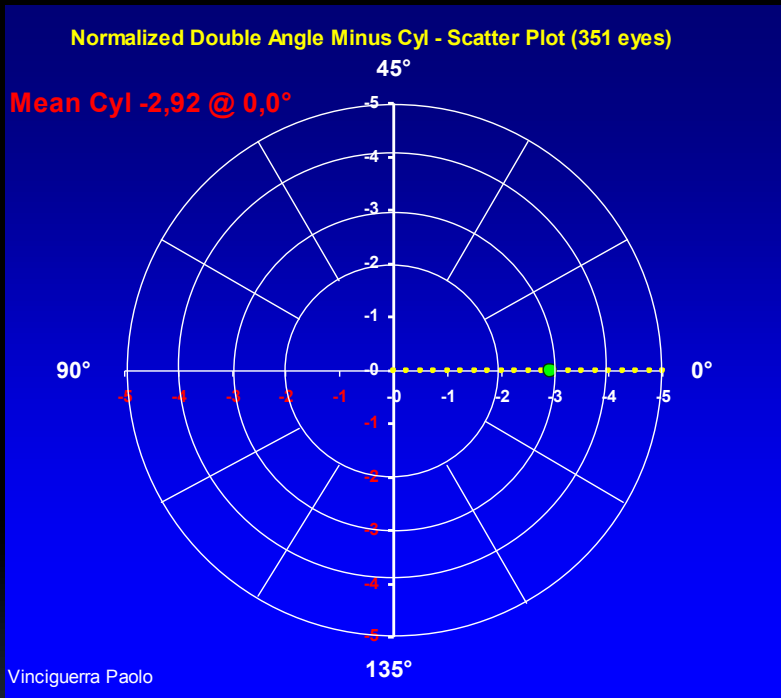


# Achieved Correction SEQ over time

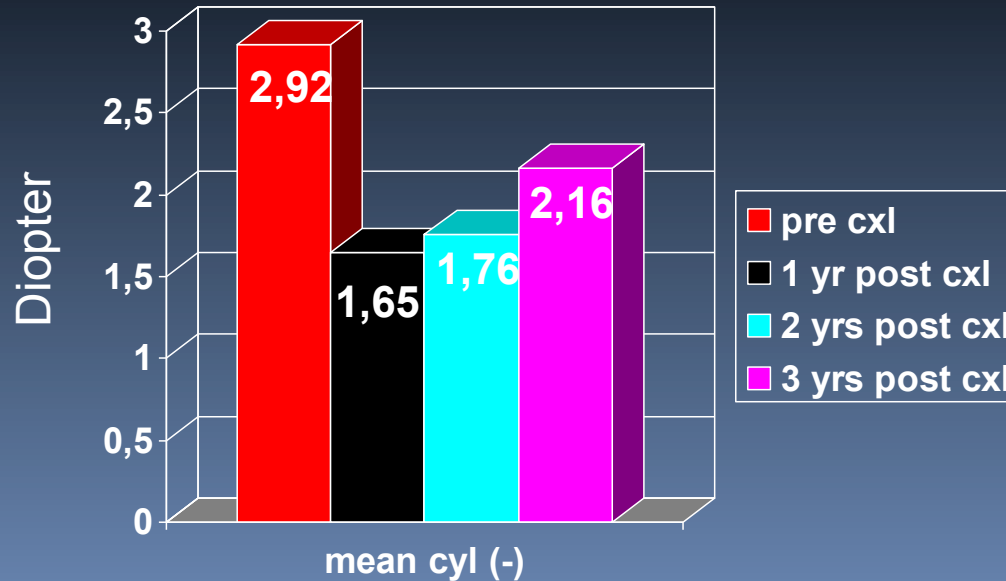
Diopeters

## “STABILITY”





	Mean cyl	@
Pre cxi	-2.92	0°
1 yr post cxi	-1.65	179.9°
2 yrs pos cxi	-1.76	2°
3 yrs post cxi	-2.16	177.7°

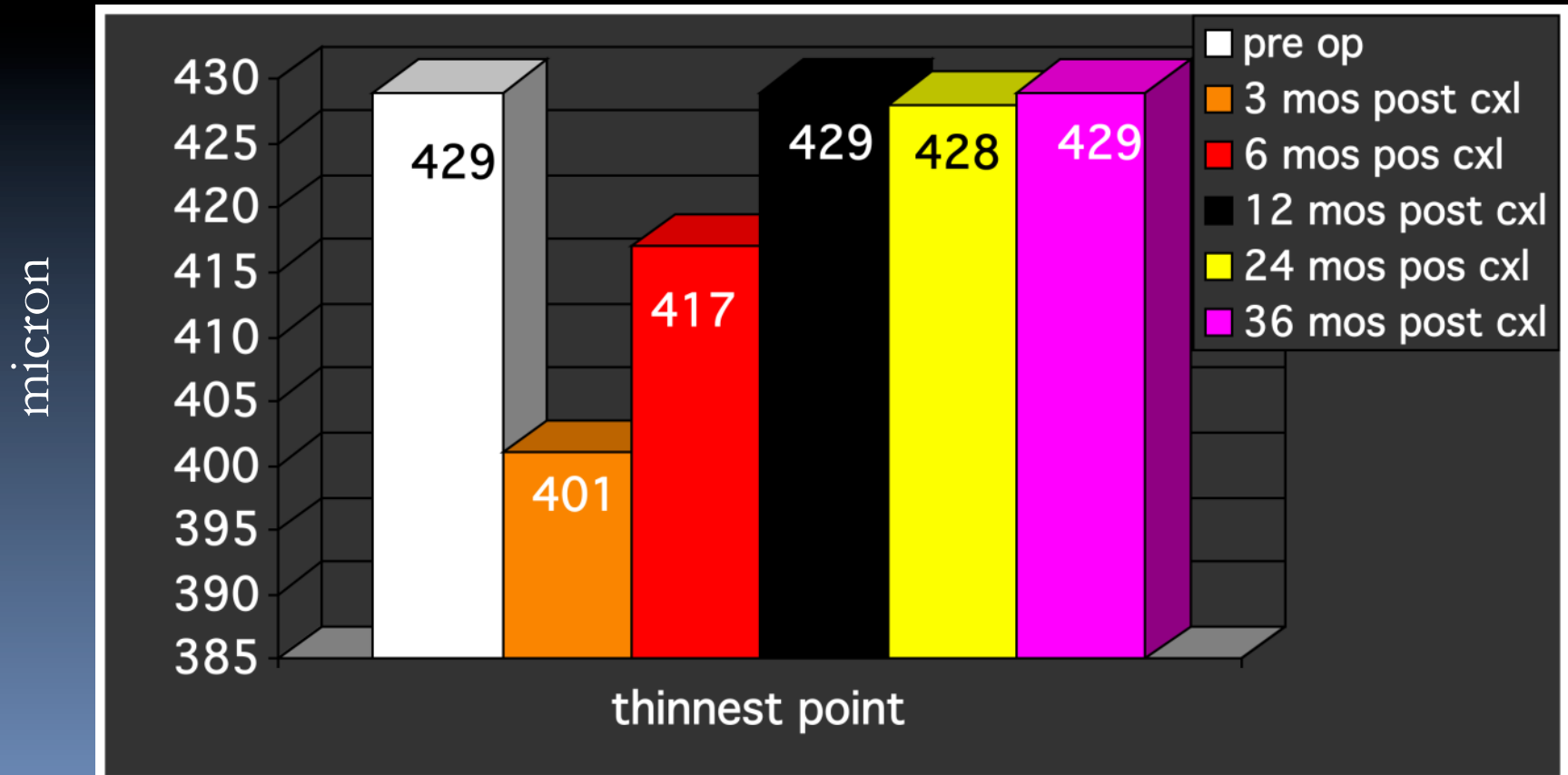




# Result pentacam--pachymetry

## THINNEST POINT

- PRE 429 ± 48.15 μm
- POST 3 m 401 ± 59.03 μm
- POST 6 m 417 ± 64.03 μm
- POST 12 m 429 ± 45.10 μm
- POST 24 m 428 ± 35.6 μm
- POST 36 m 429 ± 33.03 μm



# OPD CORNEAL NAVIGATOR

## KLYCE INDEXES

N = 351  
PRE

170  
POST 12 m

40  
POST 24 m

19  
POST 36 m

ACP	44.75	43.6	42.08	40,5
CYL	2,57	1.98	1.75	1,68
CVP	73.14	60.12	57	55
SDP	4.12	2.7	2.5	1,9
AA%	85,68	82.75	80.03	78,2
CEI	0,37	0.1	0.09	0,06
LogMAR	0,17	0.1	0.14	0,09
DSI	8,7	5.9	5.5	4,9
SRI	1.34	1.22	1.21	1,19
SRC	1,19	1.10	1.07	1,02
SAI	1,88	1.3	1.26	1,26
IAI	5,86	0.56	0.58	0,58
OSI	7,18	4.2	3.95	3,94
CSI	0.9	0.02	0.03	0,02
KCI	8,9	0.25	0.24	0.23
KPI	0,43	0.27	0.28	0.25
EDP	2,67	2.40	2.45	2.39
EDD	10.01	6.5	5.1	4,9

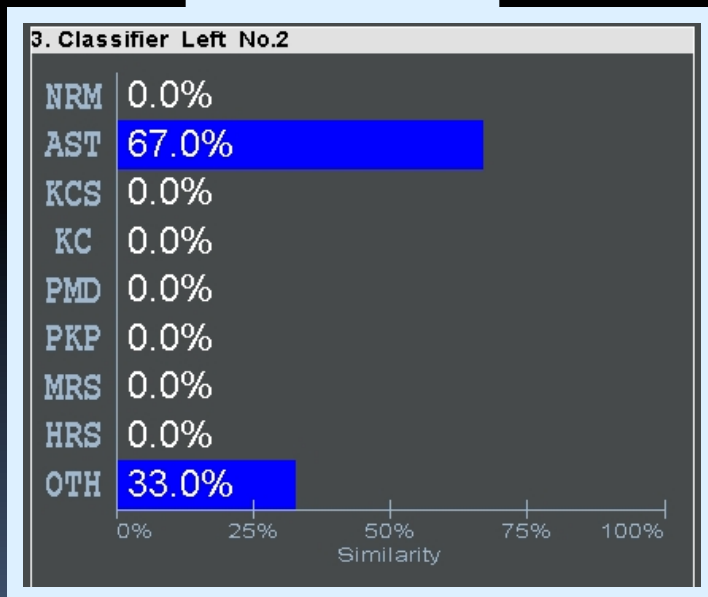
IMPROVED

UNCHANGED

WORSED

# Topo classifier map

## GRAFICA



## Klyce classification

NRM (Normal): Emmetropia (0.5 D or less of astigmatism)

AST (Astigmatism): Eye with astigmatism exceeding 0.5 D

KCS (Keratoconus suspect)

KC (Clinical Keratoconus)\*<sup>1</sup>: Conical Cornea

PMD (Pellucid Marginal Degeneration)

PKP (Penetrating keratoplasty)

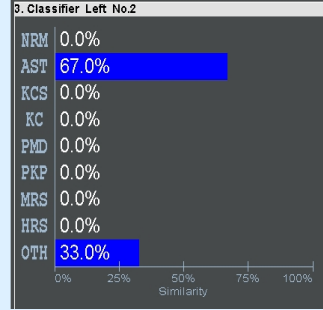
MRS (Myopic Refractive Surgery): Myopic refractive surgical correction

HRS (Hyperopic Refractive Surgery): Hyperopic refractive surgical correction

OTH (Unclassified variations): Others

Le classi di probabilità sono ottenute da una correlazione tra indici cheratometrici e le corrispondenti patologie o distrofie corneali, e sono **basate** sulle deviazioni standard provenienti dalla rete neurale Nidek.

