Collagen crosslinking
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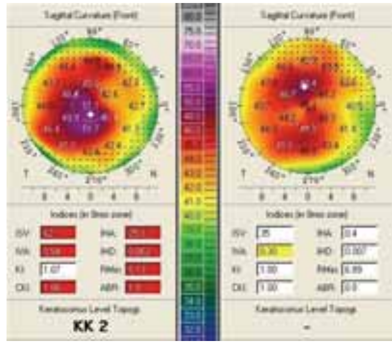

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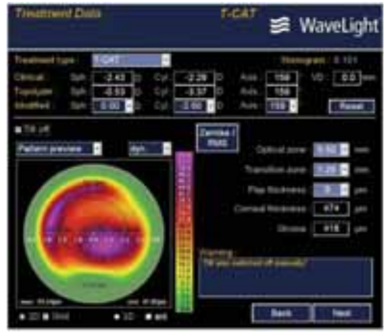

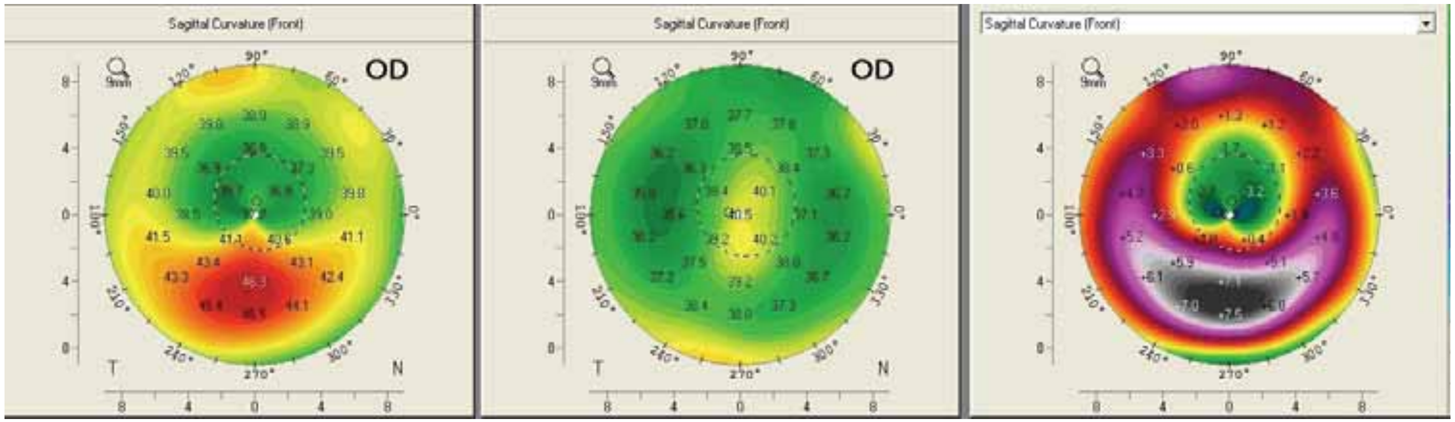

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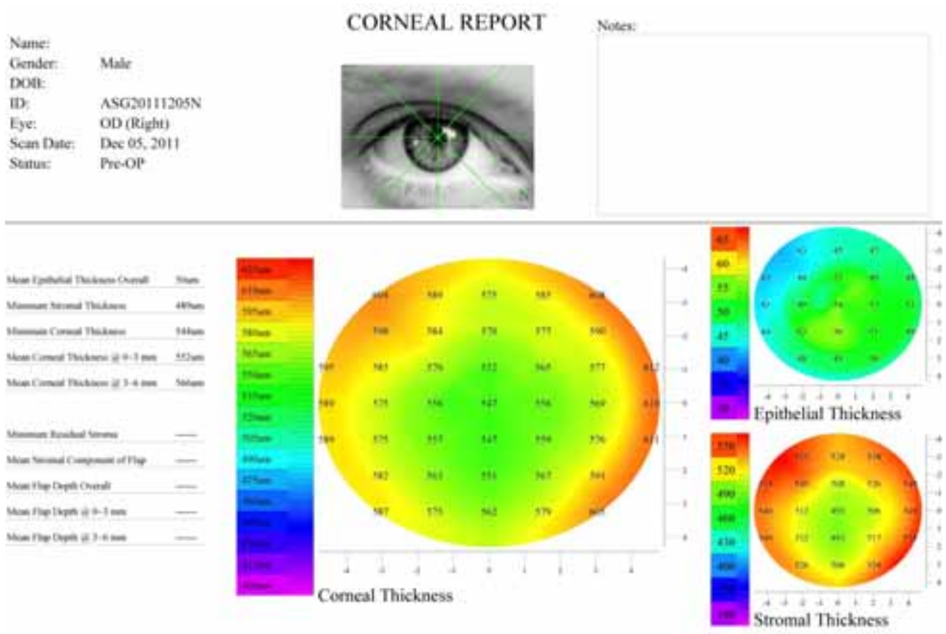


Figure 2: Corneal report produced by the Zeus software showing total corneal, epithelial, and stromal thickness pachymetry maps over 8 mm diameter. The subject's eye is normal. We observe the overall thicker epithelium over the pupil center.

Epith ... Ncxl’ed

Epithelial and mapping on normal and keratoconic (non-treated and treated) eyes. Kanellopoulos et al

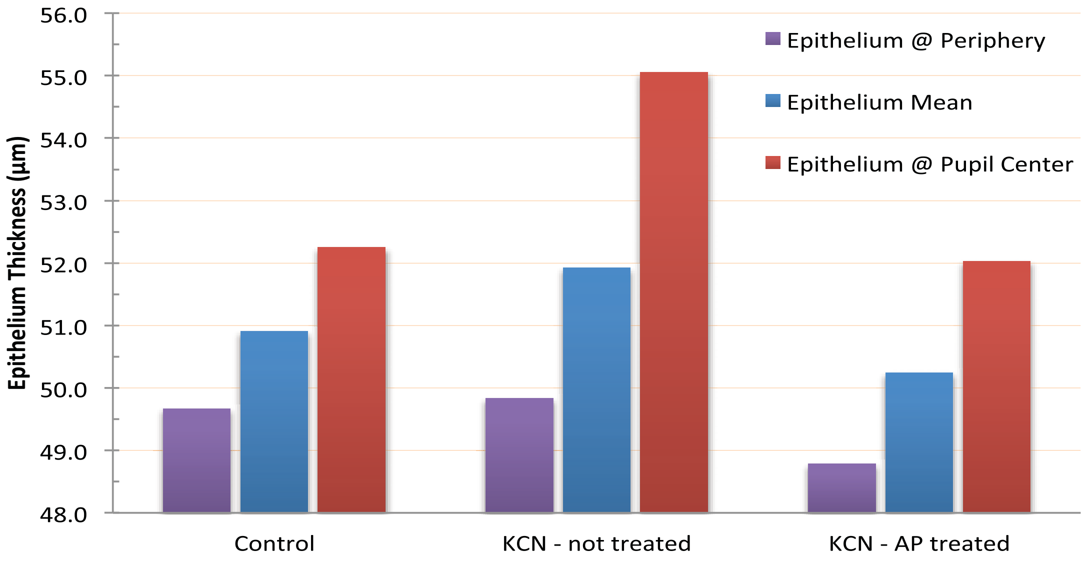


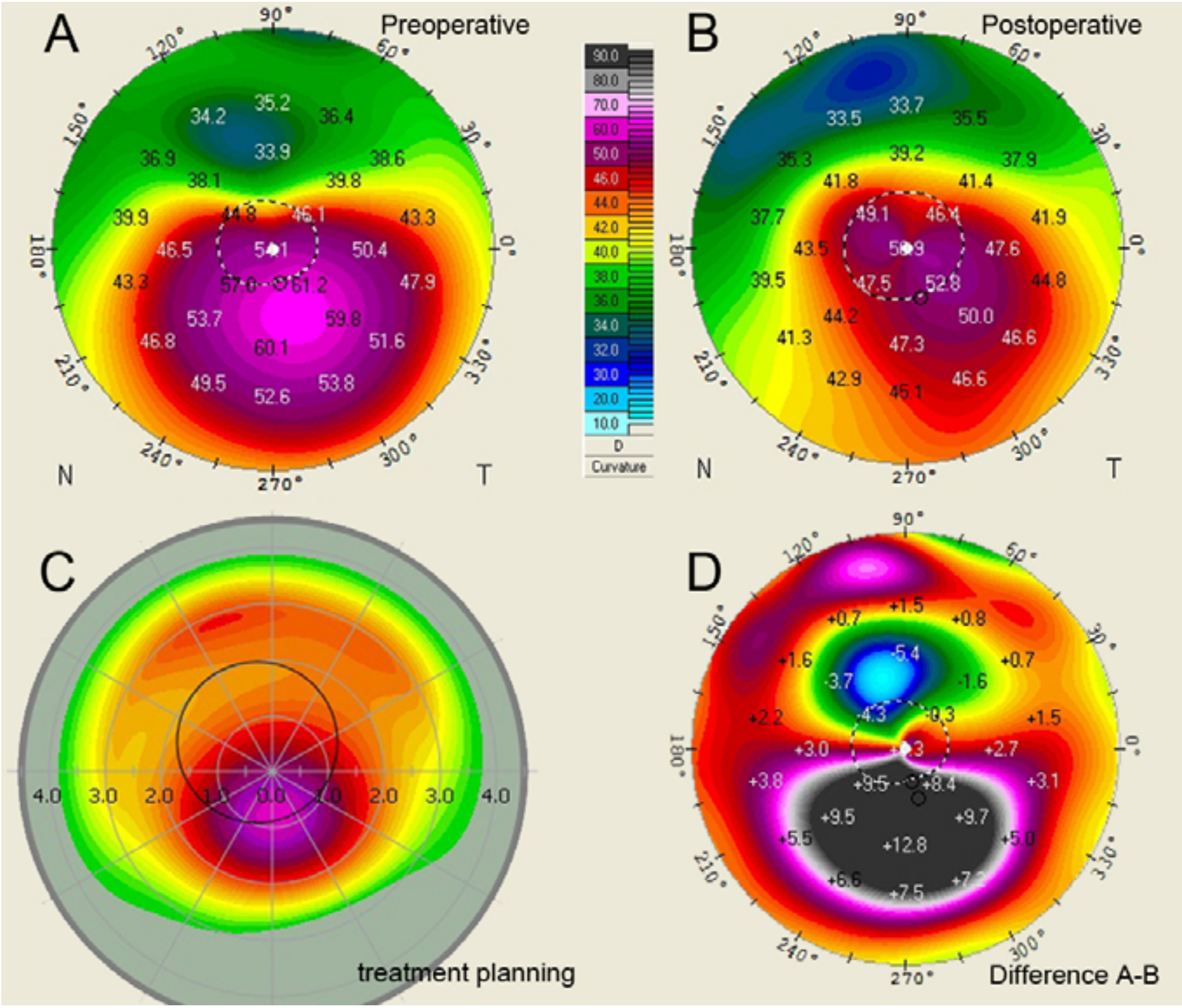
Figure 7: Epithelium thickness across the three groups of study, at the periphery, mean, and at the pupil center.

Epithelial thickness maps

May become the earliest prognostic factor for ectasia

We have found that in KCN there is overall INCREASE in average epithelial thickness

Following CXL the same eyes show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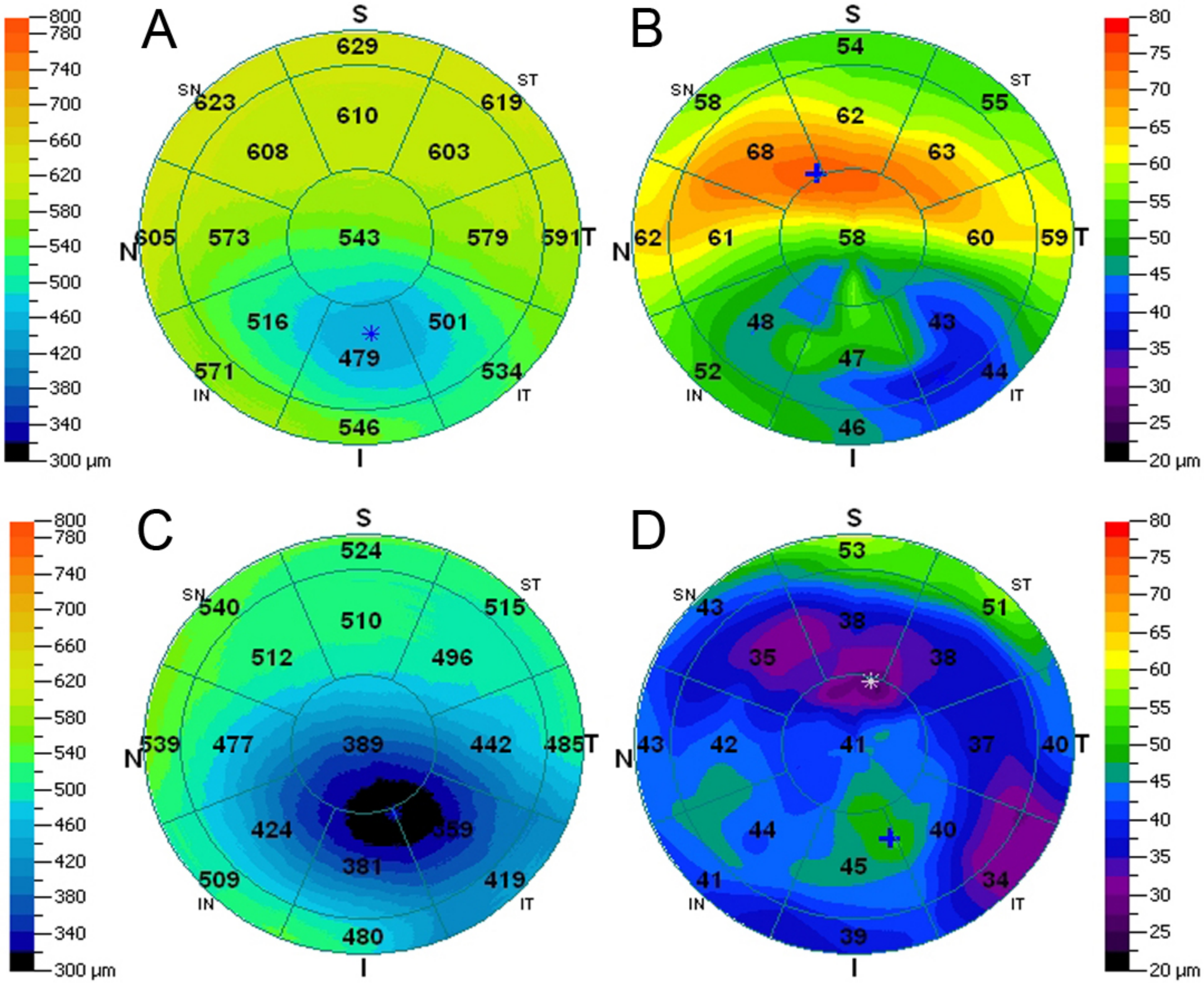

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Clinical Ophthalmology

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ORIGINAL RESEARCH

Introduction of quantitative and qualitative cornea optical coherence tomography findings induced by collagen cross-linking for keratoconus: a novel effect measurement benchmark

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Purpose: To introduce a novel, noninvasive technique to determine the depth and extent of anterior corneal stroma changes induced by collagen cross-linking (CXL) using quantitative analysis of high-resolution anterior-segment optical coherence tomography (OCT) post-operative images.