# OPD corneal navigator %



	KCS	KC	PMD	PKP	KSI
PRE XL (351)	6,64	32.03	15,10	0	17,33
POST 3 M (160)	9.72	32.6	12,1	0	12
POST 6 M (202)	0	32	0	0	23
POST 1 Y (170)	<b>0,3</b>	35.95	<b>0</b>	<b>0</b>	<b>5.03</b>
POST 2 Y (40)	0.27	34.78	0	0	3.79
POST 3 Y (19)	<b>0.18</b>	<b>35.2</b>	<b>0</b>	<b>0</b>	<b>3.7</b>

# Ambrosio's Indexes

Indices (in 8mm zone)			
ISV:	16	IHA:	3.3
IVA:	0.07	IHD:	0.007
KI:	1.00	RMin:	7.12
CKI:	1.01	TKC:	-

- **ISV**: index surface variance—*this index is elevated in all types of irregularity of the corneal surface (astigm, warpage, kc, etc).*
- **IVA**: *Ind of vertical Asymmetry: this index is elevated in case of oblique astigmatism, in kc or in ectasiae*
- **KI**: *kc index*
- **CKI**: *center keratoconus index: increases with severity of central kc*
- **IHA**: *ind of Height Asimmetry: this index is analogous of IVA, this index but it is more sensitive*
- **IHD**: *index of Height Decentration is elevated in keratoconus*
- **Rmin**: *Minimum Sagittal curvature in 8 mm-zone*
- **TKC**: *topographical Keratoconus Classification only based on anterior corneal data*

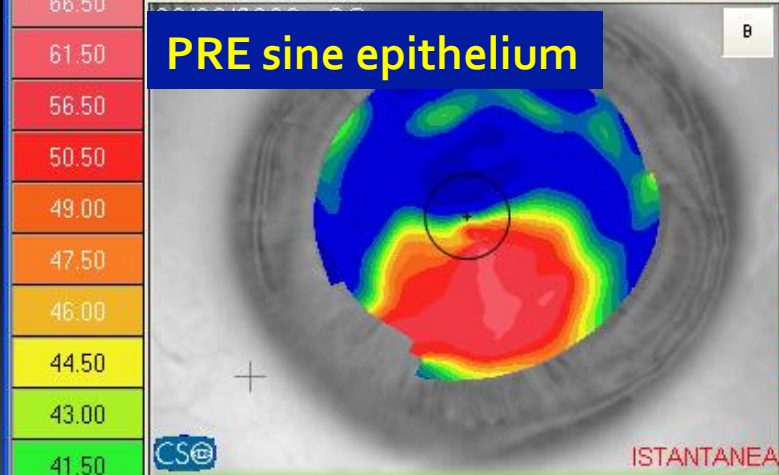
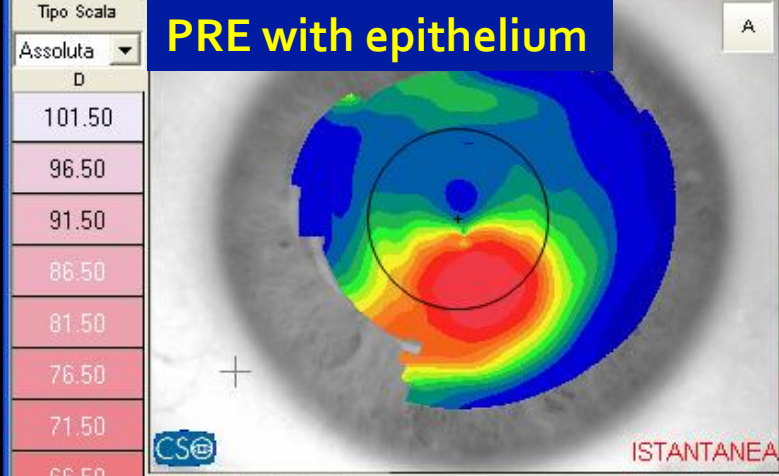
# Indici di Ambrosio

	isv	iva	ki	cki	iha	ihd	rmin
PRE CXL	77,4	0,78	1,13	1,02	19,12	0,08	6,57
POST 3 mos	79,0	0,8	1,17	1,12	19,1	0,065	6,66
POST 6 mos	86	1,19	1,07	0,89	19,6	0,075	6,67
POST 1 yrs	<b>61,27</b>	<b>0,76</b>	<b>1,09</b>	1,01	<b>14,56</b>	<b>0,04</b>	6,89
POST 2 yrs	<b>59.07</b>	<b>0.55</b>	<b>1.03</b>	1.02	<b>13.12</b>	<b>0.023</b>	5.9
POST 3 yrs	<b>52,9</b>	<b>0.38</b>	<b>0.76</b>	<b>0.87</b>	<b>11.5</b>	<b>0.020</b>	<b>5.6</b>

# Intra-operative findings

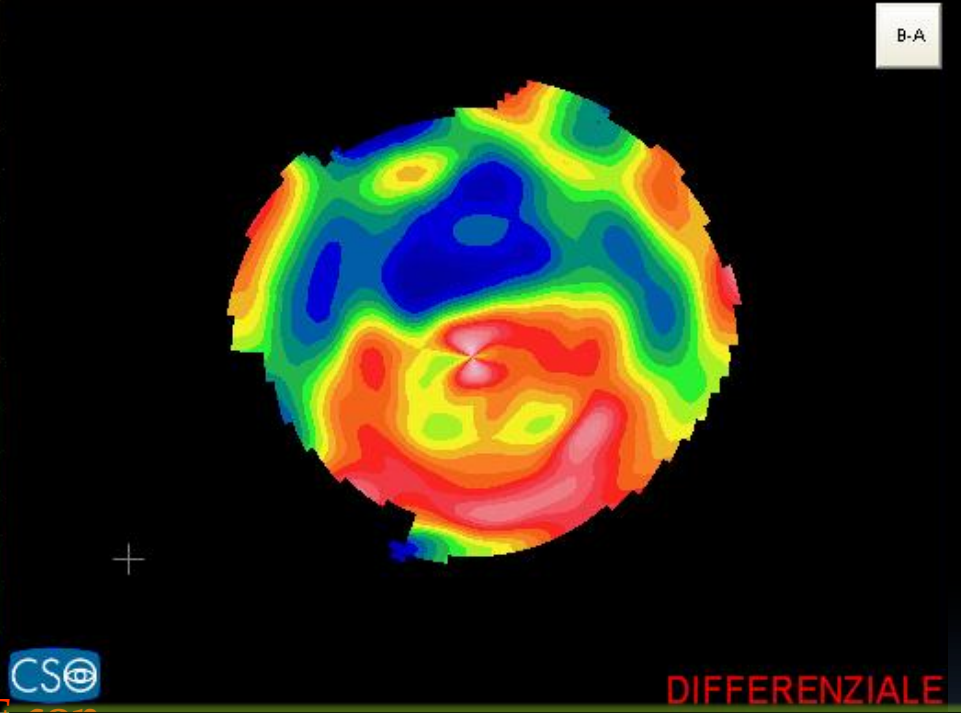
## Why dealing with intra-operative findings?

- To understand the real shape of the cornea without the masking effect of the epithelium
- To determine the changes occurring after epithelial removal
- To document the changes induced by CXL
- To explain why topography and BCVA do deteriorate during the first 3 months after CXL



Keratoconus eye during CXL

15.00
14.00
13.00
12.00
11.00
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
-1.00
-2.00
-3.00
-4.00
-5.00
-6.00
-7.00
-8.00
-9.00
-10.00
Media
0.00
Passo
1.00
Applica



Note the increased power and diameter of the cone and the flattening of the surrounding area