Setting: Private clinical ophthalmology practice.

Patients and methods: Two groups of corneal cross-sectional images obtained with the OptoVue RTVue anterior-segment OCT system were studied: group A (control) consisted of unoperated, healthy corneas, with the exception of possible refractive errors. The second group consisted of keratoconic corneas with CXL that were previously operated on. The two groups were investigated for possible quantitative evidence of changes induced by the CXL, and specifically, the depth, horizontal extent, as well as the cross-sectional area of intrastromal hyper-reflective areas (defined in our study as the area consisting of pixels with luminosity greater than the mean +2 × standard deviation of the entire stromal cross section) within the corneal stroma.

Results: In all images of the second group (keratoconus patients treated with CXL) there was evidence of intrastromal hyper-reflective areas. The hyper-reflective areas ranged from 0.2% to 8.8% of the cross-sectional area (mean ± standard deviation; 3.46% ± 1.92%). The extent of the horizontal hyper-reflective area ranged from 4.42% to 99.2% (56.2% ± 23.35%) of the cornea image, while the axial extent (the vertical extent in the image) ranged from 40.00% to 86.67% (70.98% ± 7.85%). There was significant statistical difference ($P < 0.02$) in these values compared to the control group, in which, by application of the same criteria, the same hyper-reflective area (owing to signal noise) ranged from 0.00% to 2.51% (0.74% ± 0.63%).

Conclusion: Herein, we introduce a novel, noninvasive, quantitative technique utilizing anterior segment OCT images to quantitatively assess the depth and cross-sectional area of CXL in the corneal stroma based on digital image analysis. Mean cross-sectional area showing evidence of CXL was 3.46% ± 1.92% of a 6 mm long segment.

Keywords: Collagen cross-linking, keratoconus, optical coherence tomography, higher fluence cross-linking, cornea ectasia, Athens Protocol

Video abstract

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Introduction

Keratoconus (KCN) is a degenerative bilateral, progressive, noninflammatory disorder characterized by ectasia, thinning, and increased curvature of the cornea, and is associated with loss of visual acuity, particularly in relation to high-order aberrations.[1–4]

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Corneal collagen cross-linking (CXL) with riboflavin and ultraviolet-A irradiation is a common technique for tissue stabilization.[5,6] Several studies have shown that CXL is an effective intervention to halt the progression of keratoconus and corneal ectasia.[7]

Anterior-segment optical coherence tomography (AS-OCT) is a promising imaging mode providing high-resolution cross-sectional images across a meridian of choices that can be employed in KCN diagnosis.[8,9] The most advanced AS-OCT systems invariably employ Fourier spectral-domain signal processing. As of today, there are a number of different spectral domain OCT systems commercially available.[10,11]

The ability to provide real-time cross sectional mapping, in conjunction with the very principle of operation, namely photon back scattering, provides the understudied application of quantitative assessment of the extent of stromal changes due to CXL.

OCT and CXL demarcation line observations

To date, the efficacy of CXL treatment can be monitored only indirectly by postoperative follow-up observations, such as with a Scheimpflug camera,[12] or with corneal confocal microscopy.[13]

In addition, a corneal stromal demarcation line indicating the transition zone between cross-linked anterior corneal stroma and untreated posterior corneal stroma can be detected in slit-lamp examination as early as 2 weeks after treatment.[14] In our clinical assessment, the presence of this finding over the anterior two-thirds of the stroma confirms that sufficient CXL treatment has occurred.

Following our presentation and the introduction in the peer-reviewed literature of the use of OCT imaging in order to evaluate the CXL-induced demarcation line, OCT has seen some recent interest as a tool for investigating CXL effects, such as corneal thickness before and after CXL for KCN, and demarcation line depth following CXL.[15–22]

The principle lies in the fact that although these lines do not appear to affect vision, as they correspond to changes in stromal density, they appear as brighter (hyper-reflective) areas on cross-sectional corneal OCT scans. However, the depth and extent of stromal changes induced by CXL has been difficult to evaluate quantitatively in the clinic.

The motivation for our study was to advance this aforementioned theory by examining not only the demarcation line depth between the suspected CXL and the deeper cornea with corneal OCT, but also to attempt to quantitatively assess the extent of this area on a large number of patients over a large postoperation interval. Our novel technique is based on digital signal processing on cross-sectional OCT images of corneas, and evaluates quantitatively and, in our opinion, free of examiner bias, the extent of CXL changes in the corneal stroma.

Methods

This prospective interventional case series study received approval by the Ethics Committee of our Institution and adhered to the tenets of the Declaration of Helsinki. Informed consent was obtained from each subject at the time of the CXL intervention or at the first clinical visit. The study was conducted in our clinical practice on patients during their regular clinical visits (control group) and scheduled postoperative procedure visits (KCN group).

Patient inclusion criteria

The control group (50 patients, 100 eyes) consisted of patients with eyes with unoperated corneas (ie, normal eyes with no ocular pathology other than refractive error). Mean patient age was 35.2 ± 9.1 years (range 19–48), equally divided between males and females. Before OCT corneal mapping, a complete ocular examination and tomographic topography was performed to screen for corneal abnormalities.

The second group (47 patients, 94 eyes) consisted of KCN patients previously operated with CXL by employing the Athens Protocol, which combined same-day phototherapeutic keratectomy epithelial removal and partial topographically-guided photorefractive keratectomy normalization of the cornea ectasia, followed by high-fluence, short-duration riboflavin induced CXL.[21]

The mean patient age in this group was 28.1 ± 7.1 years (range 16–45 years). There is a bias towards males in this group (33 males, 14 females), which is consistent with our clinical experience of the male–female incidence of keratoconic

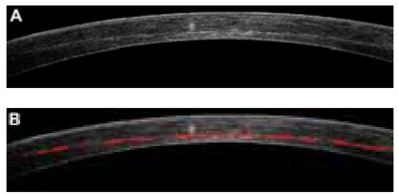

Figure 1 (**A**) Typical cornea cross-sectional meridian image of a patient with KCN. (**B**) The selected hyper-reflective intrastromal area is indicated in red.

Table 1 Hyper-reflective area corresponding to meridional corneal cross section, as measured in the two groups

	Group A (control)		Group B (KCN)	
	Hyper-reflective area (pixels)	Cross-sectional area (%)	Hyper-reflective area (pixels)	Cross-sectional area (%)
Mean	427	0.74%	2018	3.46%
Max	1518	2.50%	4927	8.80%
Min	0	0.00%	121	0.18%
Stdev	374	0.63%	1105	1.92%

Abbreviations: KCN, keratoconus; Max, maximum; Min, minimum; Stdev, standard deviation.

patients, and with previous reports.[2] Of the 94 eyes included in the study, 47 were oculus sinister and 47 were oculus dexter. Mean postoperative time since CXL operation was 17.65 ± 20.83 months, with a range of 1 to 72 months.

Most patients enrolled in the group had bilateral CXL operation, and thus both eyes were included in the study, while in some patients only one eye was included in the study. For some patients, images from more than one visit were included in the study (separated by at least 3 months).

Materials

The OptoVue RTVue (OptoVue Inc, Fremont, CA, USA) AS-OCT system was employed in the study. Using the L-Cam lens, a 6 mm long Hi-Res Cross Line Scan, centered at the pupil center along the vertical meridian, was recorded. The meridional cross-sectional images were processed with the RTVue software (version 5.1.0, processing algorithm A5, 1, 0, 90). The software averages up to 32 successive acquisitions. In our study, we included images consisting of at least five averages.

Our novel investigation technique

All images from both groups were investigated for possible quantitative evidence of changes induced by CXL. Evidence of such was considered as the existence of the intrastromal hyper-reflective demarcation line. To search for such a line, images were loaded into commercially available software, Adobe Photoshop CS5 Version 12.04 (Adobe Systems Inc, San Jose, CA, USA).

For every meridional cross-sectional image, the pixels associated with the stromal cross-section were selected with the marquee tool. The area separated by 10 pixels from the anterior and the exterior corneal surfaces were deselected, as they are typically of higher luminosity (Figure 1). The extent (pixel count) of the selected stromal image area was determined with the histogram tool report. The dialog box for this tool also provides the mean ± standard deviation of the luminosity for the selected area.

The hyper-reflective demarcation area was quantitatively defined in this study as the population of pixels (pixel count) having luminosity greater than the value defines as luminosity mean +2 × standard deviations, as obtained in the previous step.

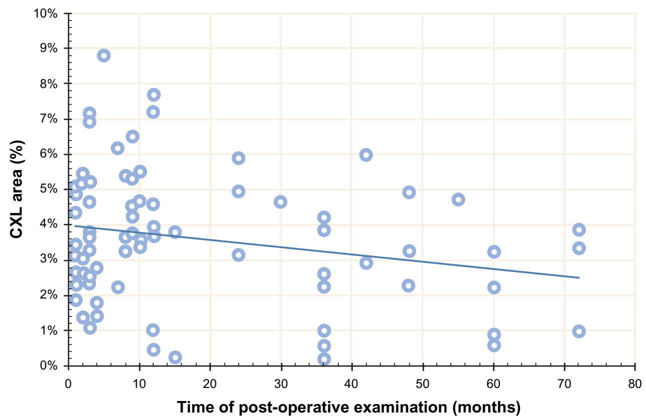

Figure 2 Demarcation line area as a function of time elapsed since the CXL operation.
Note: The trend line shows that over time, this area diminishes.
Abbreviation: CXL, cross-linking.

Table 2 Horizontal and axial extent of hyper-reflective area in group B (KCN)

	CXL width (pixels)	Horizontal extent	V line total	Axial extent	% V
		Overall width		V line CXL	
Mean	483.35	56.20%	61.93	43.81	70.98%
Max	853	99.19%	80	65	86.67%
Min	38	4.42%	38	30	40.00%
Stdev	200.82	23.35%	8.18	6.96	7.85%

Abbreviations: KCN, keratoconus; CXL, cross-linking; V, vertical; Max, maximum; Min, minimum; Stdev, standard deviation.

Subsequently, after using the histogram tool report again, the extent (pixel count) of the hyper-reflective intrastromal area was recorded, as well as its horizontal extent (pixels across the y axis), and this was compared to the horizontal extent of the captured image, which was set to a standard of 860 pixels across the y-axis.

Similarly, the axial extent (depth of demarcation line) was assessed and compared to the depth of the corneal section (vertical line in the image; that is, pixels in the x-axis) to which it corresponded.

Descriptive statistics (average, minimum, maximum, standard deviation, bias, and range), comparative statistics, and linear regression were performed in Microsoft Excel 2010 (Microsoft Corp, Redmond, WA, USA) and OriginLab version 8 (OriginLab Corp, Northampton, MA, USA). Analysis of variance between groups was performed using the OriginLab statistics tool.

Results

Areal extent (depth and diameter) of demarcation

Cross-sectional meridian area measurements had an average of 59,183 pixels (±5778), ranging from 80,729 to 39,951 (maximum to minimum). This corresponds to an area of 2.88 mm^2. Mean luminosity values were, on a grayscale of 0 to 255, 63 ± 13, ranging from 89 to 25 (maximum to minimum).

As shown in Table 1, the intrastromal hyper-reflective area found with this technique for group A (control) had a mean area of 427.25 ± 373.81 pixels (range, maximum to minimum, 1518-0), corresponding to a mean of 0.74% ± 0.63% (range, 2.50%–0.00%), corresponding to 0.02 mm^2. This contrasts with group B (KCN), in which the mean hyper-reflective area had a mean of 2018.21 ± 1104.70 (range, 4927–121), corresponding to a mean of 3.46% ± 1.92% (range, 8.80%–0.18%), or 0.098 mm^2 of the corneal cross-sectional area. Of the 94 cases examined, 72 had more than 2.50% hyper-reflective areas, whereas six were close to and 16 were below this mark. The two groups were found to be statistically different (comparison of hyper-reflective area pixel count; $P < 0.02$). The over time development of the extent of the area of demarcation; that is, the CXL area over post-operative time, is plotted in Figure 2.

Horizontal extent of demarcation

The horizontal extent of demarcation was assessed for the KCN group and was compared to the standard 860 pixel

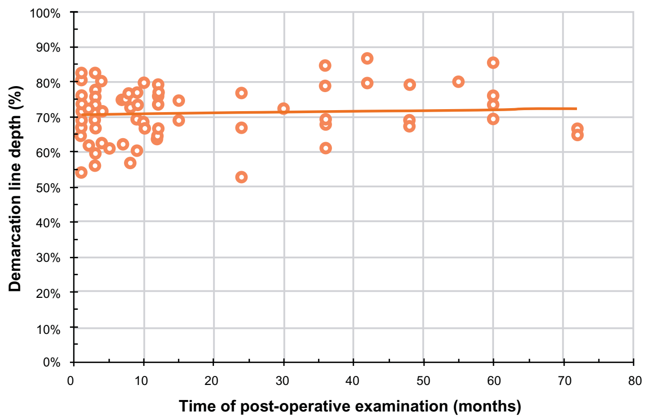

Figure 3 Demarcation line depth as a function of time elapsed since the CXL operation.
Note: The trend line shows that over time this depth remains constant to about two-thirds of the corneal depth.
Abbreviation: CXL, cross-linking.

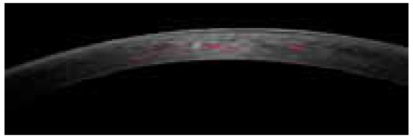

Figure 4 Example of epithelium-on CXL cornea with minimal appearance of the demarcation line.
Note: Of the 61,770 pixels (cornea cross-section), only 443 correspond to a hyper-reflective area.
Abbreviation: CXL, cross-linking.

width extent of the corneal cross-section. As shown in Table 2, on average the extent of the hyper-reflective area (CXL width) was 483.35 ± 200.82 pixels (range, 853–38), corresponding to an average of 56.20% of the cross-section width, ranging from 99.19% to 4.42%. Of the subgroup of 78 corneas with more than a 2.50% hyper-reflective area, the minimum was 12.45%.

Axial extent (depth) of demarcation

The axial extent of demarcation corresponds to what we describe as the depth of the CXL effect. The quantitative assessment is subject to the corneal thickness, which varies significantly among images. In each image studied, the corneal thickness was measured in pixels (vertical line total in Table 2), and was found to correspond to an average of 61.93 ± 8.18 pixels (max to min, 80–38). Considering that 6 mm across the image corresponded to 860 pixels, the 61.93 pixels corneal thickness translates to 432 µm of thickness.

Having measured the corneal thickness of each individual section, the distance in pixels (vertical line CXL) from the anterior corneal surface was measured. On average, it was found to be 43.81 ± 6.96 pixels (range, 65–30), corresponding to 305.6 µm or 70.98% of the total corneal thickness. The over time (postoperative) development of the depth of the area of demarcation, that is CXL area over time, is presented in Figure 3.

Discussion

By examining high-resolution corneal OCT images, we encountered statistically different findings between the treated group (KCN; group B) and the control group (A).

It appears that there is a statistically significant difference between the control group and the KCN group regarding the presence of a demarcation line, as quantitatively measured by the extent of the area of the hyper-reflective demarcation line, indicating a localized change in stromal (treated) density over the underlying (untreated) stroma.

In 72 of 94 cases, the demarcation line area corresponded to more than 2.50% of the total corneal cross-sectional area, with a mean ± standard deviation of 3.46% ± 1.92%. In the entire control group A, by applying the same luminosity criteria, the similar area had a mean of 0.74% ± 0.63%. We believe that these pixel counts represent merely signal noise rather than reflect actual changes in stromal density. Thus, we can ascertain that the demarcation line viewed by OCT can be a good indication of the extent of collagen density changes induced by CXL.

Over time, these density changes become less apparent. The trend line shown in Figure 2 has a negative slope (reduced

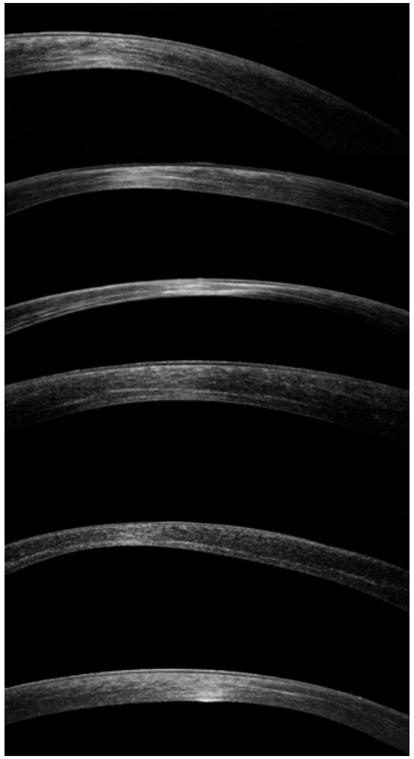

Figure 5 Example of corneal cross-sectional images examined in the study showing various degrees of demarcation line extent.

by 0.02% per month), indicating that the demarcation line area fades away by postoperative month 12, in agreement with our clinical findings.[15]

The depth of the demarcation line, found to be on average of 305 µm, is consistent with the accepted notion that in order to avoid ultraviolet-A irradiation damage to the corneal endothelium,[23] the CXL parameters are set in a way that effective treatment occurs only in the first 300 µm of the corneal stroma.[12]

The depth of the demarcation line appears, on the other hand, to be stable over time, even after 3 years following operation, at approximately 70% of the corneal depth. However, a deeper demarcation line depth (relative to the corneal depth) is associated with thinner corneal thickness, as measured postoperatively. In the selected 12 thinner corneas, the depth of the demarcation line was found to be 83% of the total corneal thickness.

One clinical example of ineffective CXL action is demonstrated in Figure 4, in which a case of a cornea treated in another institution with epithelium-on CXL technique demonstrated minimal signs of hyper-reflective areas.[24] This case, which was not part of the case study, was presented to our practice with progressive ectasia following the CXL operation in another practice. Examples of corneal cross-sectional images examined in the study showing various degrees of demarcation line extent are presented in Figure 5.

Conclusion

AS-OCT appears to demonstrate reproducible early (1 month) and long-term (up to 3 years) CXL cornea findings. The hyper-reflective lines may represent induced cornea density changes or subtle intrastromal cornea scarring. This novel quantitative and qualitative technique may constitute a possible benchmark for a noninvasive measurement to evaluate and titrate the amount, extent, and depth of intrastromal effects of the CXL treatment in KCN and possibly ectasia eyes.

Disclosure

The authors report no conflicts of interest in this work.

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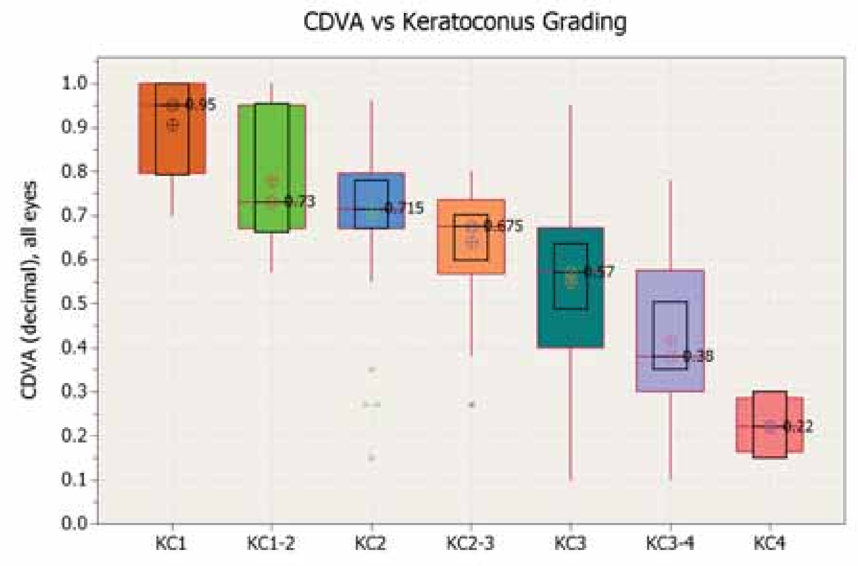
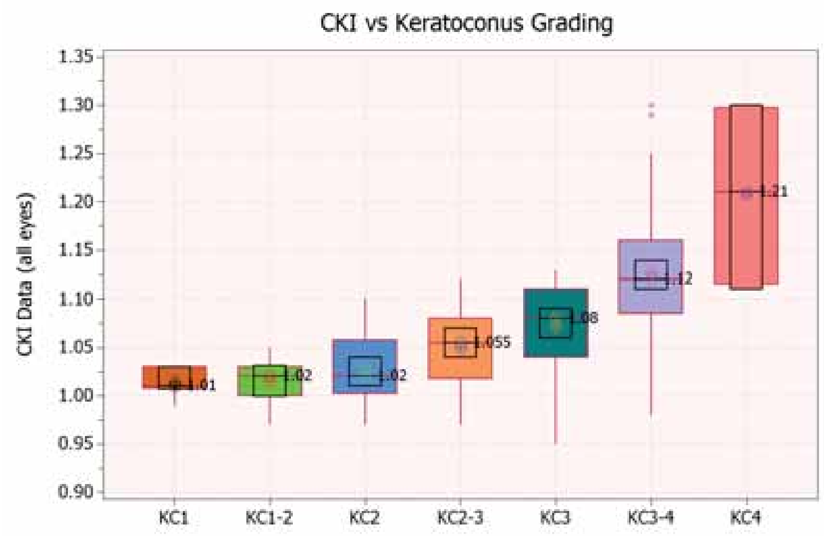
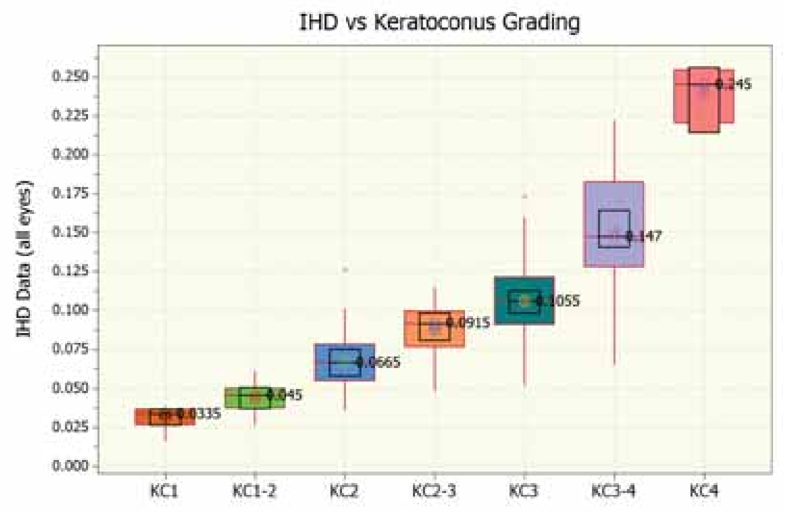
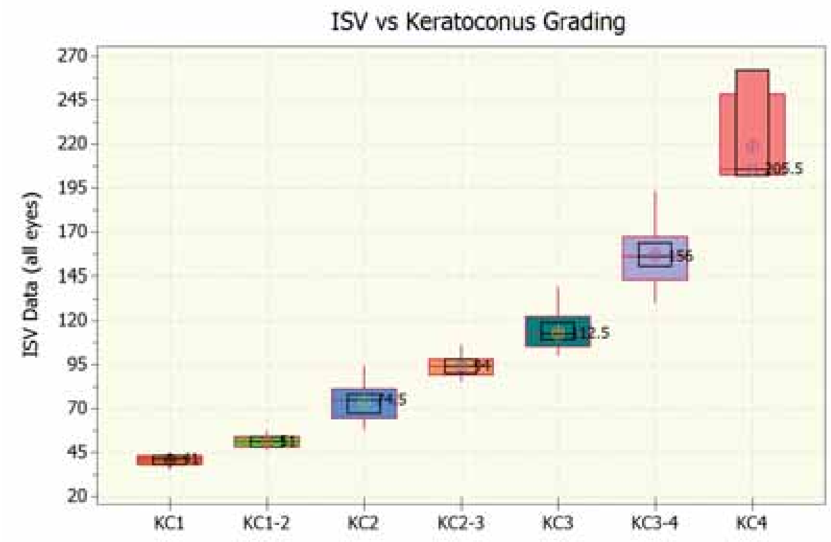
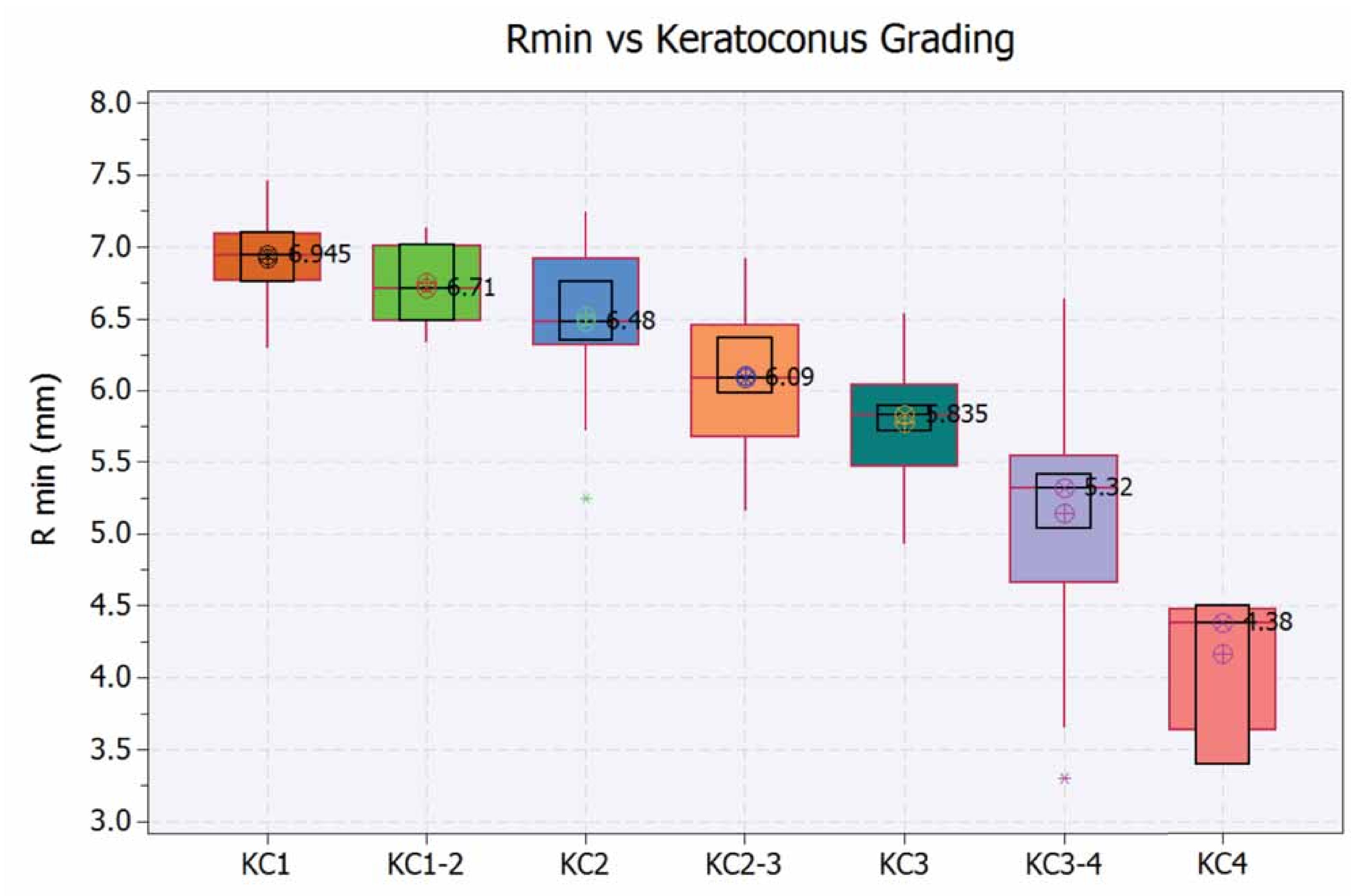
Vision, Ks=waste of time in 700 KCN cases test ISV and IHD!