Tipo Scala

Assoluta

D  
101.50

96.50

91.50

86.50

81.50

76.50

71.50

66.50

61.50

56.50

50.50

49.00

47.50

46.00

44.50

43.00

41.50

40.00

38.50

37.00

35.50

29.00

24.00

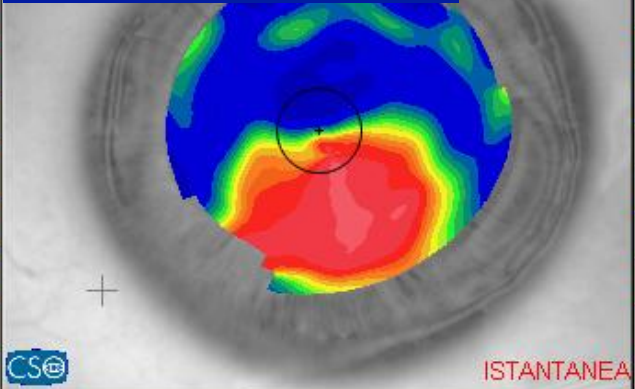
19.00

14.00

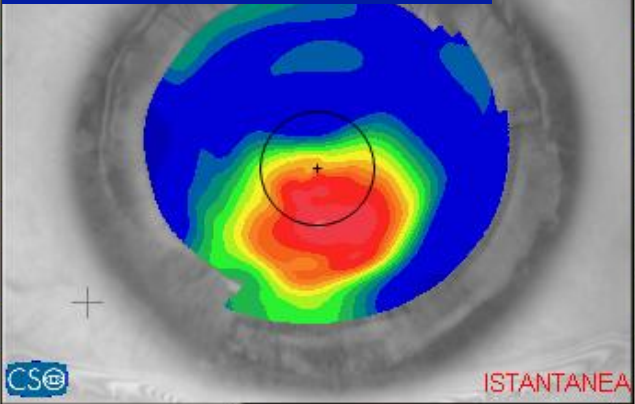
9.00

# Keratoconus eye during CXL

## PRE sine epithelium



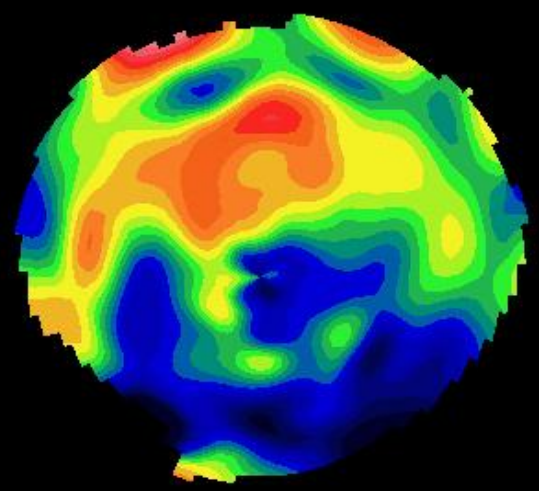
## POST sine epithelium



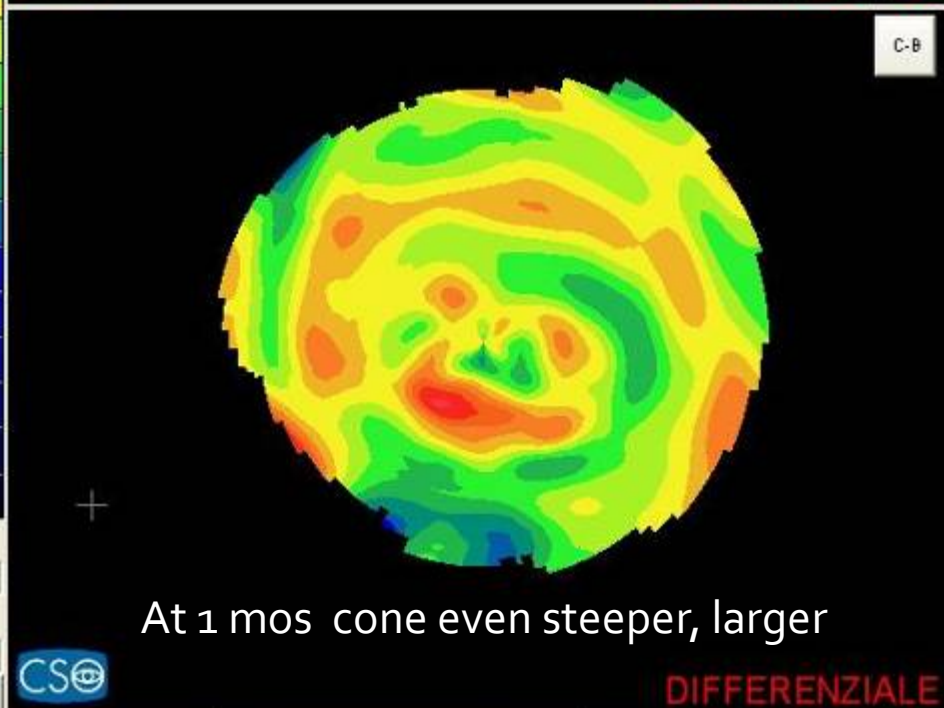
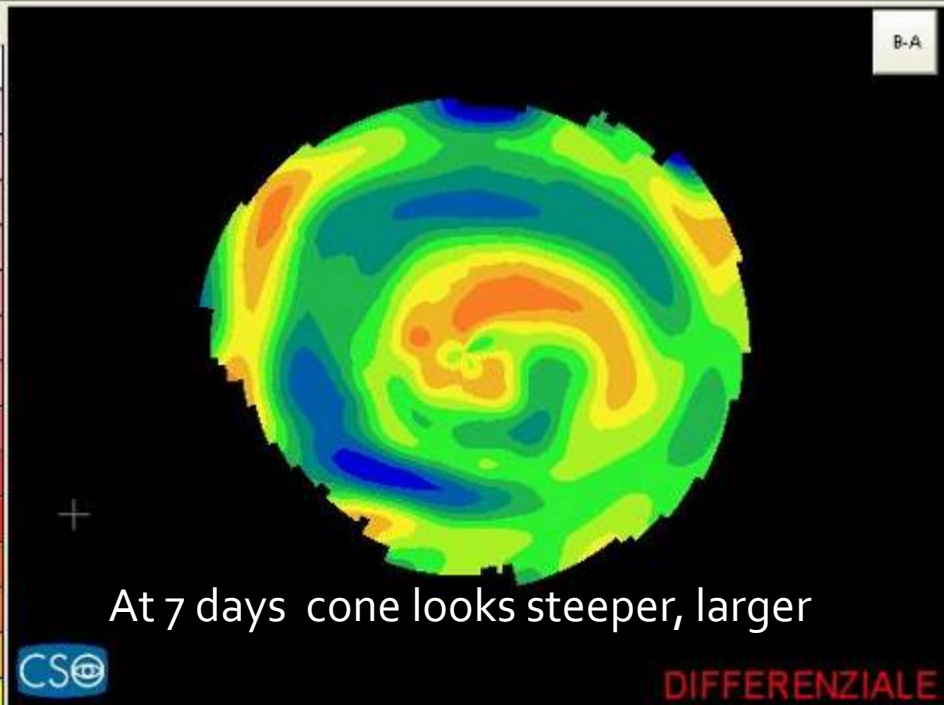
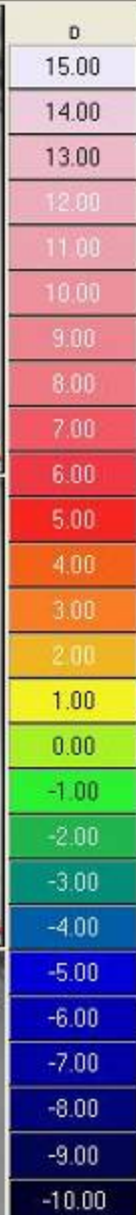
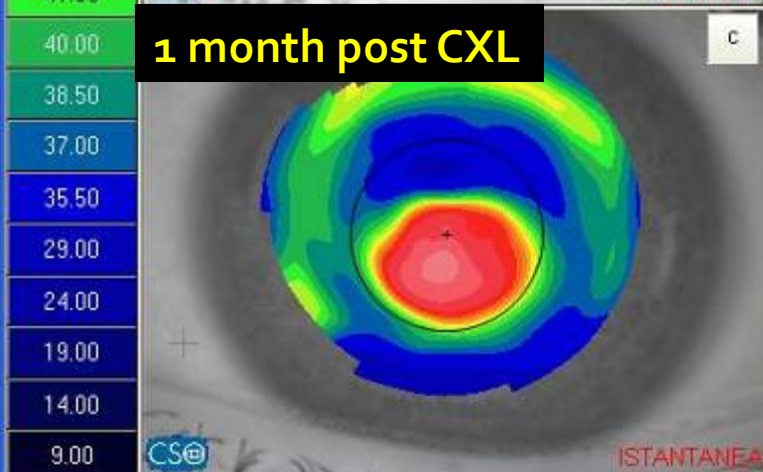
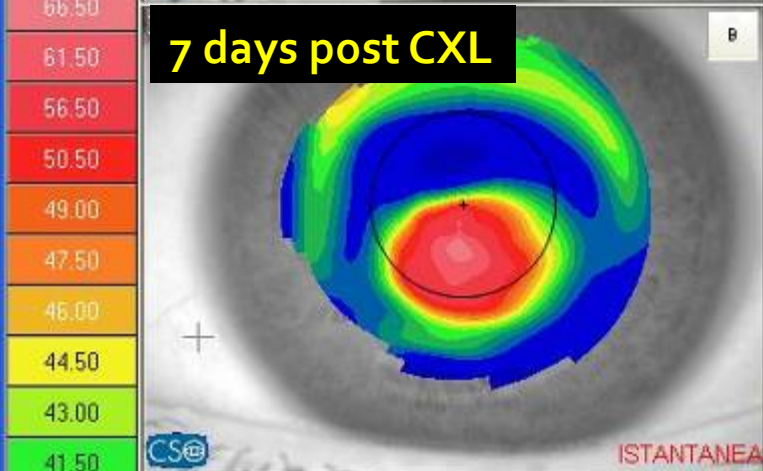
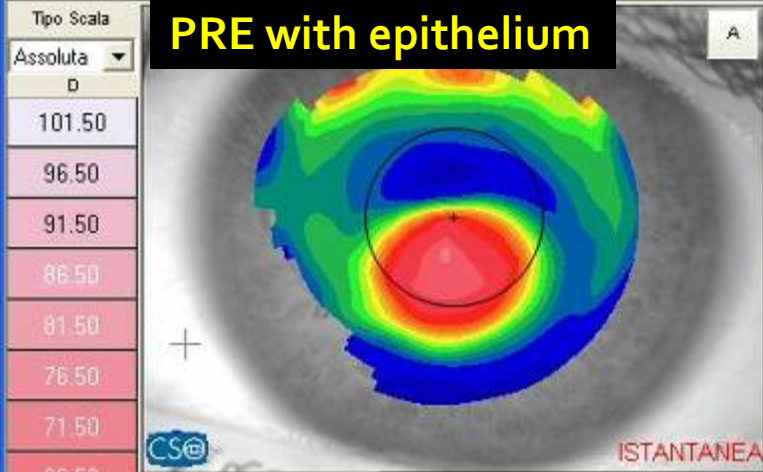
Note the decreased power and diameter of the cone and the steepening of the surrounding area immediately **after** CXL

PRE

C-B



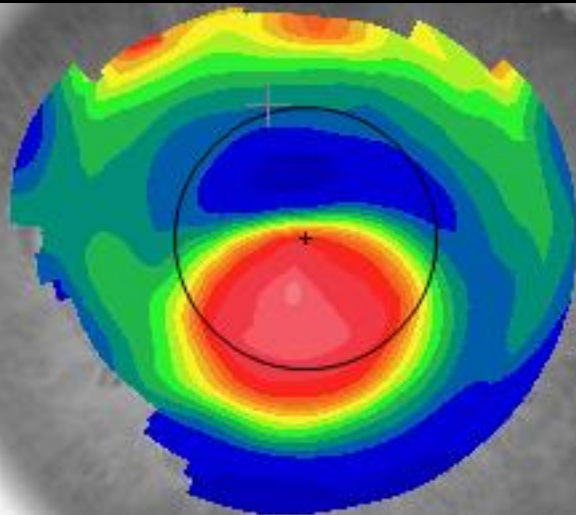
DIFFERENZIALE



At 7 days cone looks steeper, larger

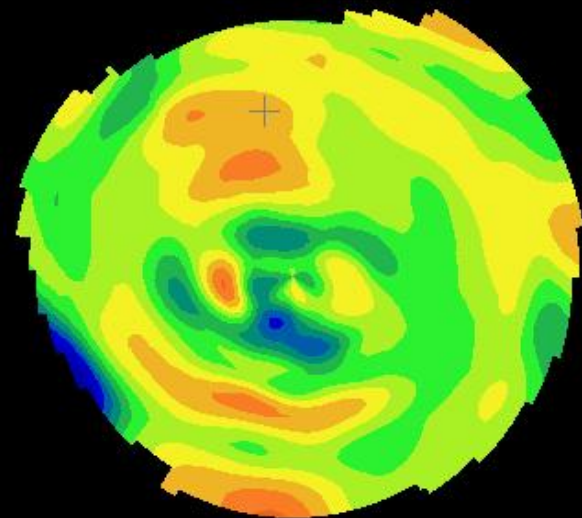
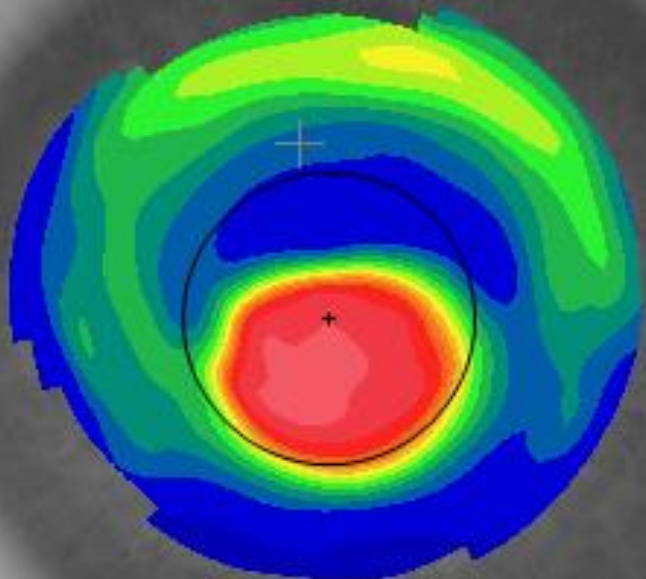
At 1 mos cone even steeper, larger

# PRE with epithelium



ISTANTANEA

3 mos after CXL



DIFFERENZIALE

Now first signs of flattening/shrinkage

Tipo Scala  
Assoluta  
D

101.50
96.50
91.50
86.50
81.50
76.50
71.50
66.50
61.50
56.50
50.50
49.00
47.50
46.00
44.50
43.00
41.50
40.00
38.50
37.00
35.50
29.00
24.00
19.00
14.00
9.00

C-B

# Why these late cone changes?

- The epithelium in a keratoconic cornea is arranged according to the law of surface tension: thinner at the apex and thicker at the edge of the cone
- This masks the real ( keratoconic) shape of the stroma

# Other intra-operative findings

- Apparent corneal thinning
- Biomechanical changes

# BSCVA is better even if there is an apparent corneal thinning

pre cxi

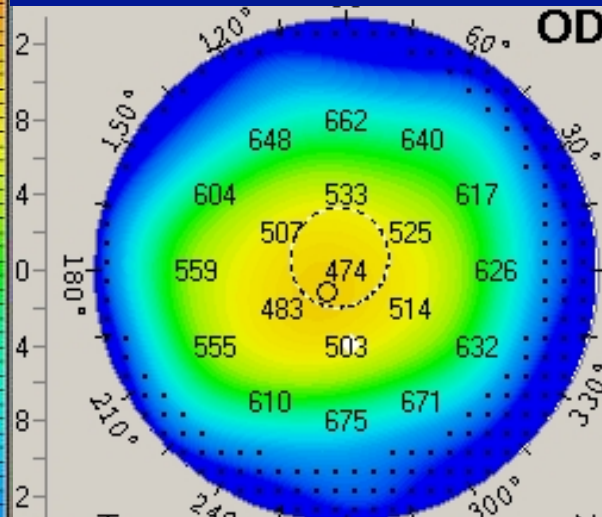
0,8 -1,25@94

1 mos post cxi

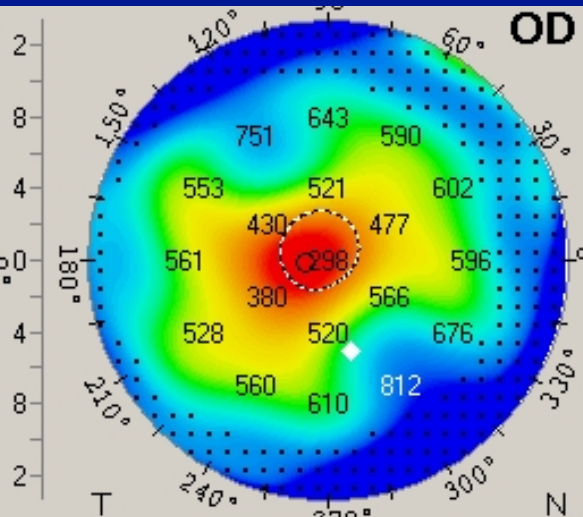
0,6 +7,00 -1,00@90

6 mos post cxi

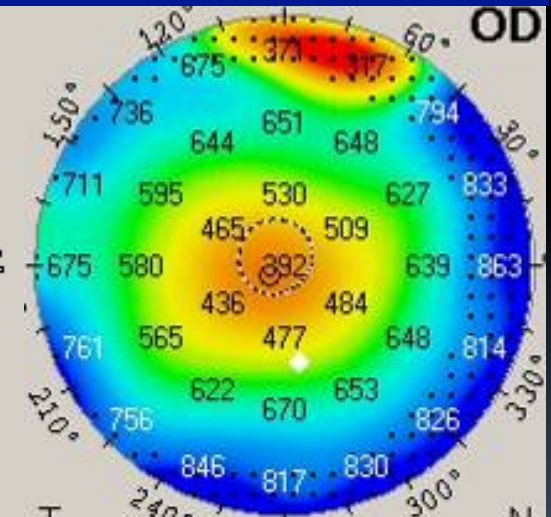
0,9 nat



474  $\mu$



-176  $\mu$



+94  $\mu$

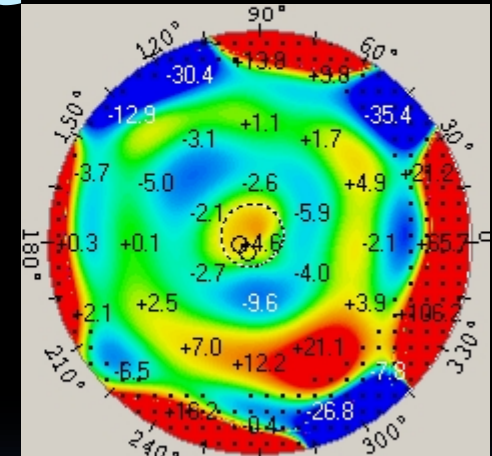
10  $\mu$ m

Pachmetria

Abs

# Reduction of the area/power of the keratoconus overtime

**Differential tangential map: -9.6 D**



pre cxl

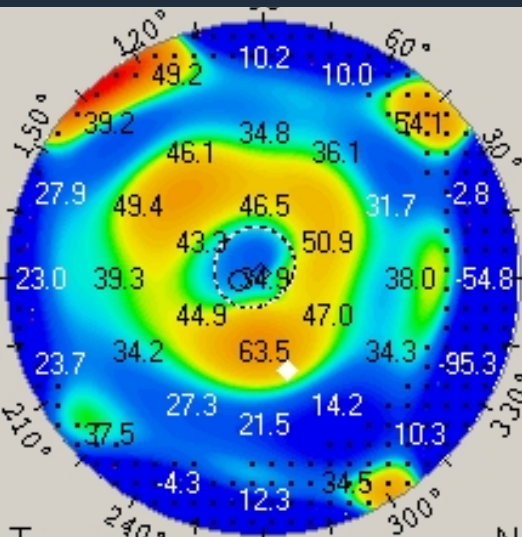
**0,8** - 1,25@94

1 mos post cxl

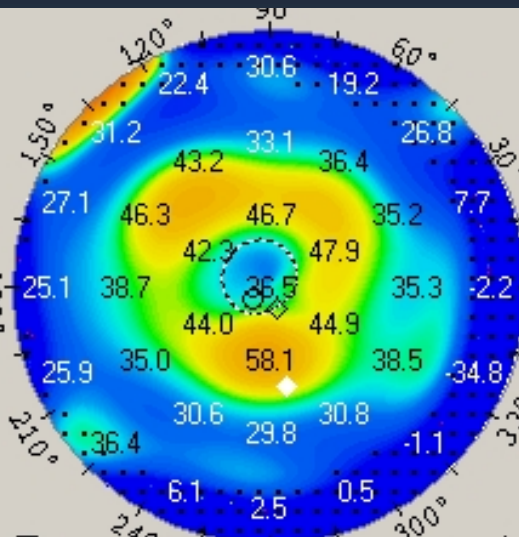
**0,6** +7,00 -1,00@90

6 mos post cxl

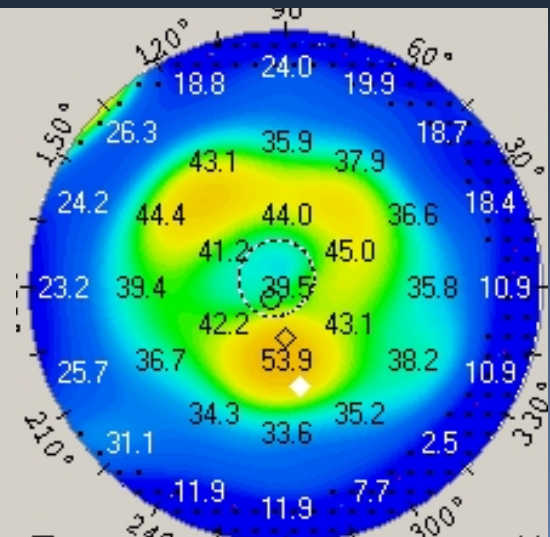
**0.9** nat



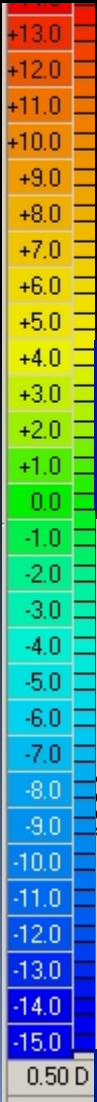
**+63.5 D**



**+ 58 D (-5.4 D)**



**+53.9(-9.6 D)**

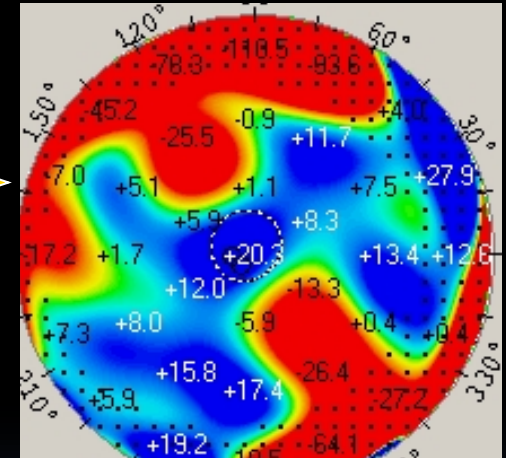


# Pachymetry distribution 6 mos after CXL

Differential Pachymetry relative map



**+22.8%**



pre cxl

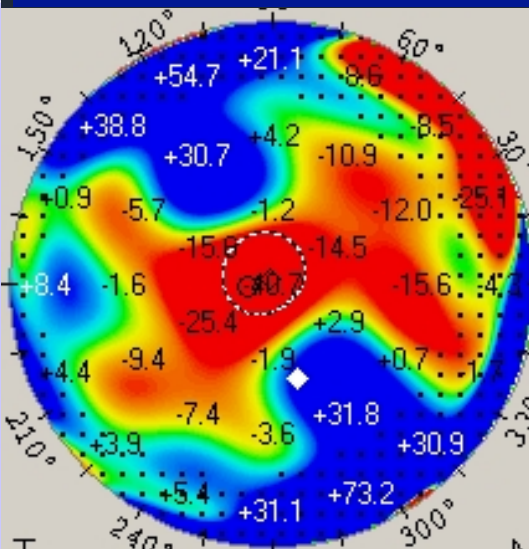
**0.8** -1.25@94

1 mos post cxl

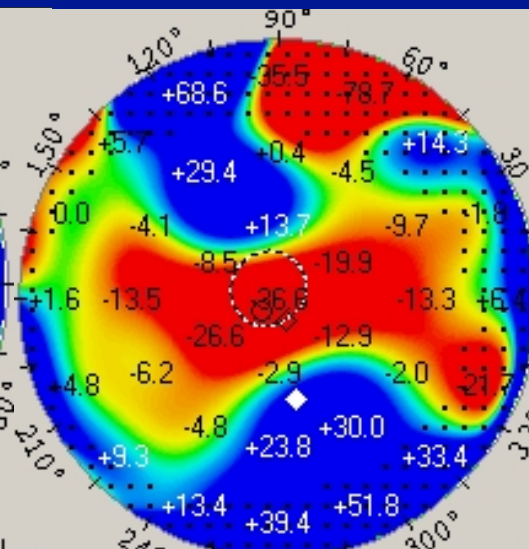
**0.6** +7.00 -1.00@90

6 mos post cxl

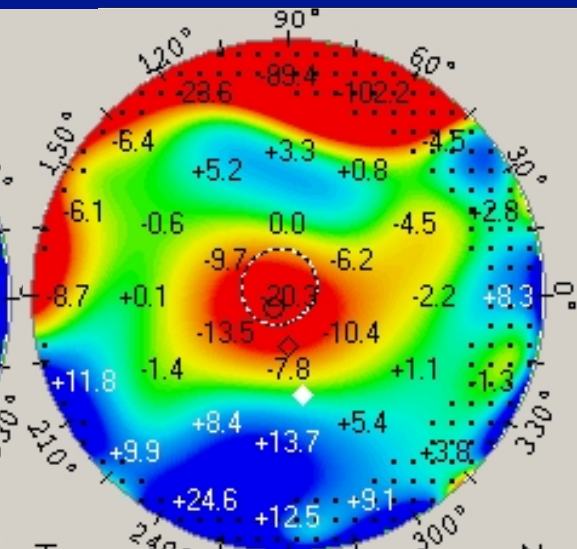
**0.9** nat



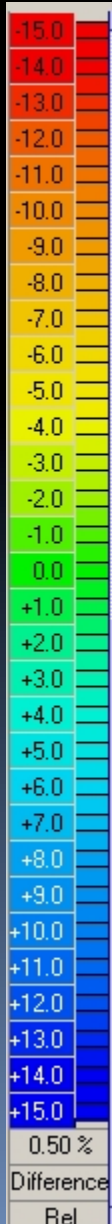
**- 44.20 %**



**-38.4 % (+ 5.8 %)**

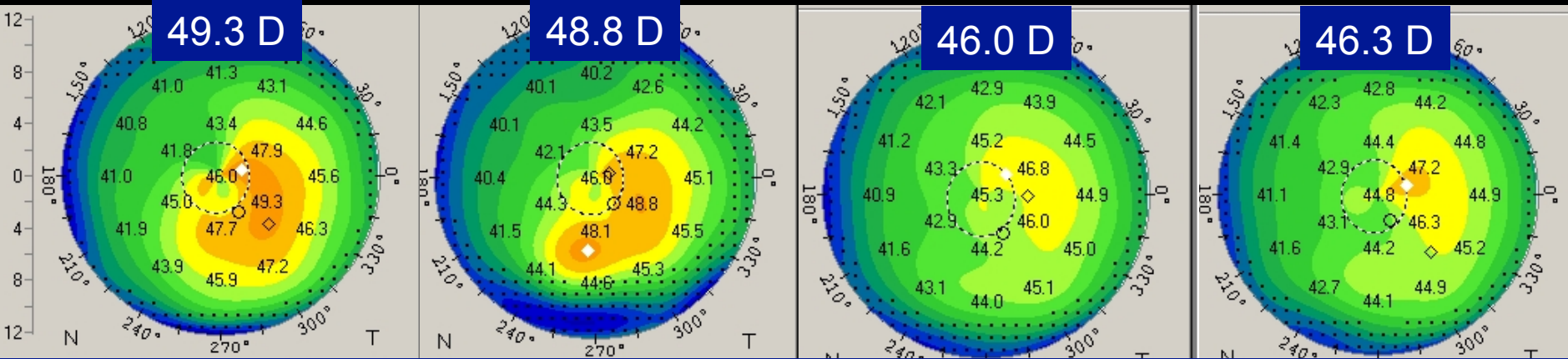


**-21.4 % (+ 22.8%)**





# Reduction of the TRUE NET power of the keratoconus overtime

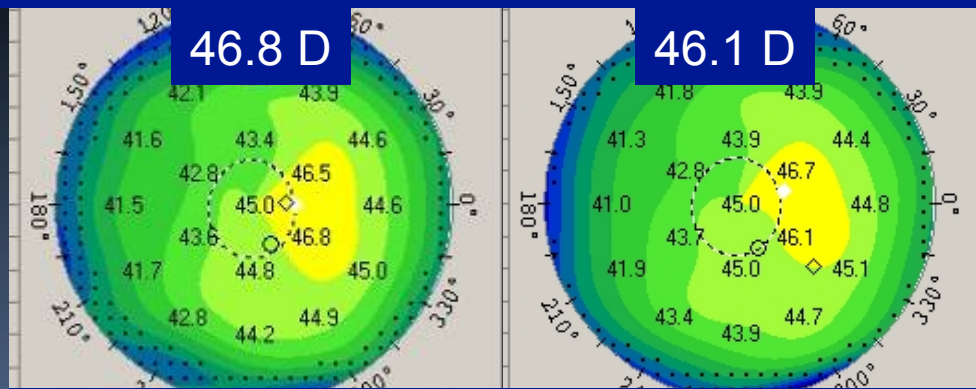


Pre op cxi

1 mos post cxi

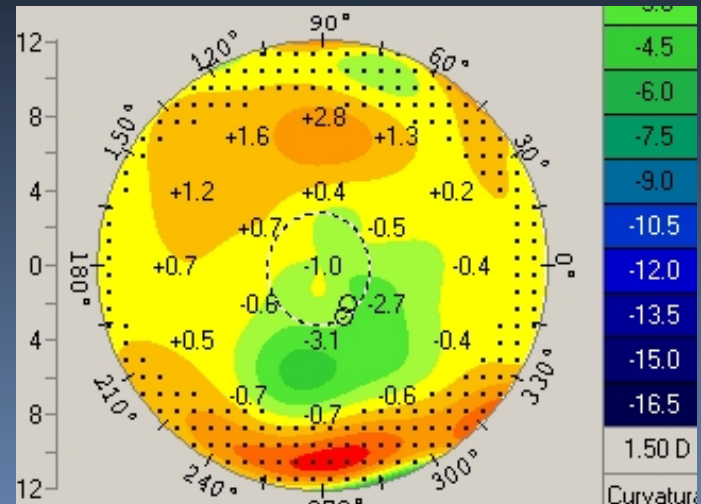