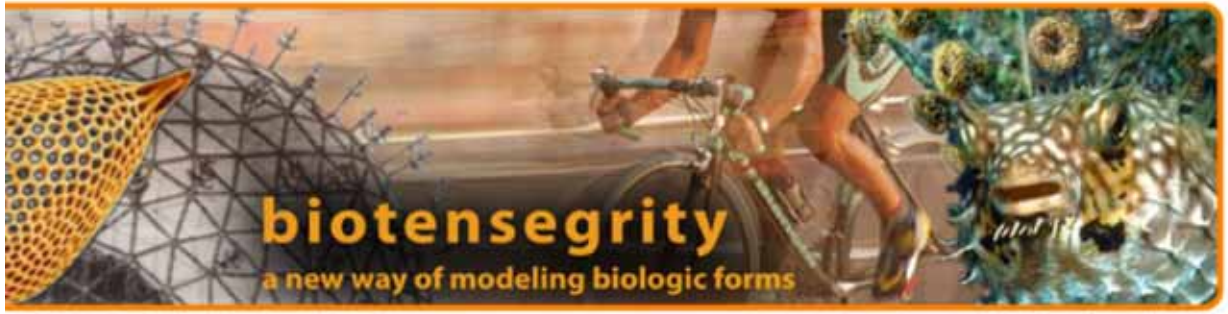






Rmin vs Keratoconus Grading
R min (mm)
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
6.945
6.71
6.48
6.09
5.835
5.32
4.38
KC1
KC1-2
KC2
KC2-3
KC3
KC3-4
KC4

- **Customised “pattern” CXL**
- **Coming from Avedro with the KXL II**



ME | UPDATES | PAPERS | HISTORY | MODELING | COMMENTARY | LINKS | CONTACT

Continuous Tension, Discontinuous Compression:
A Model for Biomechanical Support of the Body

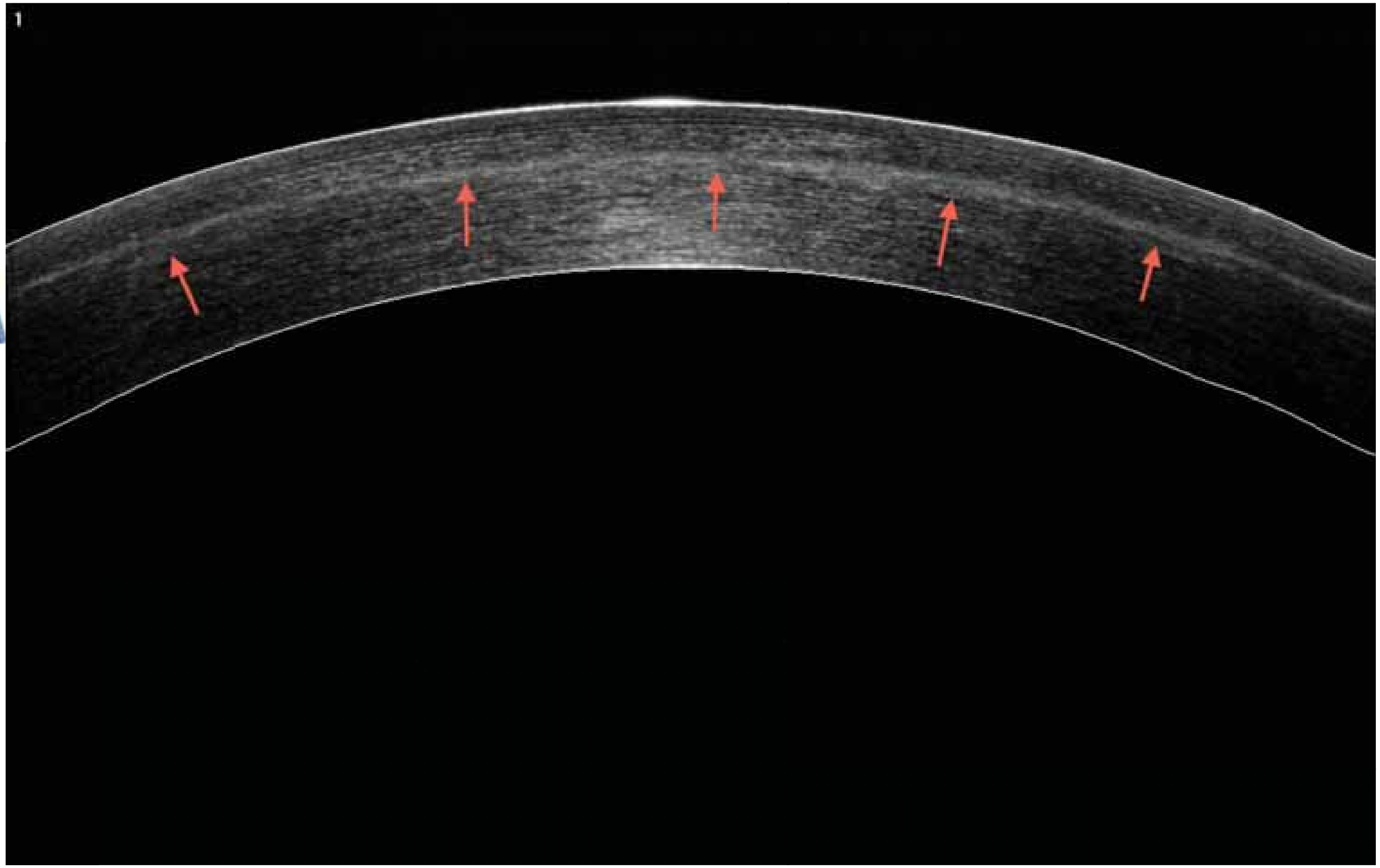
The following is the text of an address made before the North American Academy of Manipulative Medicine in 1980. Since then, refined and upgraded editions have been presented to the following: Medical College of Virginia, Anatomy Department of Howard University, The Paleontology Society of the Smithsonian Institution, the Alliance for Engineering in Biology and Medicine (fall, 1981), International Society for the Study of the Lumbar Spine in Toronto June, 1982. [Reprinted from The Bulletin of Structural Integration, Vol. 8, No. 1: Spring-Summer 1982] and numerous other venues.

It is only in recent history when we have developed newer materials that we have recognized that tension forces can play a significant role in the integrity of structures. However, engineers use tension mainly as a support system for compression loads. In humans, McNab, Farfan, White and others recognize that tensional components of muscles and ligaments probably play a role in spinal support, but only Kirkby and Robbie felt that at times tension may be the major support force of the spine. Robbie, however, still believes that the spinal column is capable of functioning only as a "stack of blocks" and Kirkby feels that only when the body is properly "balanced" in the gravitational field does tension function as the major support.

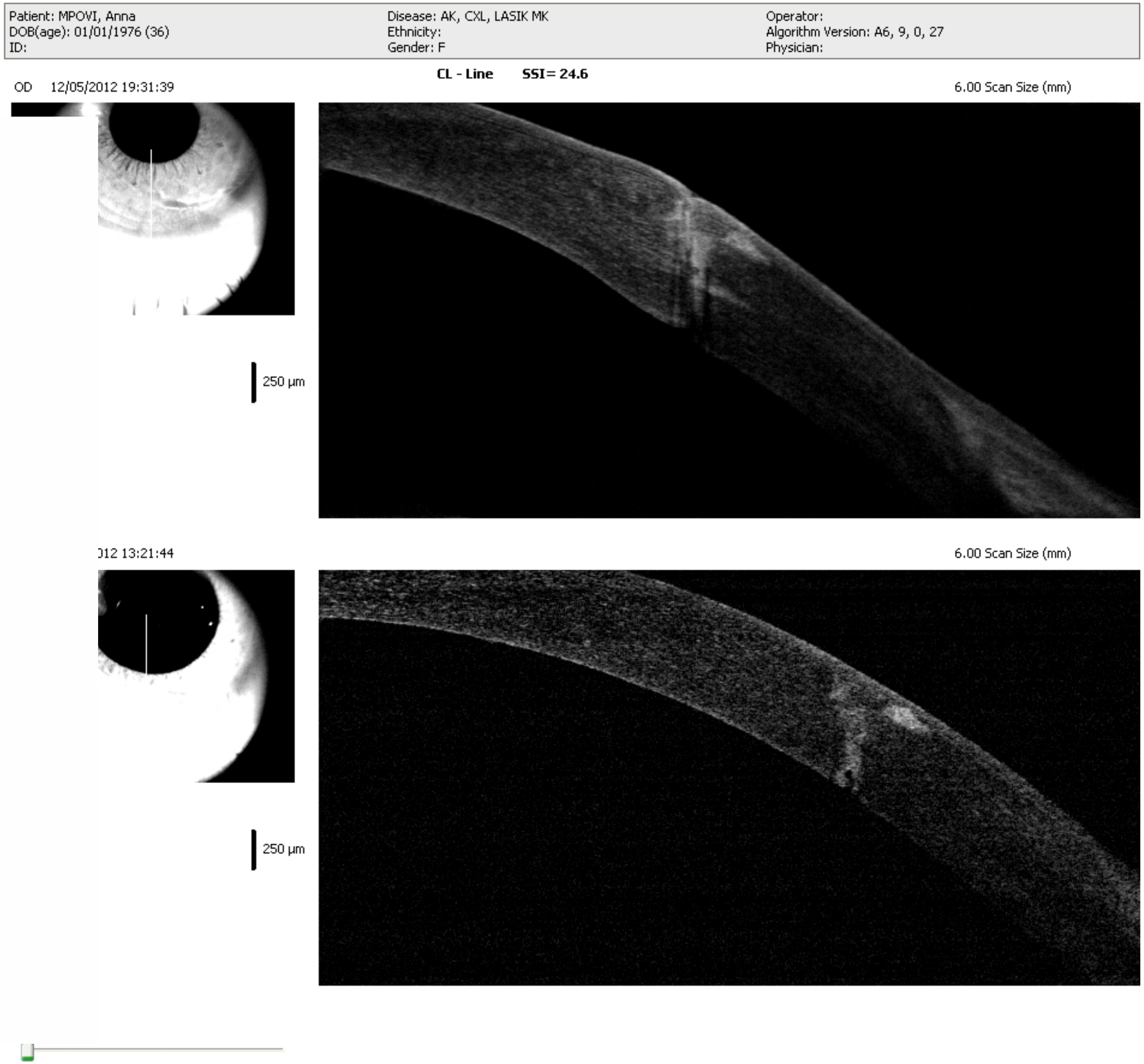
It is the author's contention that only in failure does the spinal column function as a "stack of blocks." The support system of the spine, and indeed the remainder of the body as well, is a function of continuous tension, discontinuous compression, so that the skeleton, rather than being a frame of support to which the muscles and ligaments and tendons attach, has to be considered as compression components suspended within a continuous tension network.

Since the spine is a mechanical structure, investigators have used mechanical models to attempt to

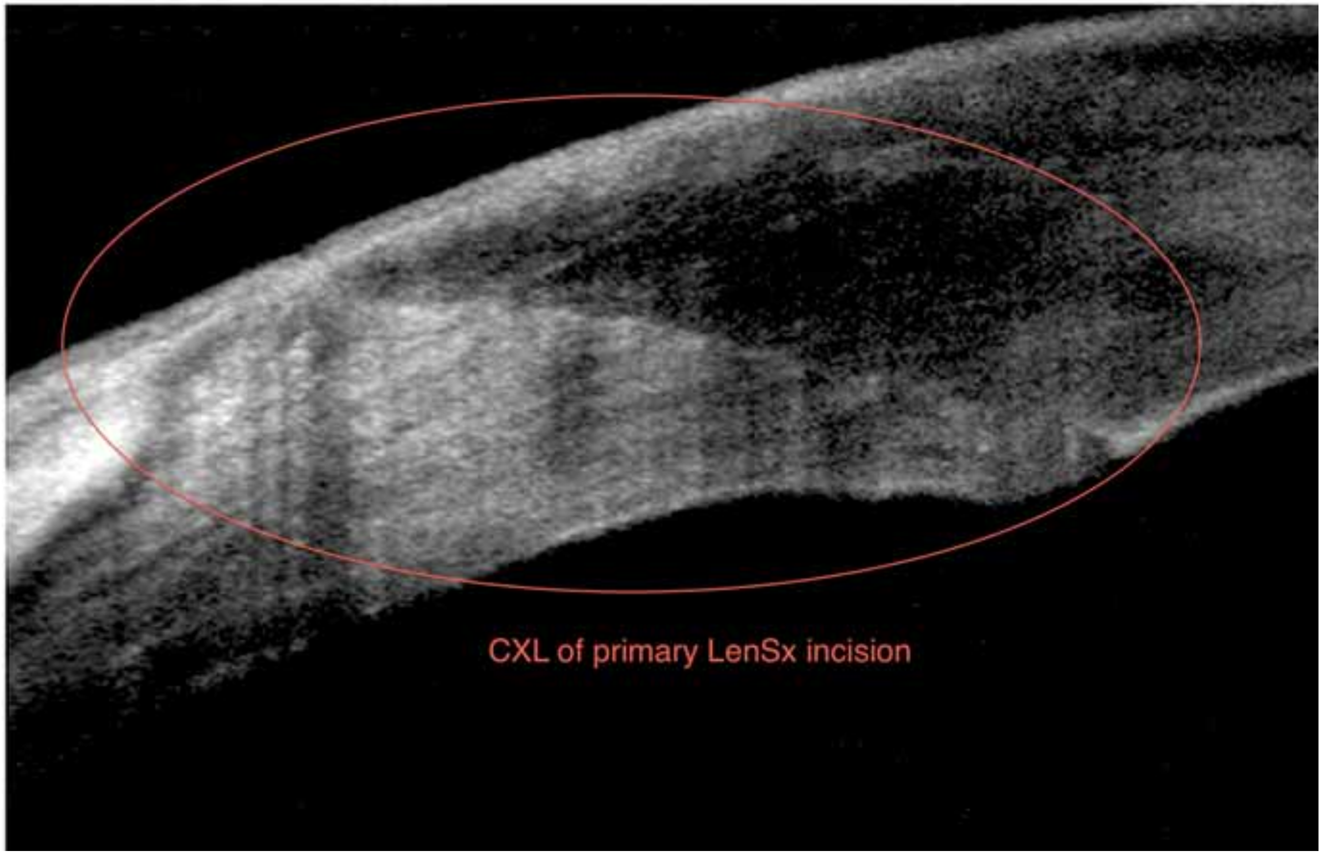
CXL evidence in Hyperopic LASIK Xtra group