3 mos post cxi

6 mos post cxi



12 mos post cxi

24 mos post cxi



Differential map from pre op cxi to 2 yrs post cxi

pt n° 75

# Apparent corneal thinning

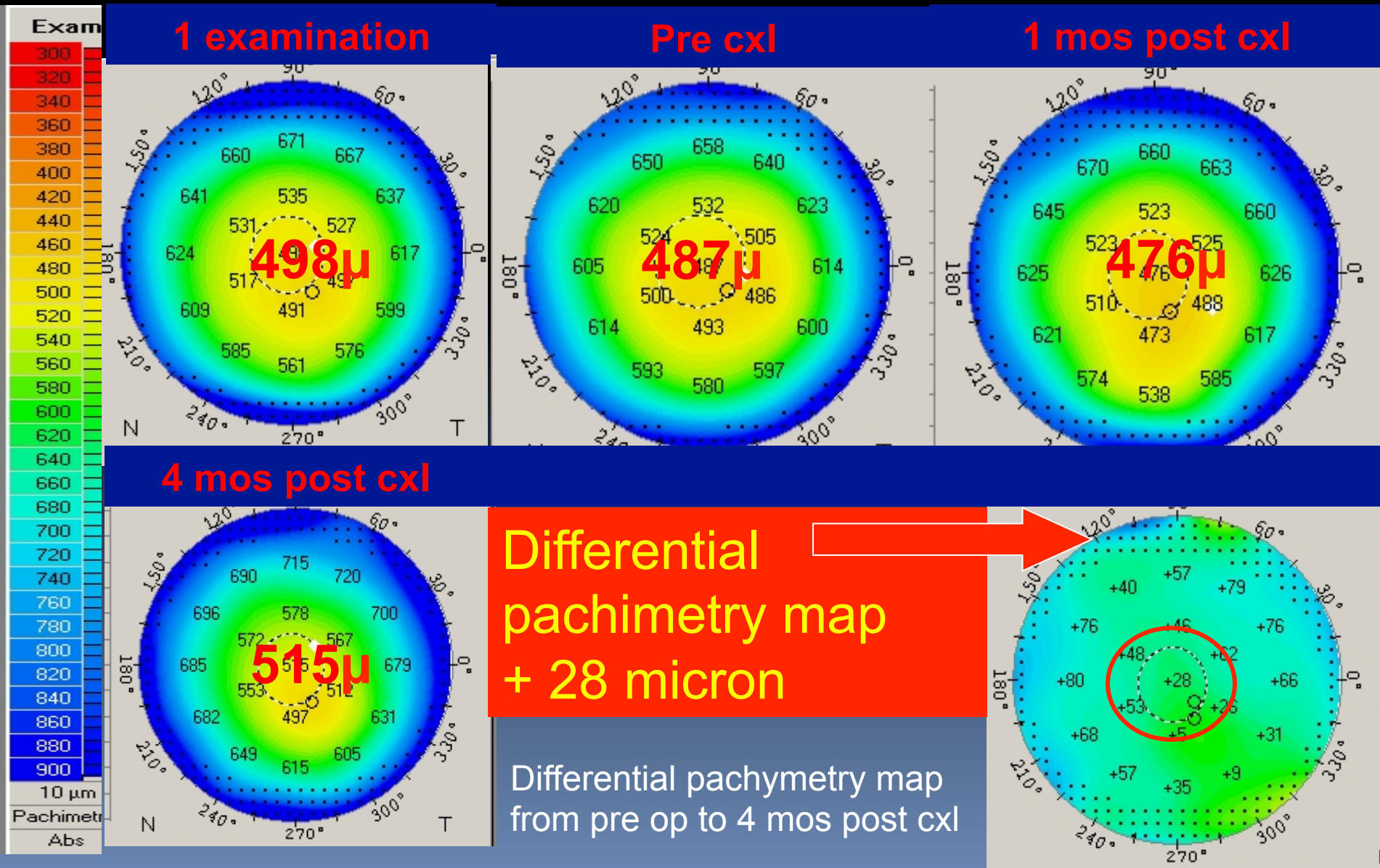
**“Thinning” is only temporary because:**

- **Riboflavine solution contain dextrane that together with the exposure to air of the denuded cornea dehydrates the stroma**
- **Collagen fibers and lamellae are packed by CXL**

# Corneal thickness normalization

- Epithelium takes weeks to return to normal thickness
- Stroma rehydrates
- Increase of fiber diameter due to CXL
- Corneal thickness can even increase with time (1-2 years)
- Pachymetry map shows a more physiological distribution with time

# Return to normal thickness: minimal thickness decrease (-9 $\mu$ ) and early regularization (+28 $\mu$ ) after 4 mos

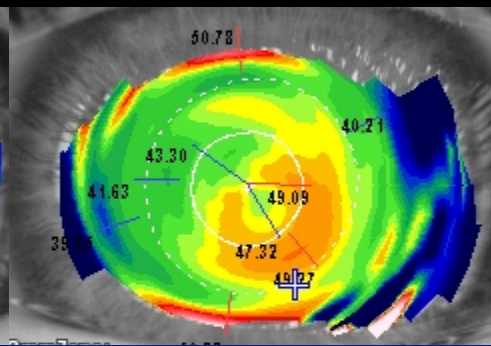
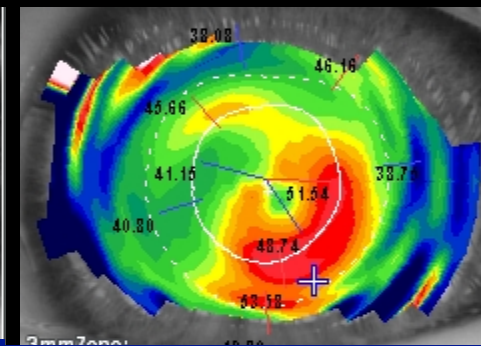
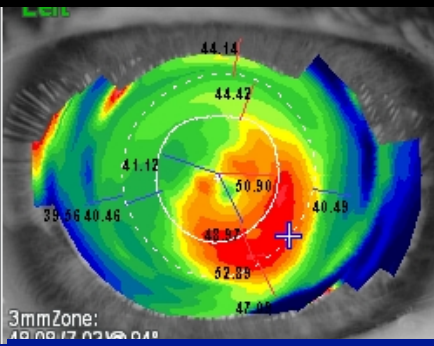
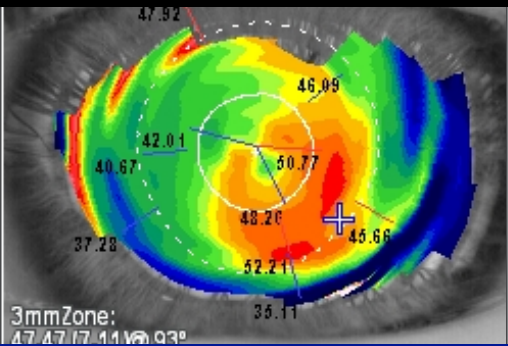


# Reduction of the area/power of the keratoconus overtime

**+3.65 D**

**-4.15 D**

**-6.18 D**

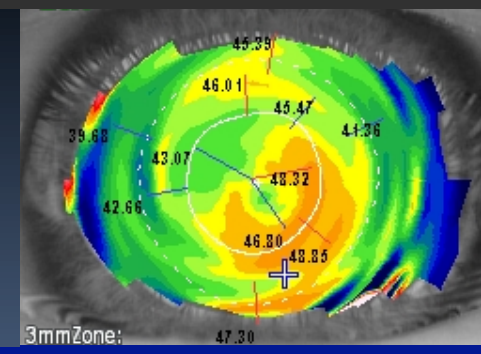
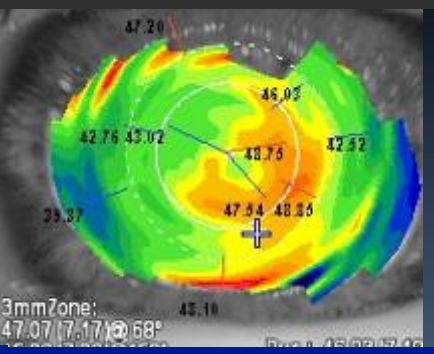
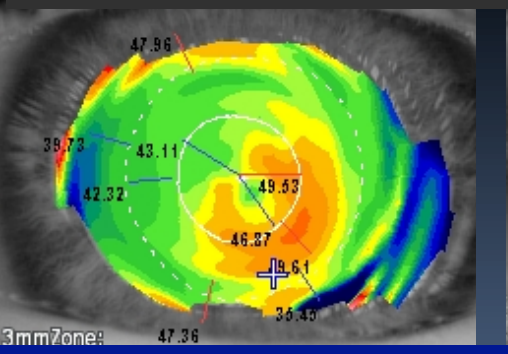


1° examination

pre cxi

1 mos post-op

3 mos post



6 mos post

12 mos post

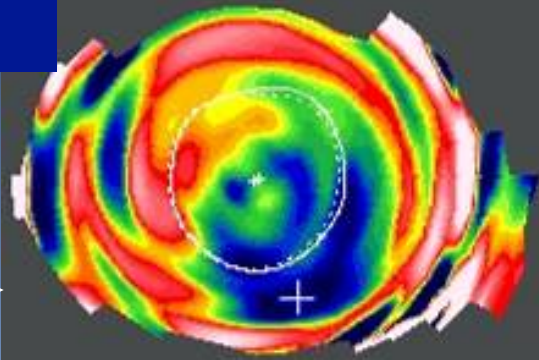
24 mos post

**-5.17 D**

**-6.08 D**

**-6.61 D**

pt n° 138 Differential map from pre cxi to 24 mos post cxi

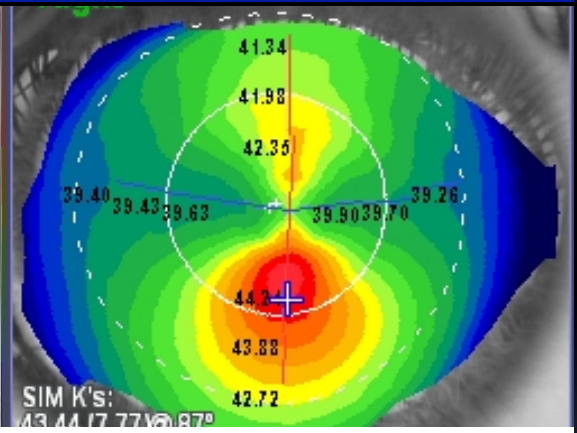
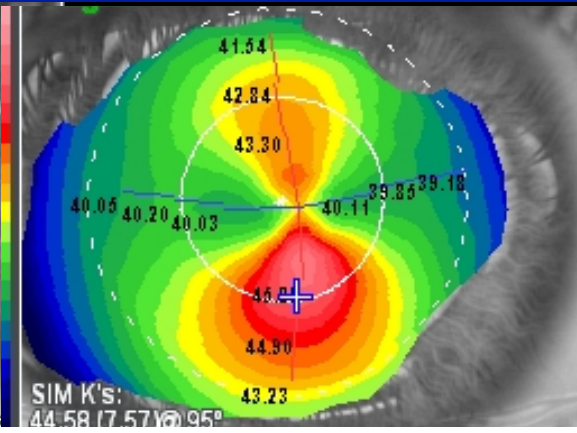
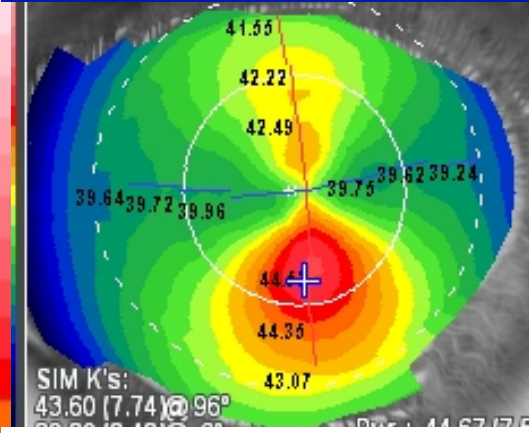