AK

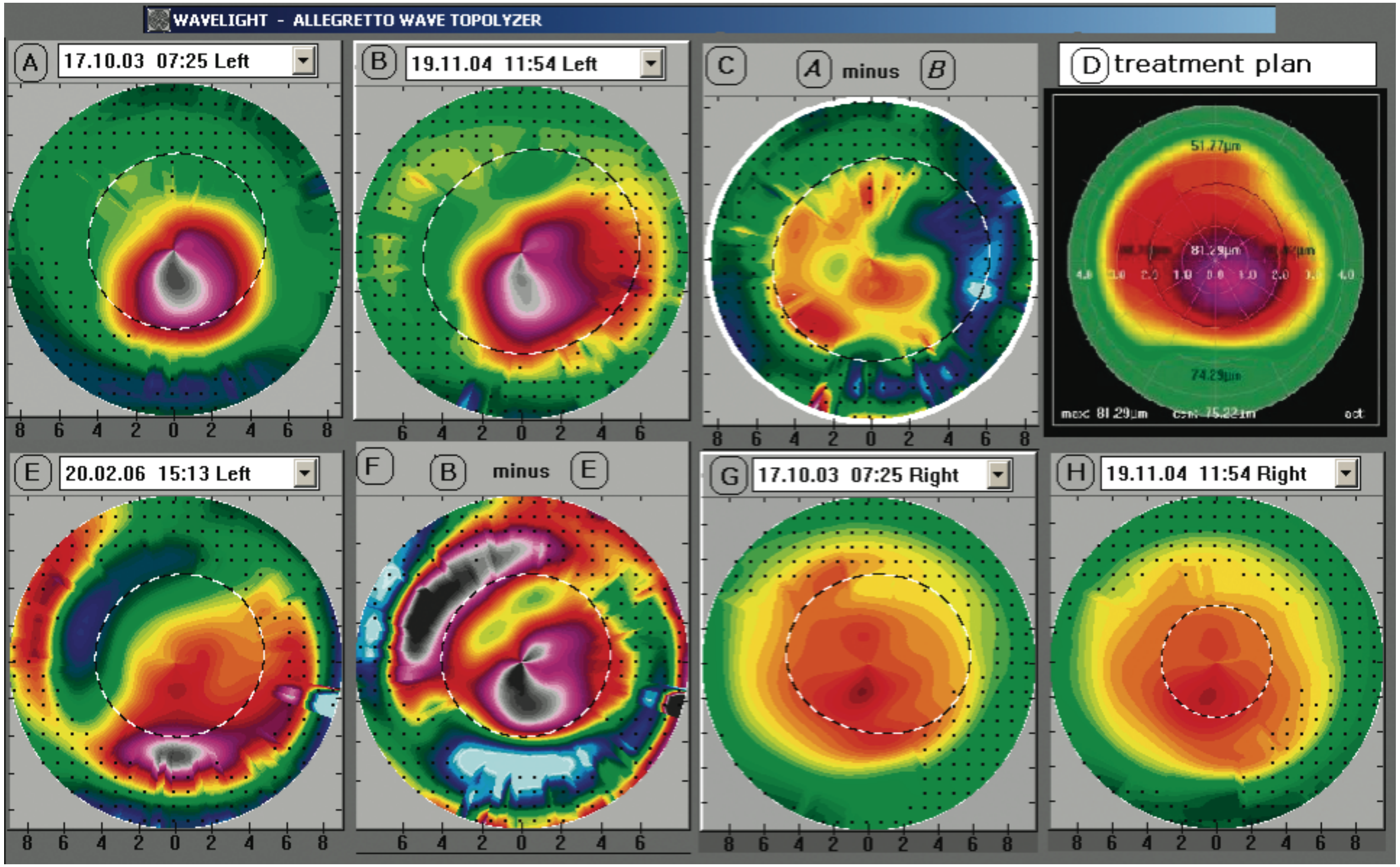


Patient: MPOVI, Anna
DOB(age): 01/01/1976 (36)
ID:
Disease: AK, CXL, LASIK MK
Ethnicity:
Gender: F
Operator:
Algorithm Version: A6, 9, 0, 27
Physician:
CL - Line SSI= 24.6
OD 12/05/2012 19:31:39
6.00 Scan Size (mm)
250 µm
012 13:21:44
6.00 Scan Size (mm)
250 µm

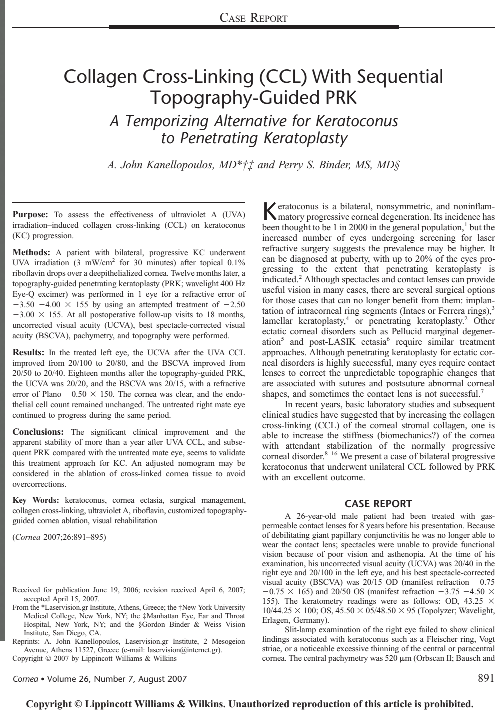

CXL of primary LenSx incision

Over the last 7 years we have treated over 800 cases of KCN and ectasia with CXL

J Cornea
August 2007



CXL followed 6 months later by a partial tPRK



CASE REPORT

Collagen Cross-Linking (CCL) With Sequential Topography-Guided PRK

A Temporizing Alternative for Keratoconus to Penetrating Keratoplasty

A. John Kanellopoulos, MD†‡ and Perry S. Binder, MS, MD§*

Purpose: To assess the effectiveness of ultraviolet A (UVA) irradiation–induced collagen cross-linking (CCL) on keratoconus (KC) progression.

Methods: A patient with bilateral, progressive KC underwent UVA irradiation (3 mW/cm^2 for 30 minutes) after topical 0.1% riboflavin drops over a deepithelialized cornea. Twelve months later, a topography-guided penetrating keratoplasty (PRK; wavelight 400 Hz Eye-Q excimer) was performed in 1 eye for a refractive error of −3.50 −4.00 × 155 by using an attempted treatment of −2.50 −3.00 × 155. At all postoperative follow-up visits to 18 months, uncorrected visual acuity (UCVA), best spectacle-corrected visual acuity (BSCVA), pachymetry, and topography were performed.

Results: In the treated left eye, the UCVA after the UVA CCL improved from 20/100 to 20/80, and the BSCVA improved from 20/50 to 20/40. Eighteen months after the topography-guided PRK, the UCVA was 20/20, and the BSCVA was 20/15, with a refractive error of Plano −0.50 × 150. The cornea was clear, and the endothelial cell count remained unchanged. The untreated right mate eye continued to progress during the same period.

Conclusions: The significant clinical improvement and the apparent stability of more than a year after UVA CCL, and subsequent PRK compared with the untreated mate eye, seems to validate this treatment approach for KC. An adjusted nomogram may be considered in the ablation of cross-linked cornea tissue to avoid overcorrections.

Key Words: keratoconus, cornea ectasia, surgical management, collagen cross-linking, ultraviolet A, riboflavin, customized topography-guided cornea ablation, visual rehabilitation

(*Cornea* 2007;26:891–895)

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From the *Laservision.gr Institute, Athens, Greece; the †New York University Medical College, New York, NY; the ‡Manhattan Eye, Ear and Throat Hospital, New York, NY; and the §Gordon Binder & Weiss Vision Institute, San Diego, CA.

Reprints: A. John Kanellopoulos, Laservision.gr Institute, 2 Mesogeion Avenue, Athens 11527, Greece (e-mail: laservision@internet.gr).

Keratoconus is a bilateral, nonsymmetric, and noninflammatory progressive corneal degeneration. Its incidence has been thought to be 1 in 2000 in the general population,[1] but the increased number of eyes undergoing screening for laser refractive surgery suggests the prevalence may be higher. It can be diagnosed at puberty, with up to 20% of the eyes progressing to the extent that penetrating keratoplasty is indicated.[2] Although spectacles and contact lenses can provide useful vision in many cases, there are several surgical options for those cases that can no longer benefit from them: implantation of intracorneal ring segments (Intacs or Ferrera rings),[3] lamellar keratoplasty,[4] or penetrating keratoplasty.[2] Other ectatic corneal disorders such as Pellucid marginal degeneration[5] and post-LASIK ectasia[6] require similar treatment approaches. Although penetrating keratoplasty for ectatic corneal disorders is highly successful, many eyes require contact lenses to correct the unpredictable topographic changes that are associated with sutures and postsuture abnormal corneal shapes, and sometimes the contact lens is not successful.[7]

In recent years, basic laboratory studies and subsequent clinical studies have suggested that by increasing the collagen cross-linking (CCL) of the corneal stromal collagen, one is able to increase the stiffness (biomechanics?) of the cornea with attendant stabilization of the normally progressive corneal disorder.[8–16] We present a case of bilateral progressive keratoconus that underwent unilateral CCL followed by PRK with an excellent outcome.

CASE REPORT

A 26-year-old male patient had been treated with gas-permeable contact lenses for 8 years before his presentation. Because of debilitating giant papillary conjunctivitis he was no longer able to wear the contact lens; spectacles were unable to provide functional vision because of poor vision and asthenopia. At the time of his examination, his uncorrected visual acuity (UCVA) was 20/40 in the right eye and 20/100 in the left eye, and his best spectacle-corrected visual acuity (BSCVA) was 20/15 OD (manifest refraction −0.75 −0.75 × 165) and 20/50 OS (manifest refraction −3.75 −4.50 × 155). The keratometry readings were as follows: OD, 43.25 × 10/44.25 × 100; OS, 45.50 × 05/48.50 × 95 (Topolyzer; Wavelight, Erlagen, Germany).

Slit-lamp examination of the right eye failed to show clinical findings associated with keratoconus such as a Fleischer ring, Vogt striae, or a noticeable excessive thinning of the central or paracentral cornea. The central pachymetry was 520 μm (Orbscan II; Bausch and

Cornea • Volume 26, Number 7, August 2007 891

The Athens Protocol 4 steps:

same day PTK > topoPRK > MMC > CXL (10mW/cm2 x 10 min)

1- PTK

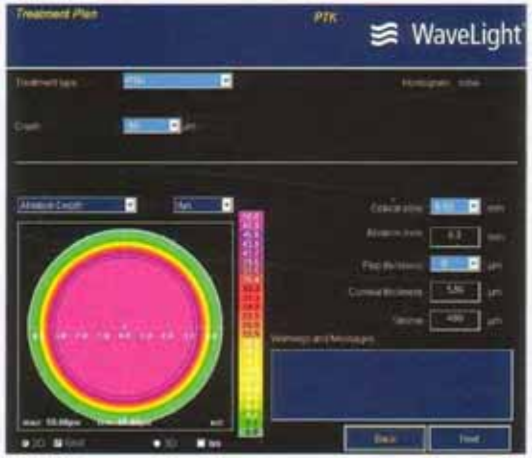


Figure 4.1: Epithelium removed with 50 micron PTK

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

4-: CXL

2- topo -guided PRK

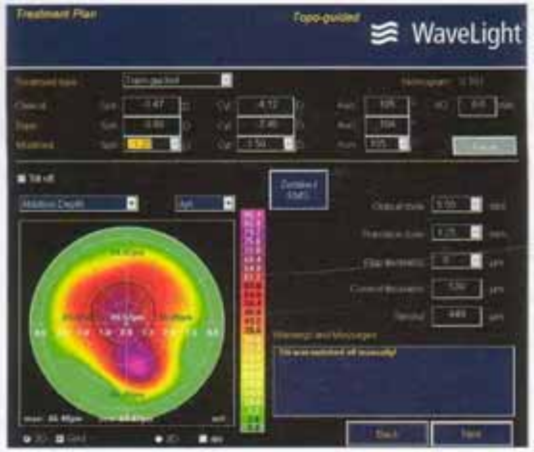


Figure 4.2: TC at treatment plan

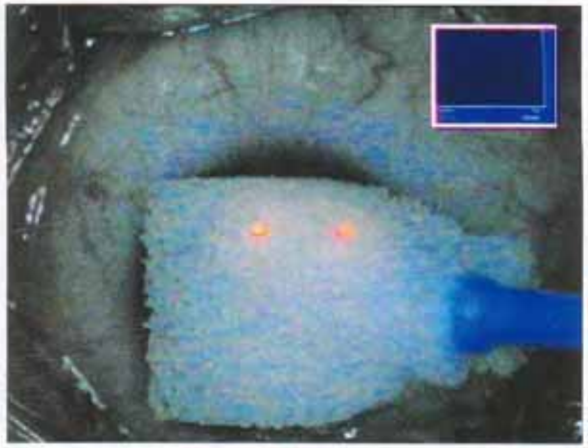
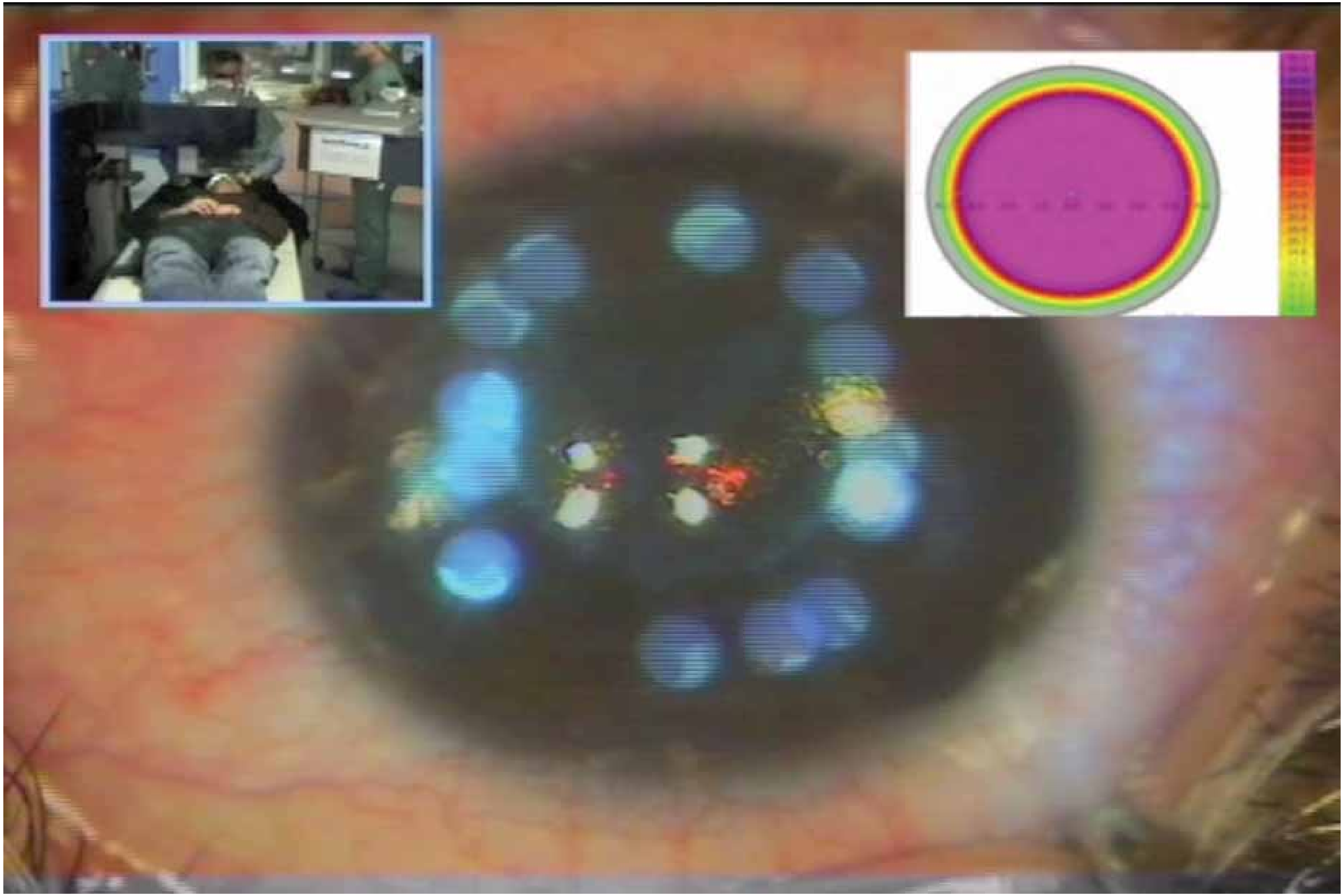