# CxI over time: from keratoconus to irregular astigmatism

48.50  
48.00  
47.50  
47.00  
46.50  
46.00  
45.50  
45.00  
44.50  
44.00  
43.50  
43.00  
42.50  
42.00  
41.50  
41.00  
40.50  
40.00  
39.50  
39.00  
38.50  
38.00  
37.50  
37.00  
36.50  
36.00

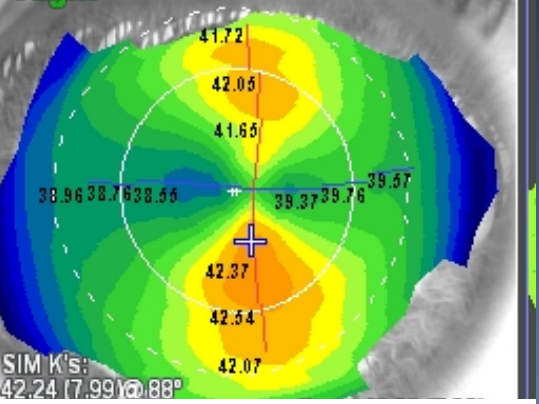
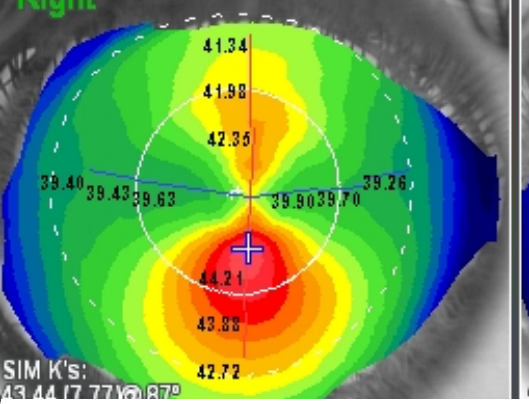
Norm  
Com .50

**Pre cxI (44,57 D)      1 mos post cxI (+1,02 D)      3 mos post cxI (-0,37 D)**



**1.0 -2.25@7      0,9 -0,75 -2.00@20      0,9 -2,50@15**

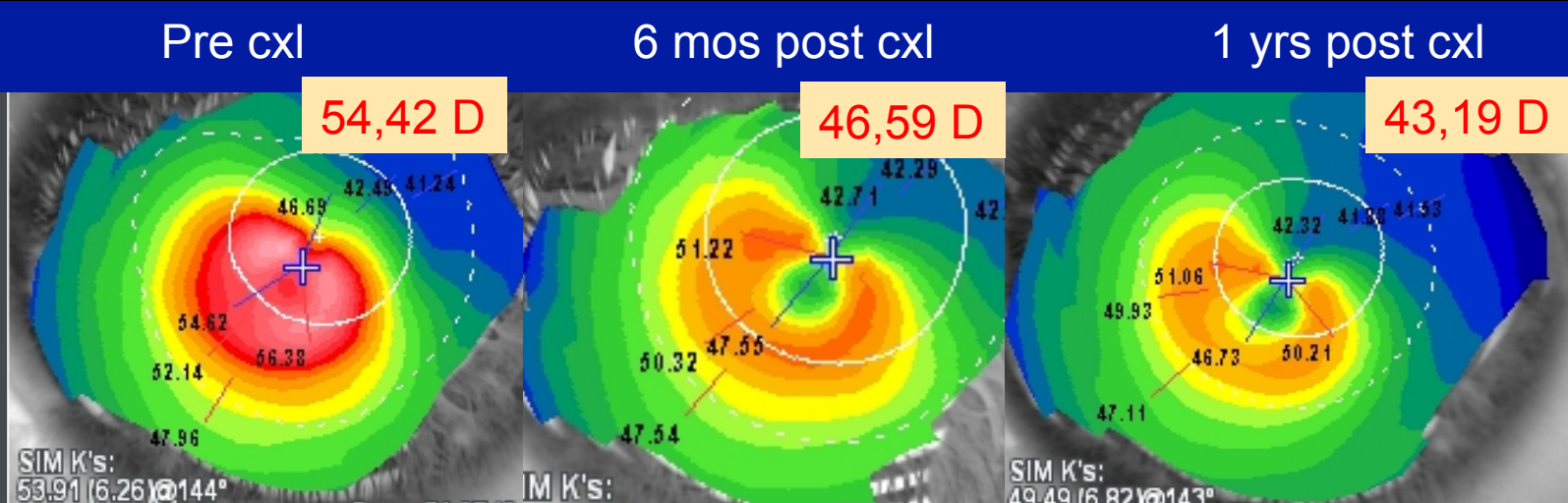
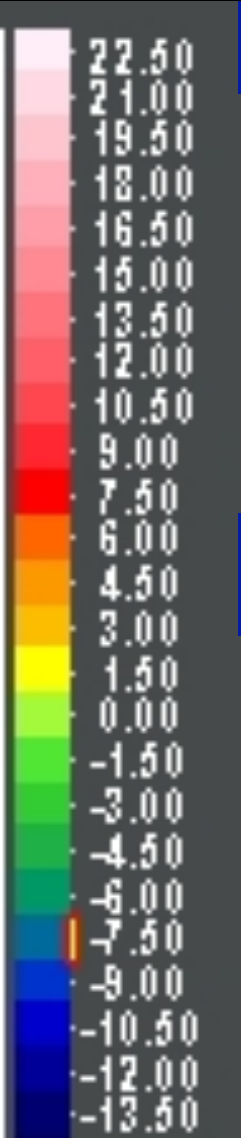
**6 mos post cxI (-0,14 D)      1 yrs post cxI (-3,42 D)**



**Differential  
Tangential map  
from pre op to 1yrs post cxI  
-3,42 D**

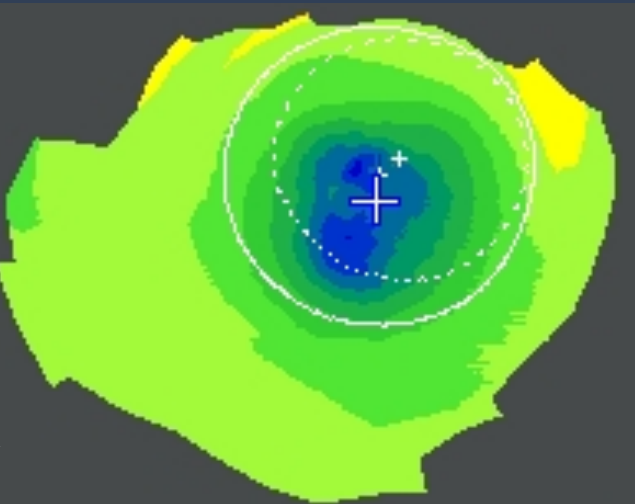
**0,9 con -2,50 @15      1.0 con -2.00@10**