Figure 4.4: MMC solution 0.02% for 20 seconds

3- 30” MMC

Athens Protocol



The Athens Protocol
7-years

Stability of Simultaneous Topography-guided Photorefractive Keratectomy and Riboflavin/UVA Cross-linking for Progressive Keratoconus: Case Reports

Ronald R. Krueger, MD, MSE; A. John Kanellopoulos, MD

ORIGINAL ARTICLE

Management of Corneal Ectasia After LASIK With Combined, Same-day, Topography-guided Partial Transepithelial PRK and Collagen Cross-linking: The Athens Protocol

Anastasios John Kanellopoulos, MD; Perry S. Binder, MS, MD

ORIGINAL ARTICLE

Comparison of Sequential vs Same-day Simultaneous Collagen Cross-linking and Topography-guided PRK for Treatment of Keratoconus

Anastasios John Kanellopoulos, MD

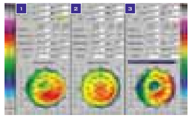
THE ATHENS PROTOCOL: PRK AND CXL

Clinical Ophthalmology

Dovepress

CASE REPORT

The management of cornea blindness from severe corneal scarring, with the Athens Protocol (transepithelial topography-guided PRK therapeutic remodeling, combined with same-day, collagen cross-linking)



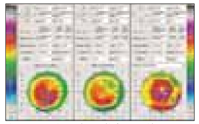
CROSS-LINKING IN FOUR CHAPTERS

COVER STORY

Sequential Versus Simultaneous CXL and Topography-Guided PRK

Simultaneous treatment appears to provide superior rehabilitation of keratoconus.

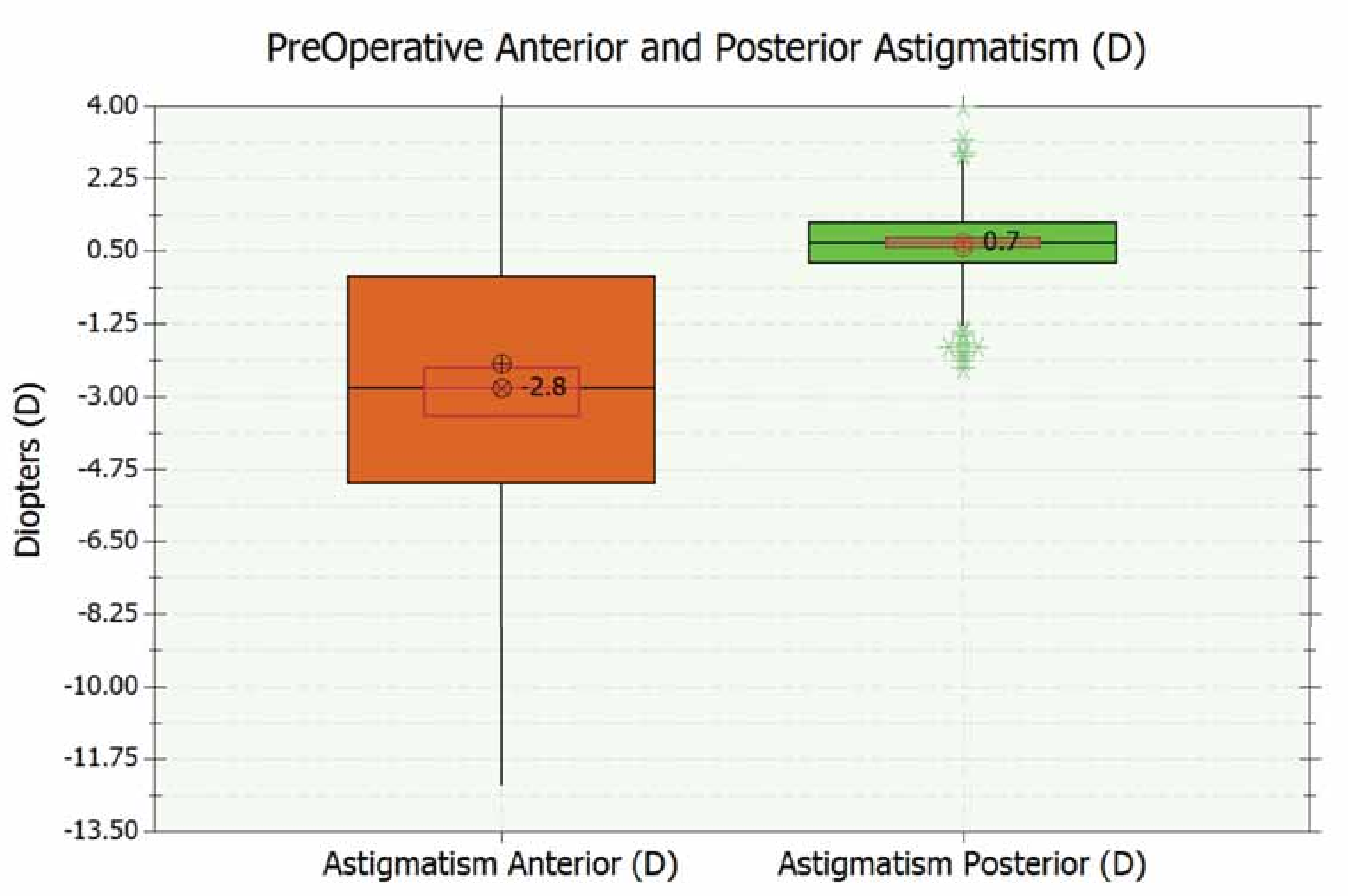
BY A. JOHN KANELLOPOULOS, MD



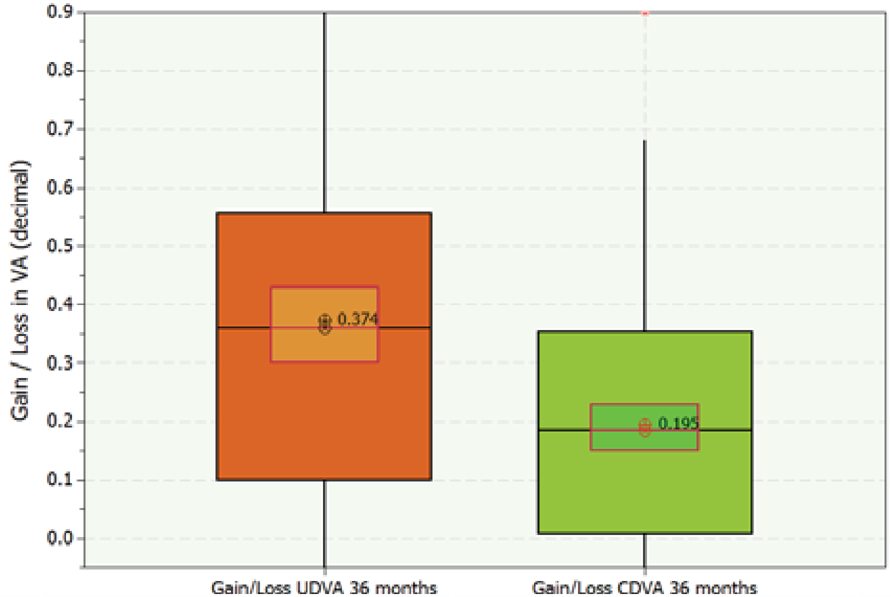
Surgical Techniques in Ophthalmology

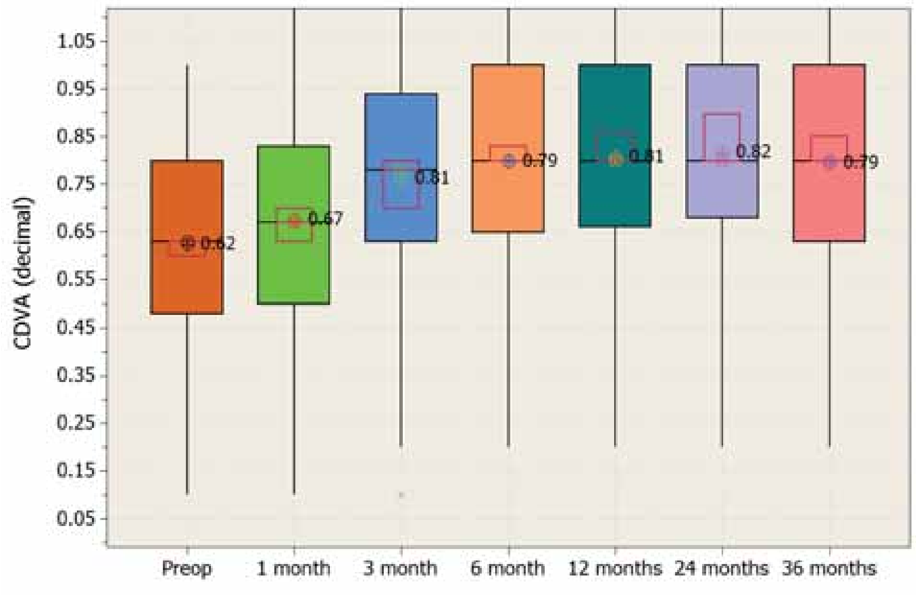
Corneal Surgery

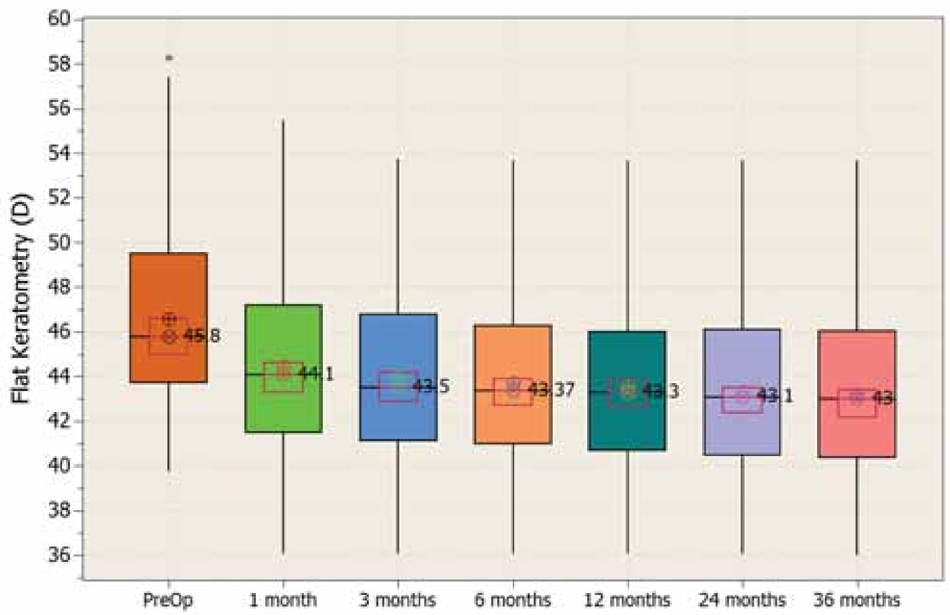
AthensProtocol

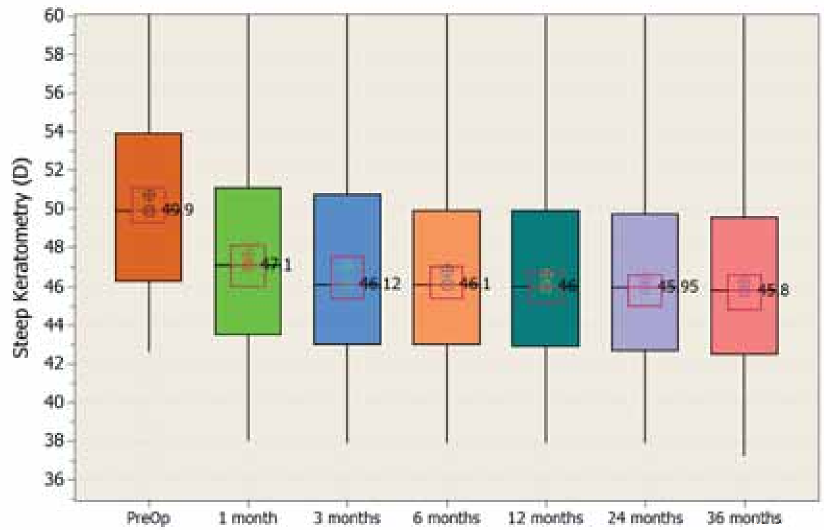


Athens protocol 36 months 500 cases

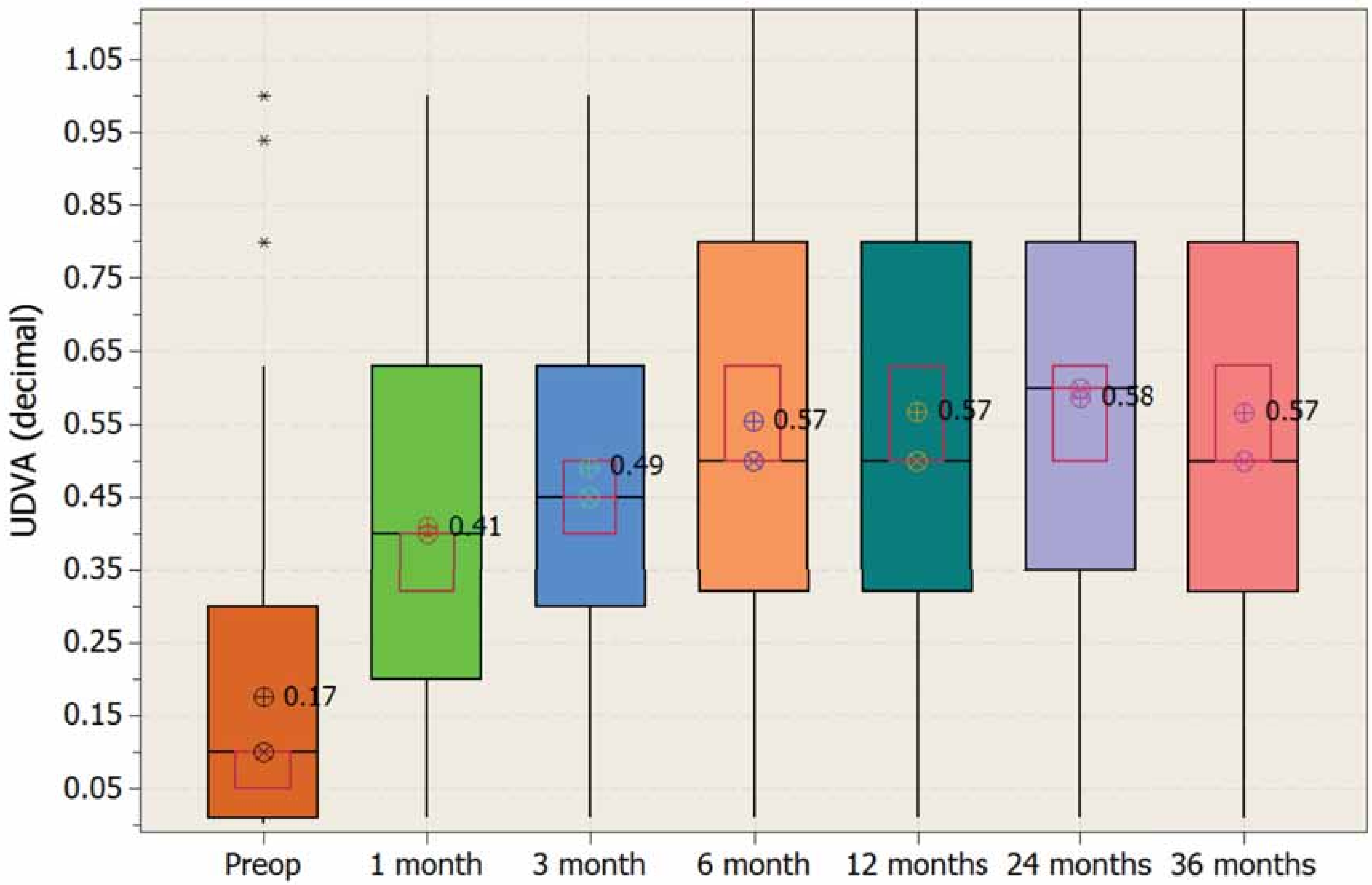






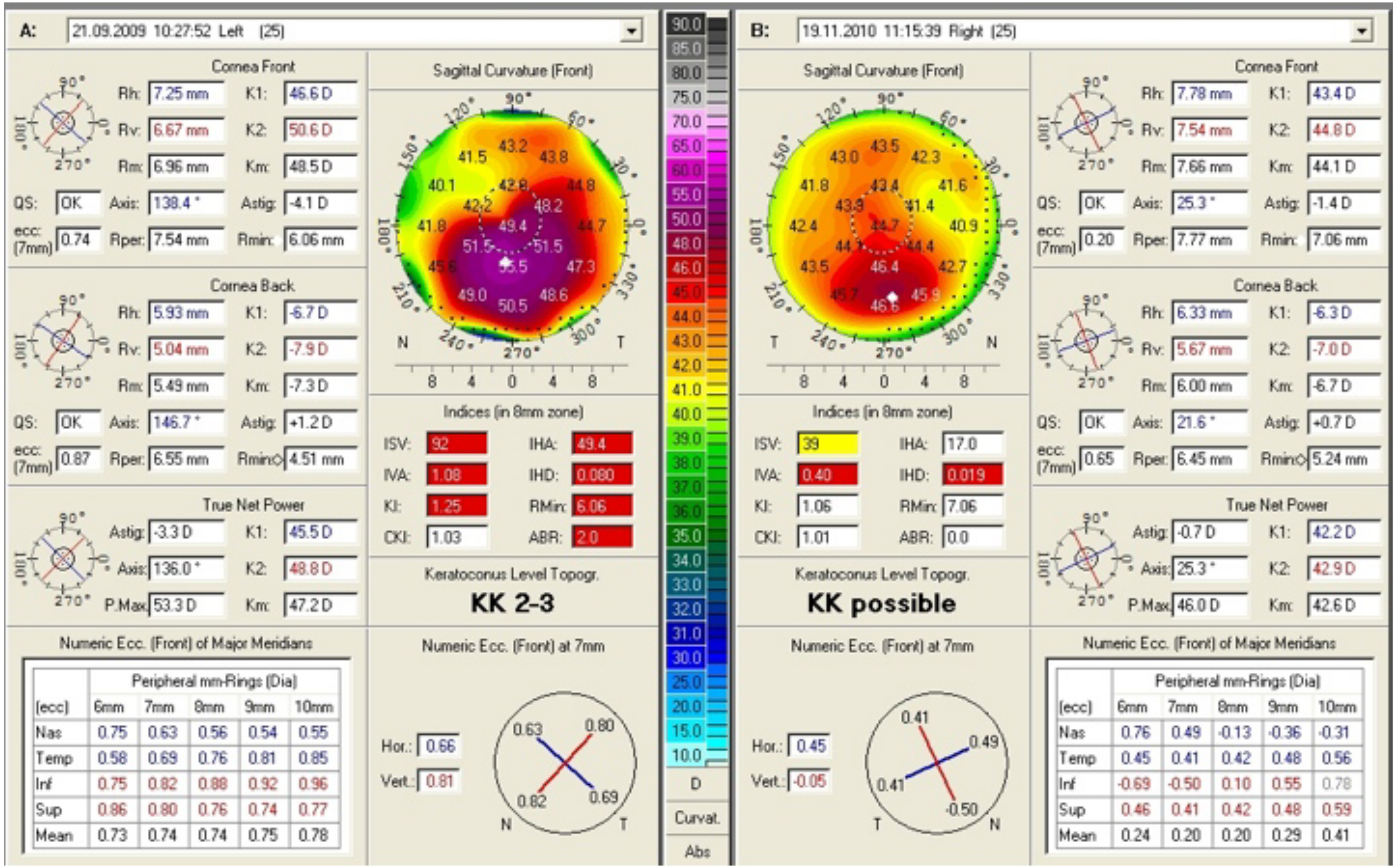


AP 36 months-UDVA



Average K from 48.5 to 44

Refraction -2.5-4.5@155 (20/70) to -1-1.5@10 (20/20)



[ecc]	6mm	7mm	8mm	9mm	10mm
Nas	0.75	0.63	0.56	0.54	0.55
Temp	0.58	0.69	0.76	0.81	0.85
Inf	0.75	0.82	0.88	0.92	0.96
Sup	0.86	0.80	0.76	0.74	0.77
Mean	0.73	0.74	0.74	0.75	0.78

[ecc]	6mm	7mm	8mm	9mm	10mm
Nas	0.76	0.49	-0.13	-0.36	-0.31
Temp	0.45	0.41	0.42	0.48	0.56
Inf	-0.69	-0.50	0.10	0.55	0.78
Sup	0.46	0.41	0.42	0.48	0.59
Mean	0.24	0.20	0.20	0.29	0.41

New York University School of Medicine

Kanellopoulos MD

LaserVision.gr Institute for laser

ASCRS 2012

Crosslinking and Long-Term Hyperopic LASIK Stability

Initial Clinical Findings in Contralateral Eye Study

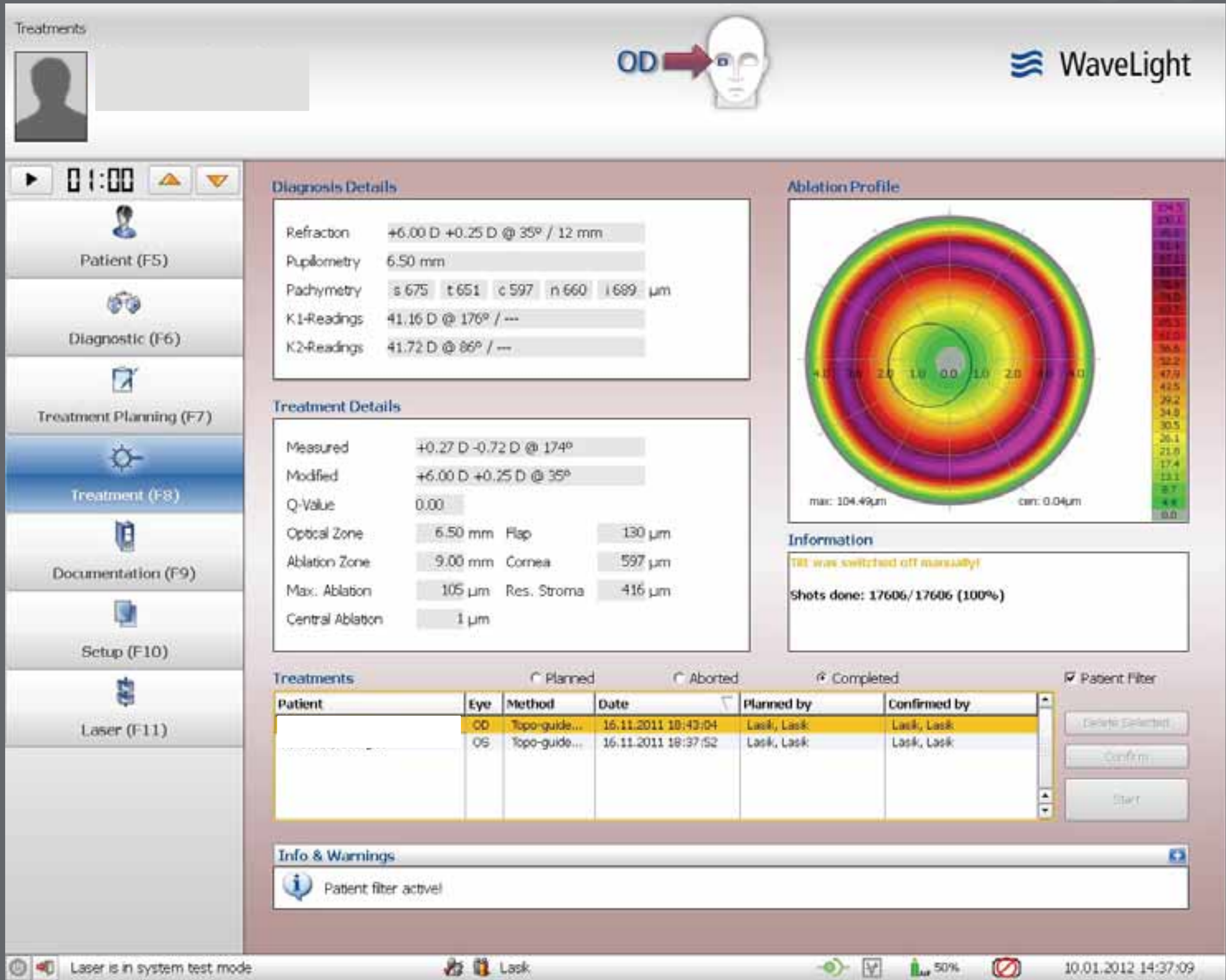
Jonathan B. Kahn, M.D.[1] and A. John Kanellopoulos, M.D.[1,2]

[1]New York University School of Medicine, New York, NY, USA

[2]Laservision.gr Institute, Athens, Greece

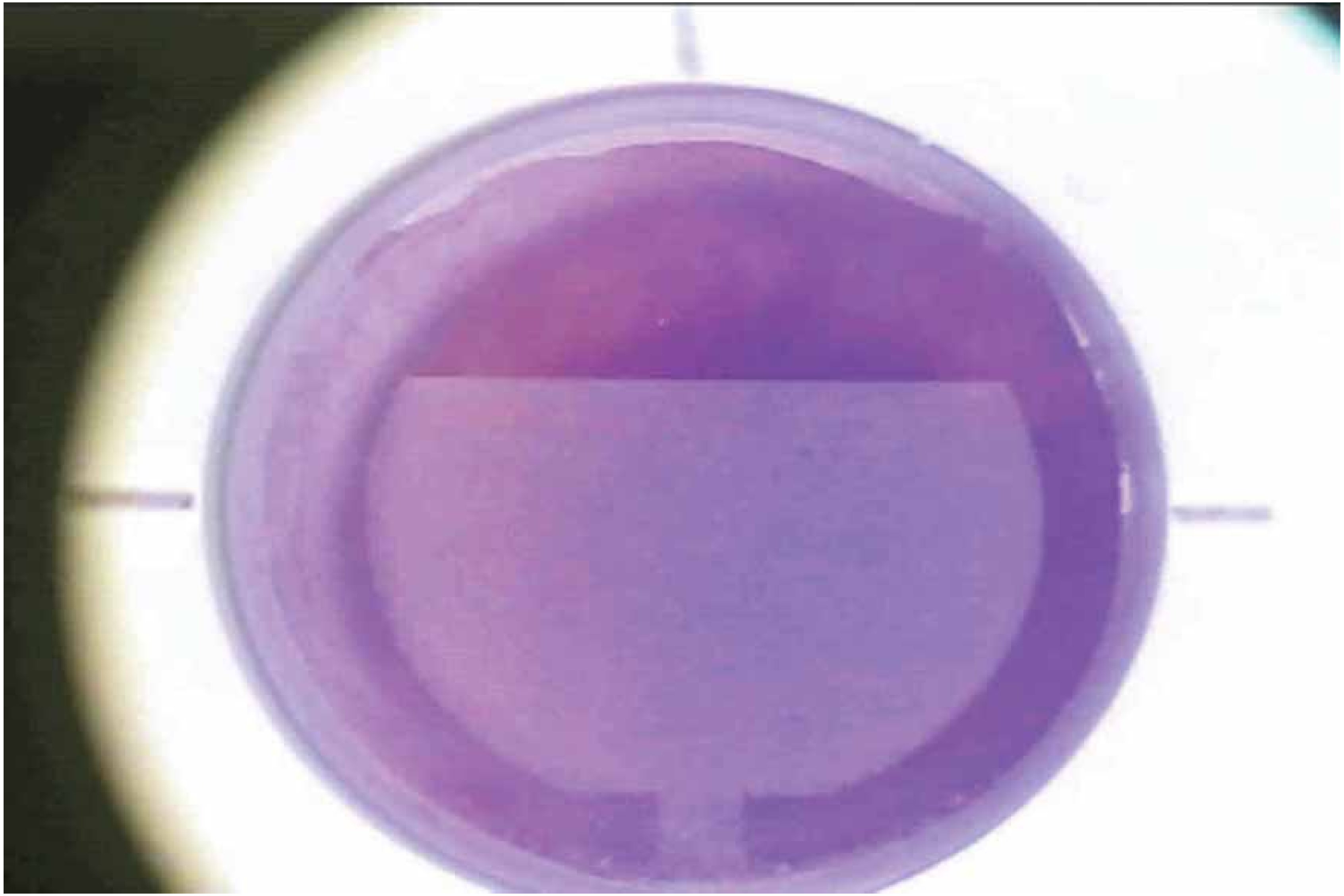
AJK is a consultant for Alcon, Wavelight and Avedro.