# Curvature reduction of keratoconus post CxI over time

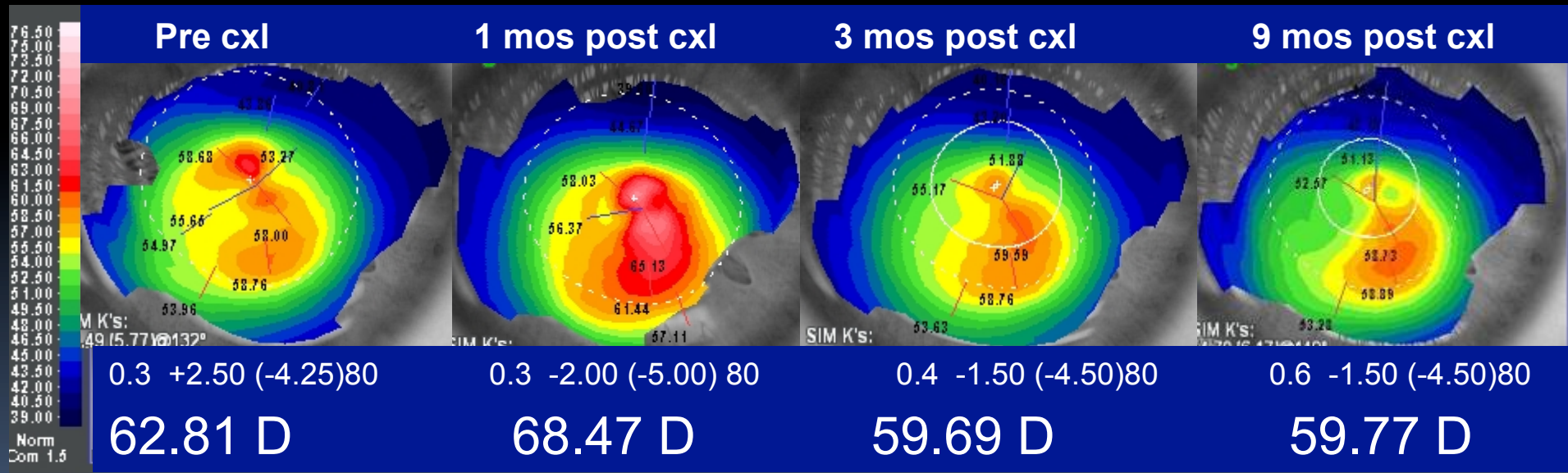


**0.2** -23sf -3.50 @55      **0,4** -15,25 (-5,25)50      **0.5** con -16sf -4.50@40

**Differential axial map**  
**-11,23D**



# Reduction of area/power over time of the keratoconus post cxi with expansion



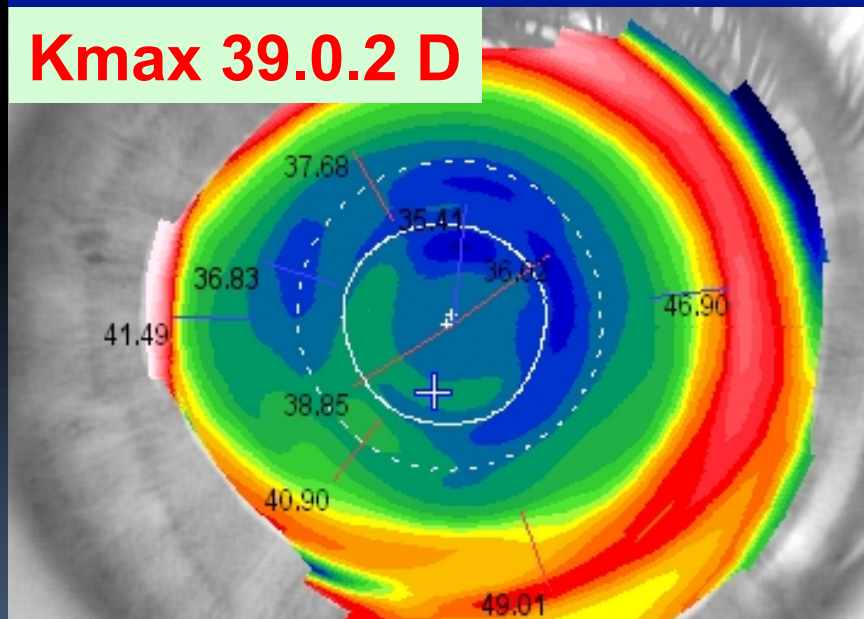
pt n° 305



Lasik : zo ricentrata molto visibile con riduzione dell'ametropia

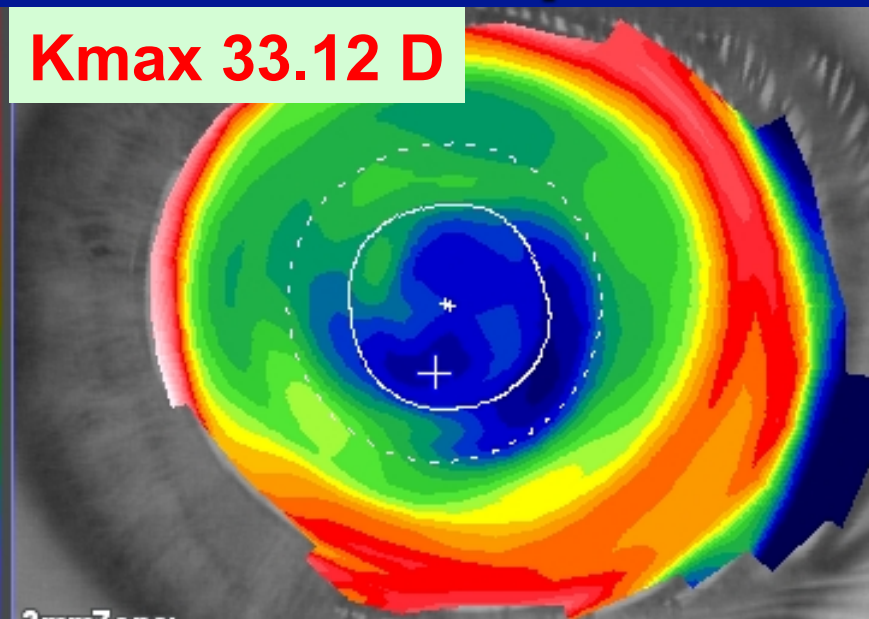
**PRE cxi**

**Kmax 39.0.2 D**



**4 mos post cxi**

**Kmax 33.12 D**



**0,7 +3.50 -2.00 (80)**

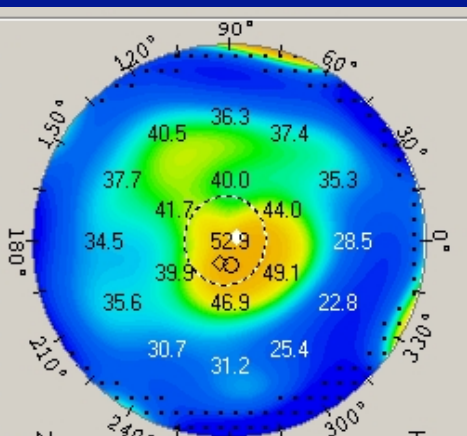
**1,0 +3.50 sph**

**-5.99D of flattening**

# BSCVA is better with minimal decrease of the curvature

Pre cxi

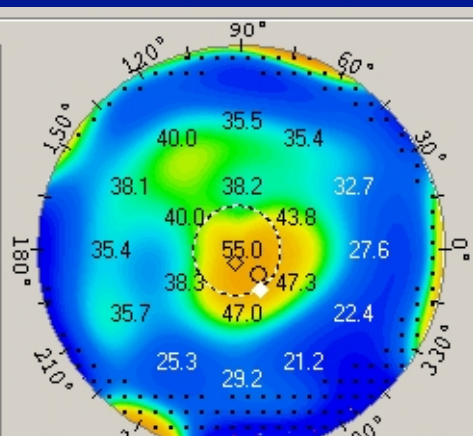
**0.4** -3.00 sph



52,9 D

1 mos post cxi

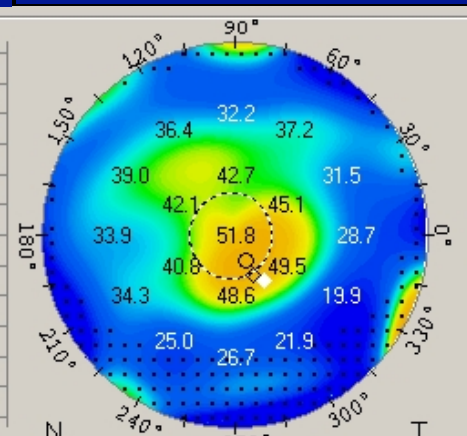
**0.4** -3.00 sph



55,0 (+2,1) D

3 mos post cxi

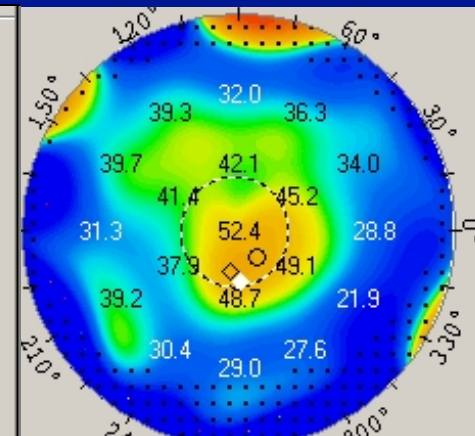
**0.4** -3.00 sph



51,8 (-0,9) D

8 mos post cx

**0.9** +0.75 33.00(115)

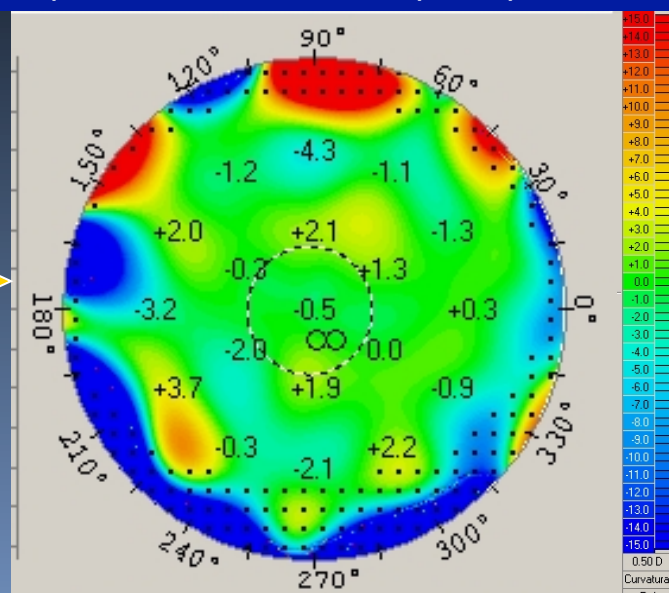


52,4 (-0,5) D

**Differential tangential map:  
only – 0,5 D!!!**

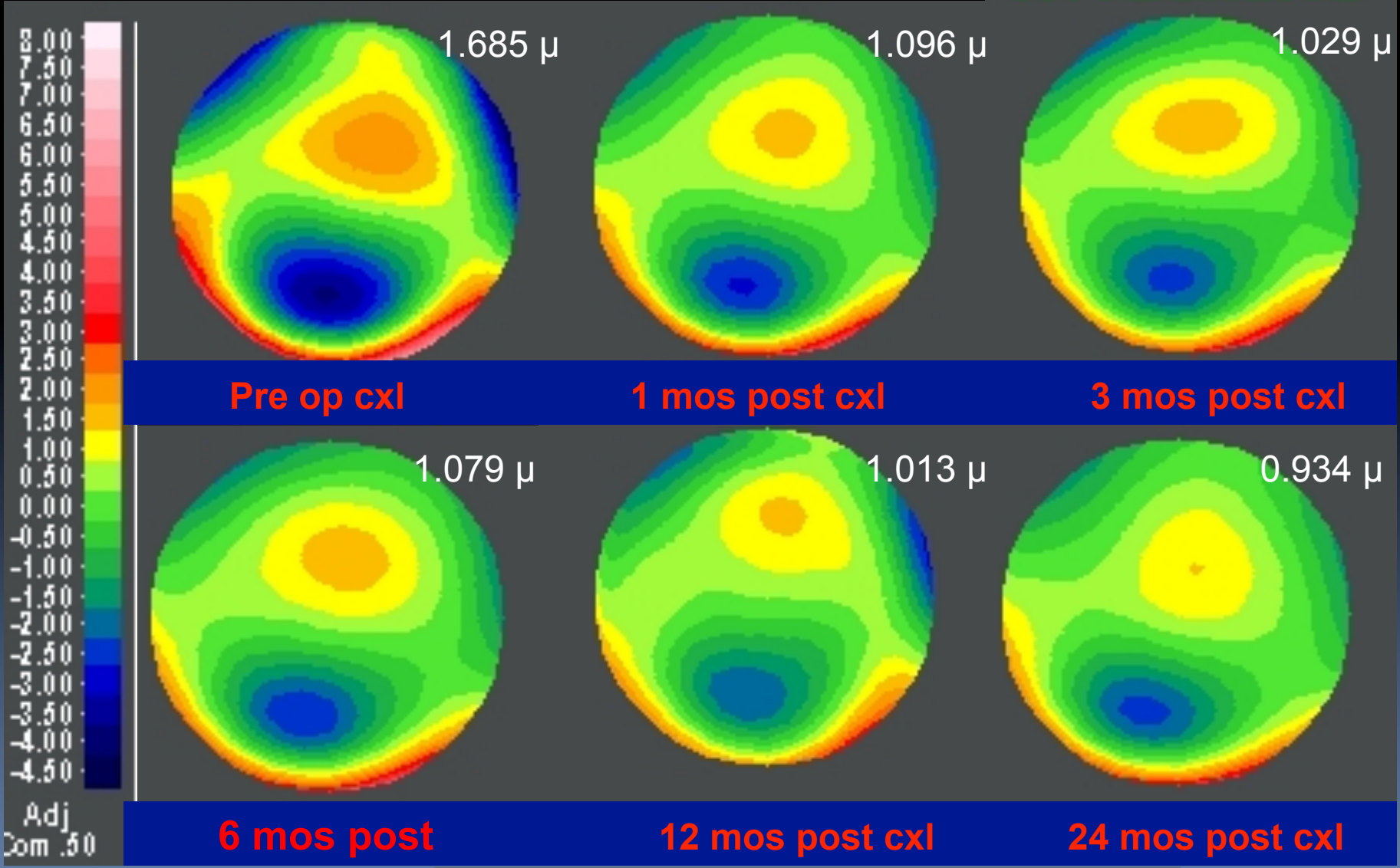
( Differential Tru net power map +1.1D )