Topo-guided LASIK excimer treatment plan centered on visual axis

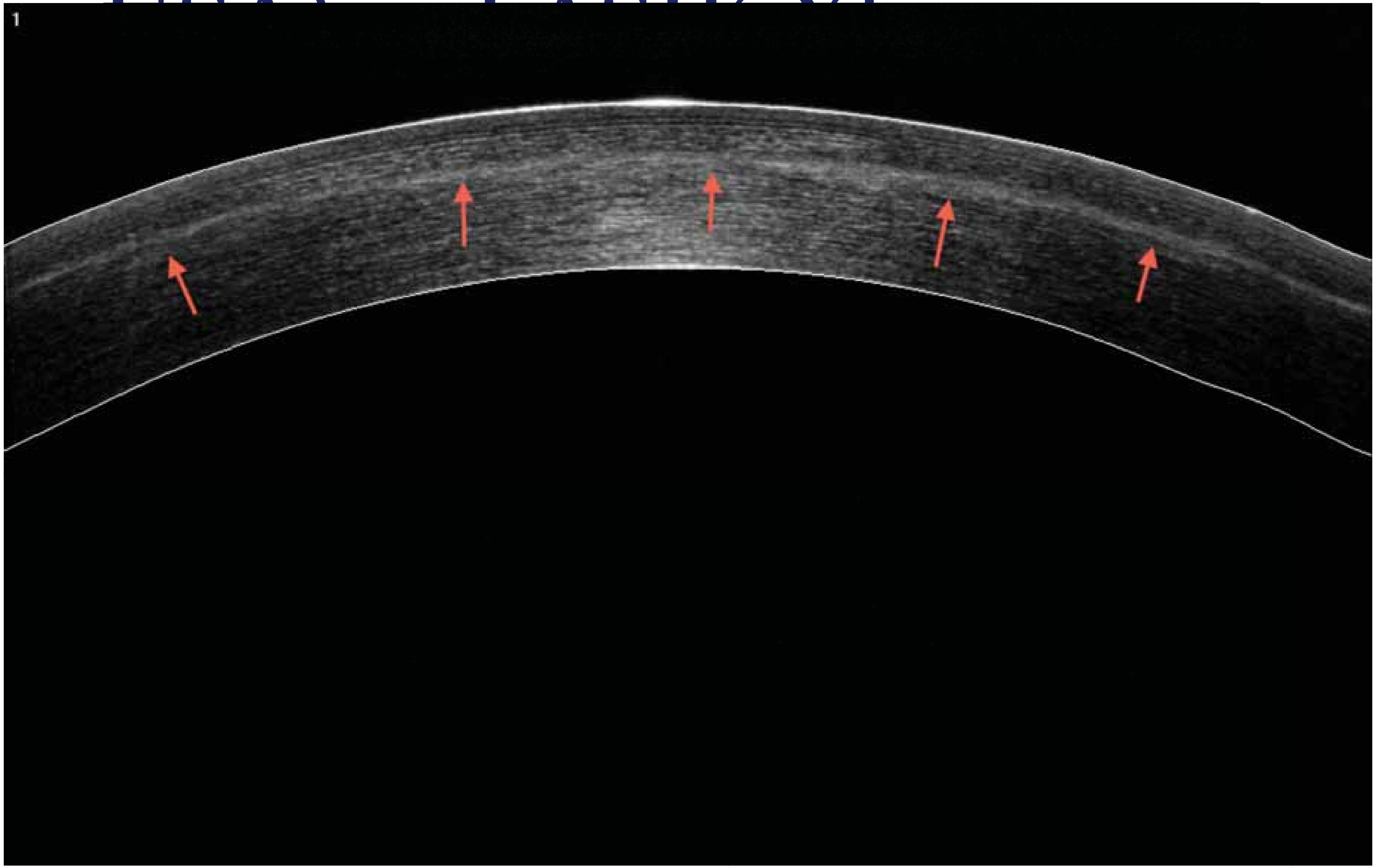


NYU School of Medicine
NYU LANGONE MEDICAL CENTER

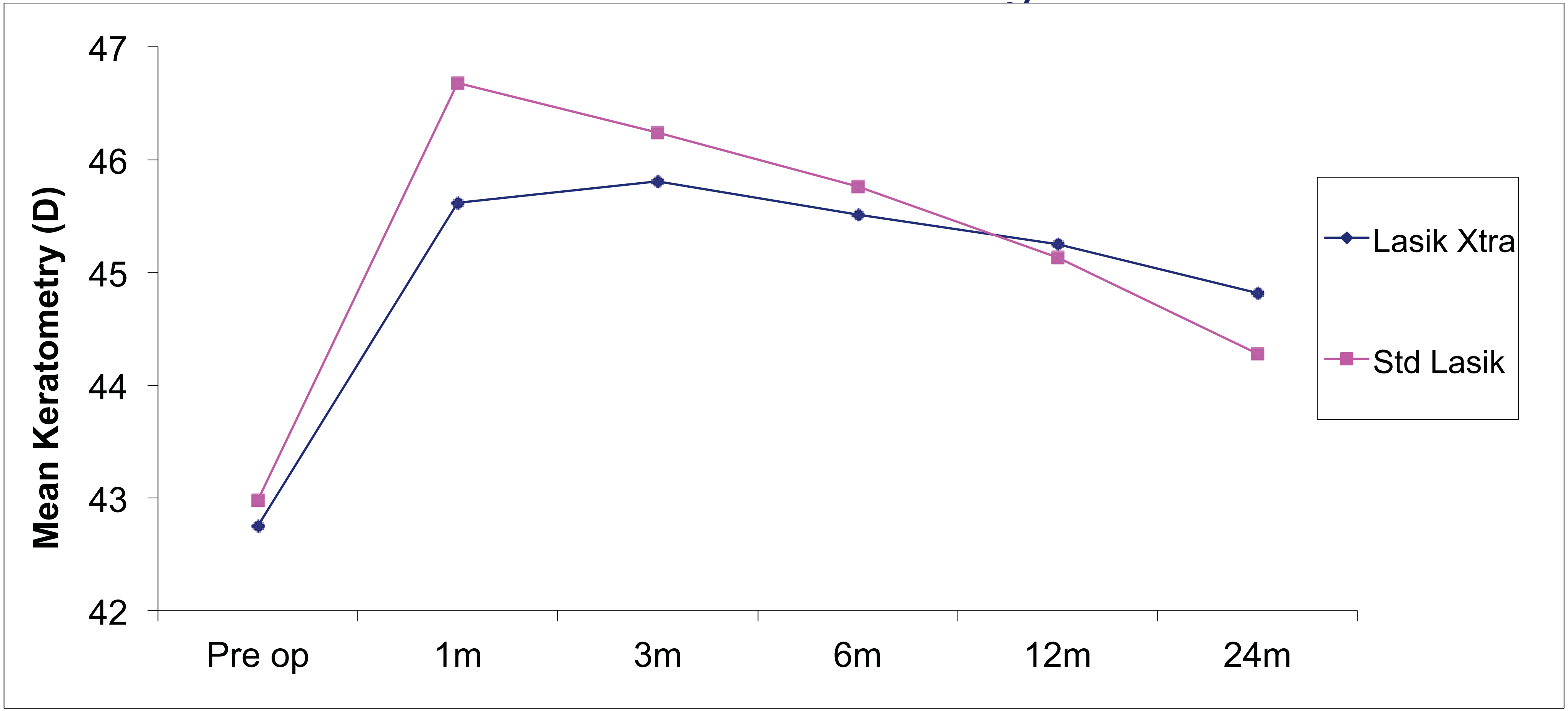
LASIK Xtra



Corneal OCT (Optovue, CA,



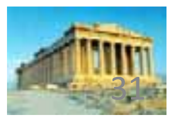
Comparison of Keratometric Stability



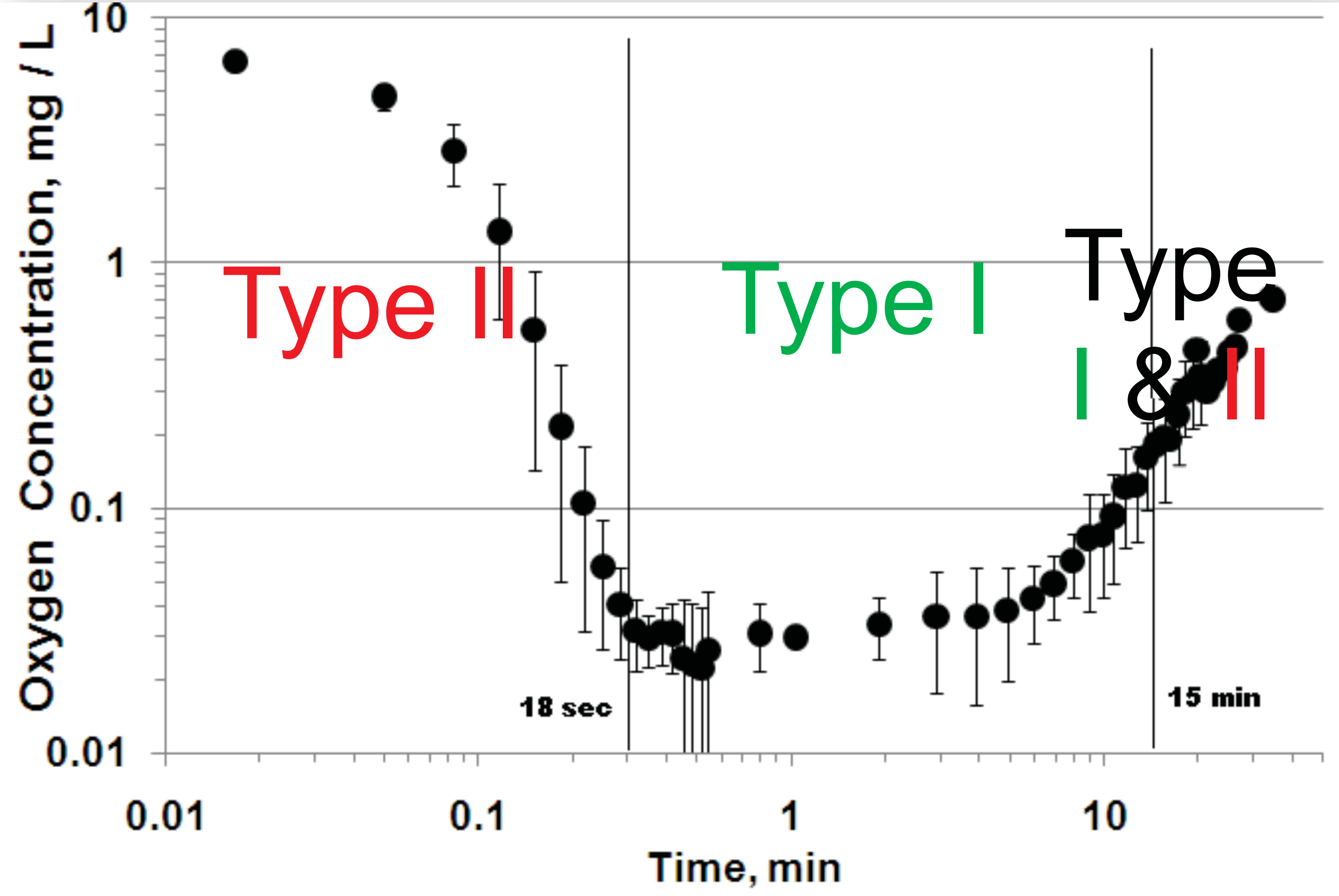
Kanellopoulos AJ, Kahn J: RS November 2012 supplement

Our current CXL protocols

- 1-**Athens Protocol**: topoPRK +10'x 10mw/cm^2
- 2-**LASIK Xtra:** 1' (90") 30mW/cm^2 all HYPERC
- 2-**PRK Xtra**: 1' (90") 30mW/cm^2
- 3- **femtoAK Xtra**: 3' 30mw/cm^2-no soaking!
- 4-Cataract incision Xtra: 45mW/cm2 for 2.5 min
- **5-TransepiCXL**: 0.25% ribo + 30mW X 3'
- **6-Infection**: 0.25% riboflavin + 45mW/cm^2 x 5 '

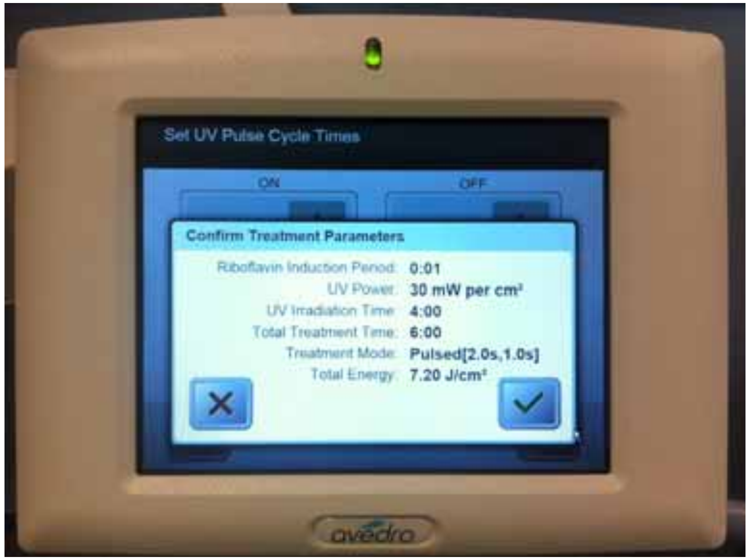


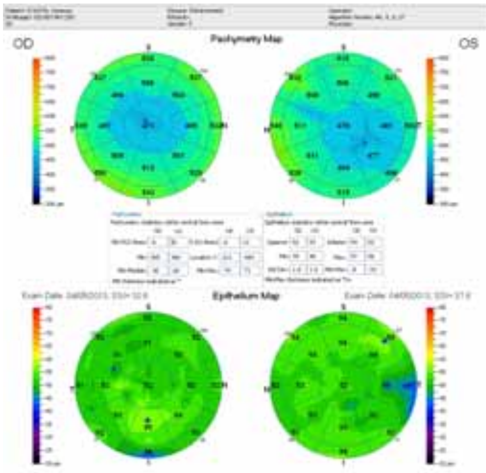
Oxygen Depletion Over 30 Minutes



Depletion and gradual replenishment of dissolved oxygen below a 100 µm thick corneal flap, saturated with 0.1% RF during 3 mW/cm² UVA irradiation at 25 ºC.

Pulsed CXL myopic LASIK Xtra





Thank you

Kanellopoulos MD