pt n° 154



# Coma reduction overtime

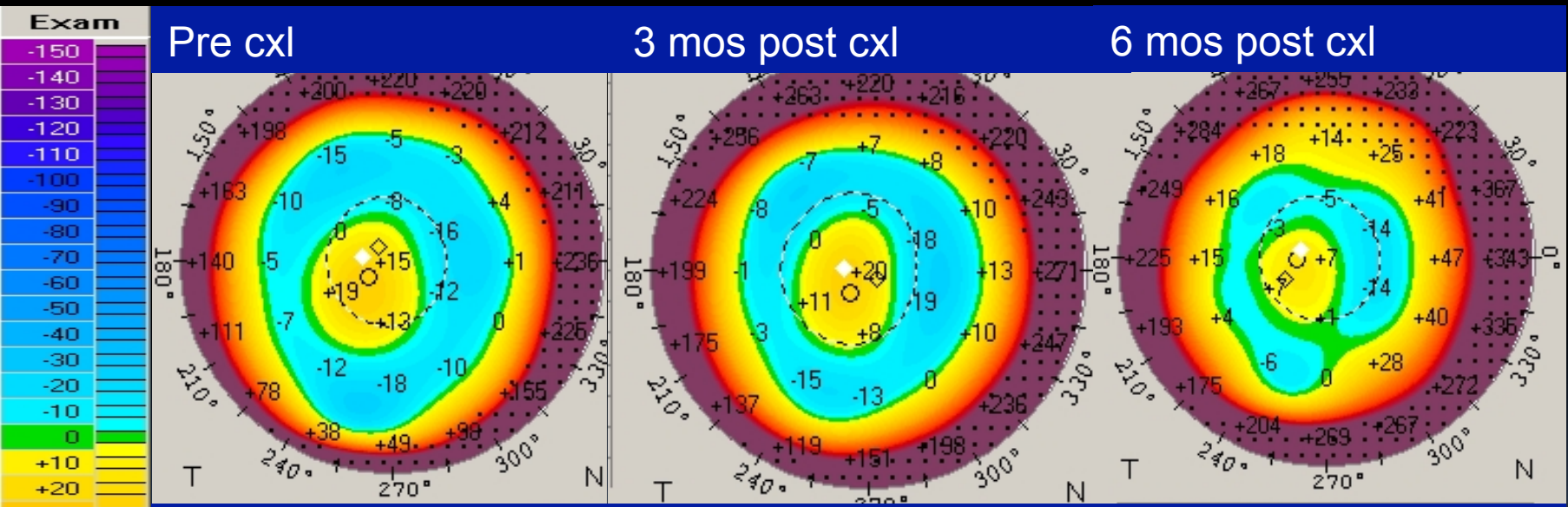
WFICorn/HO



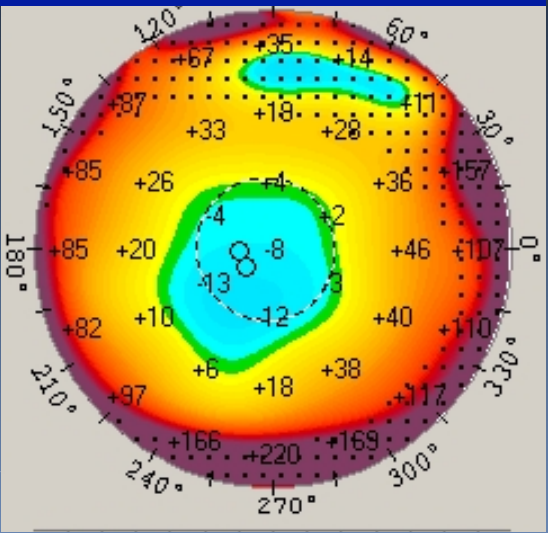
pt n° 75

coma reduction of the 44.57 %

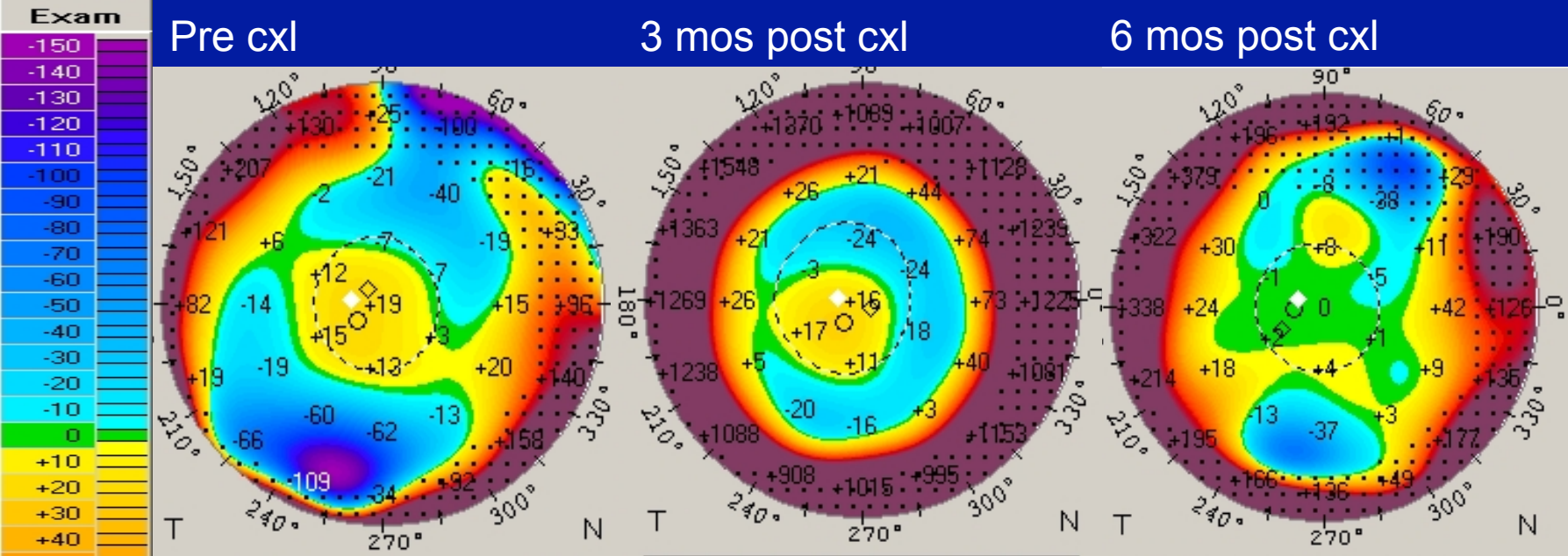
# Reduction of elevation anterior map over time of the keratoconus



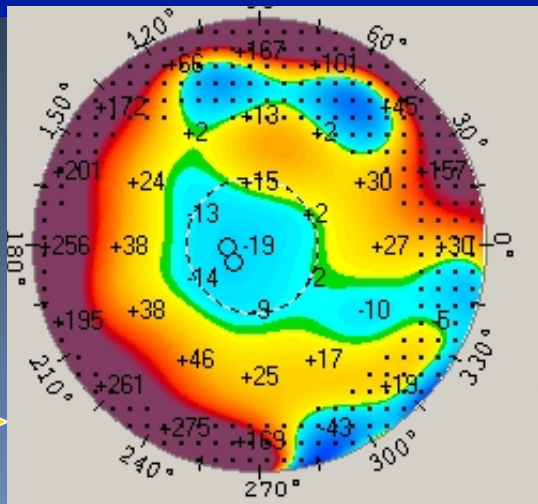
**Differential  
Elevation  
anterior map  
-13 micron**



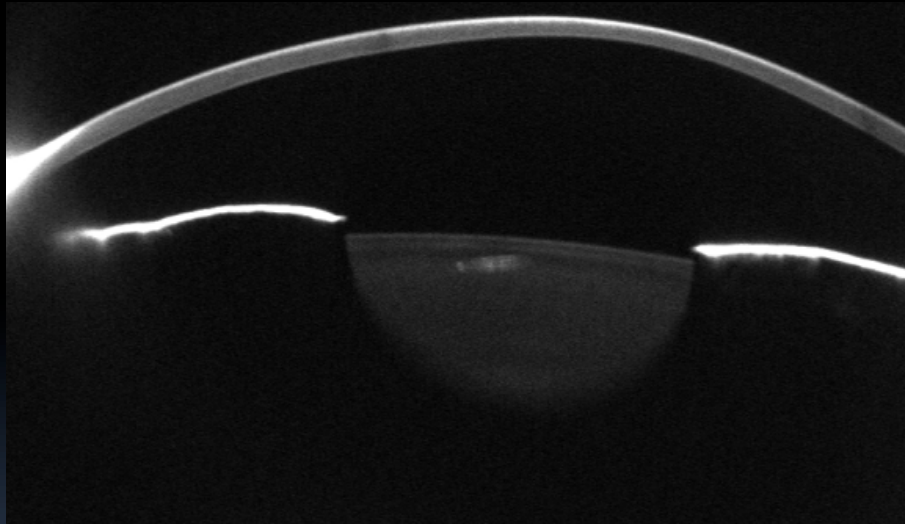
# Reduction of elevation posterior map over time of the keratoconus



**Differential  
Elevation  
posterior map  
-19+ micron**

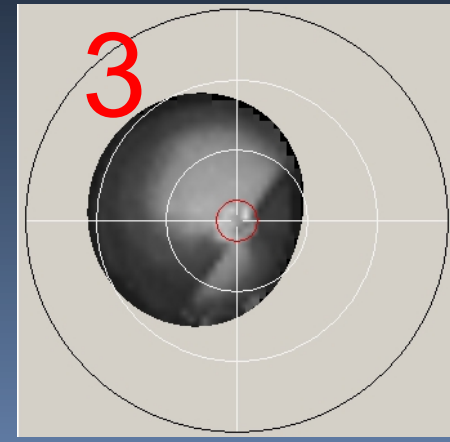
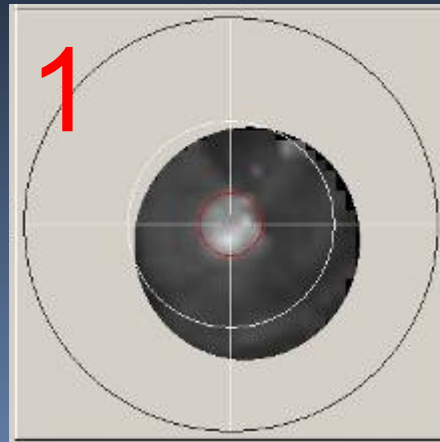


# Pentacam Nucleus Staging



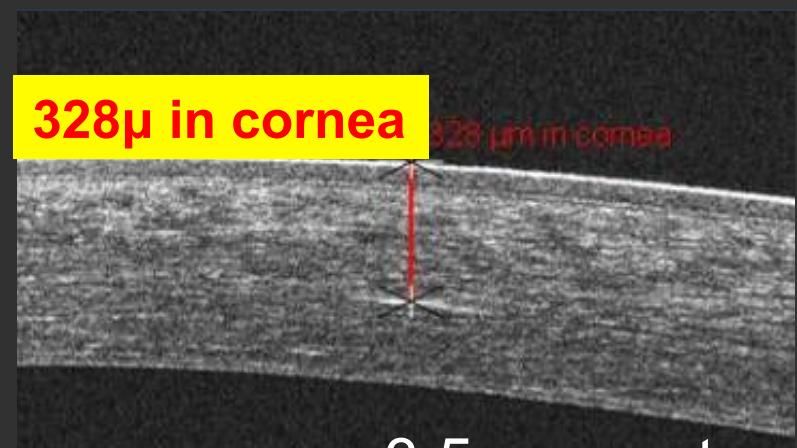
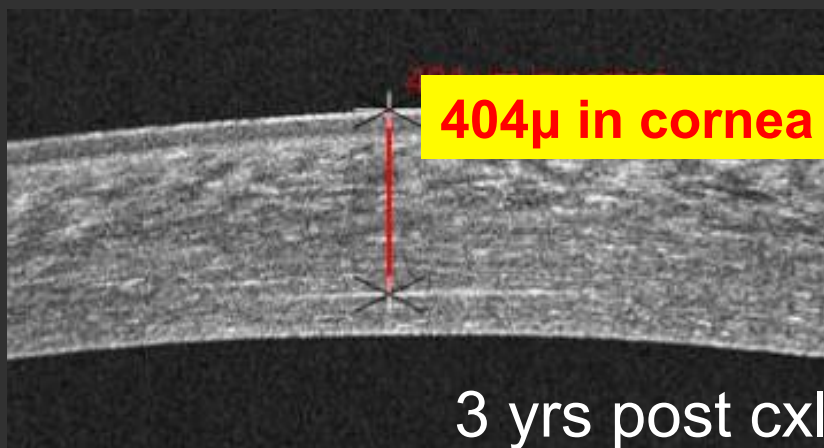
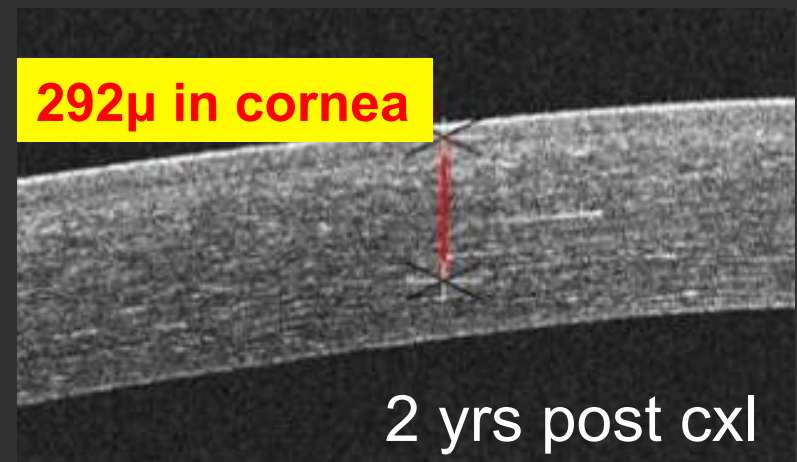
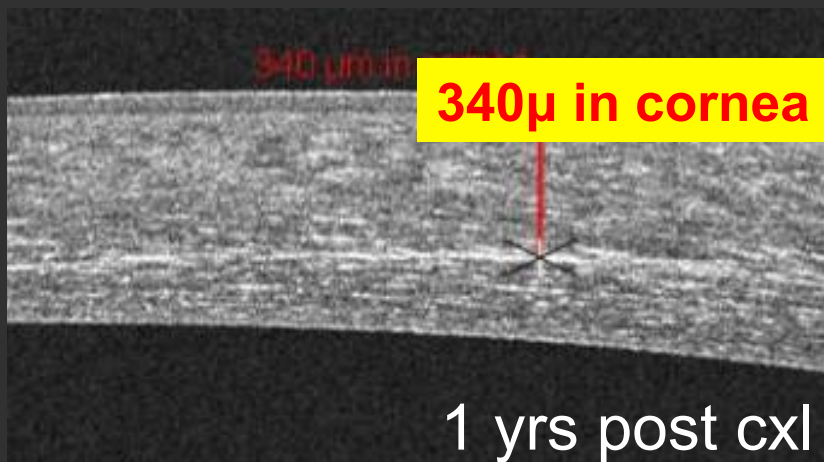
Pentacam Nucleus Staging:

Pre cxl	Post cxl 1yrs	Post cxl 2yrs	Post cxl 3yrs (19)
0	0	0	0



Staging example

# Transition line of keratoconus post cxl over time in different pts



3,5 yrs post cxl

Thank you for your attention

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