

Keratoconus Diagnosis and Progression Criteria Based on Multiple Imaging Devices



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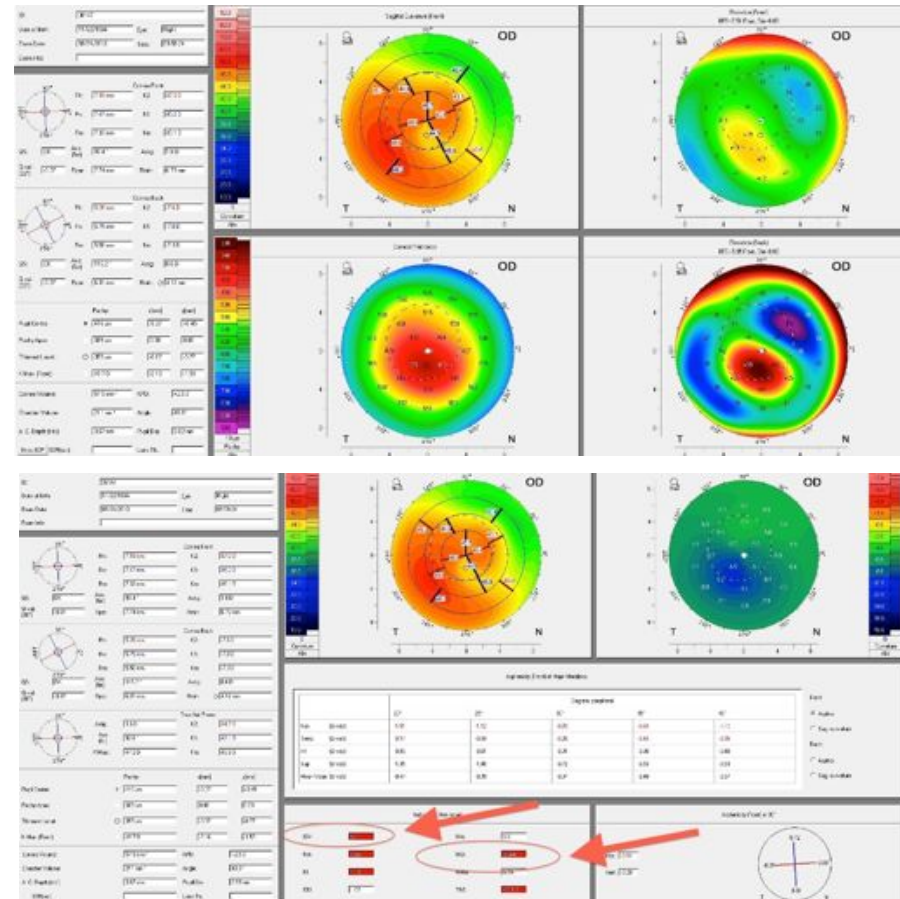
2: LaserVision.gr Eye Institute, Athens, Greece



Revisiting the Diagnosis and Progression criteria of Keratoconus

Traditionally:

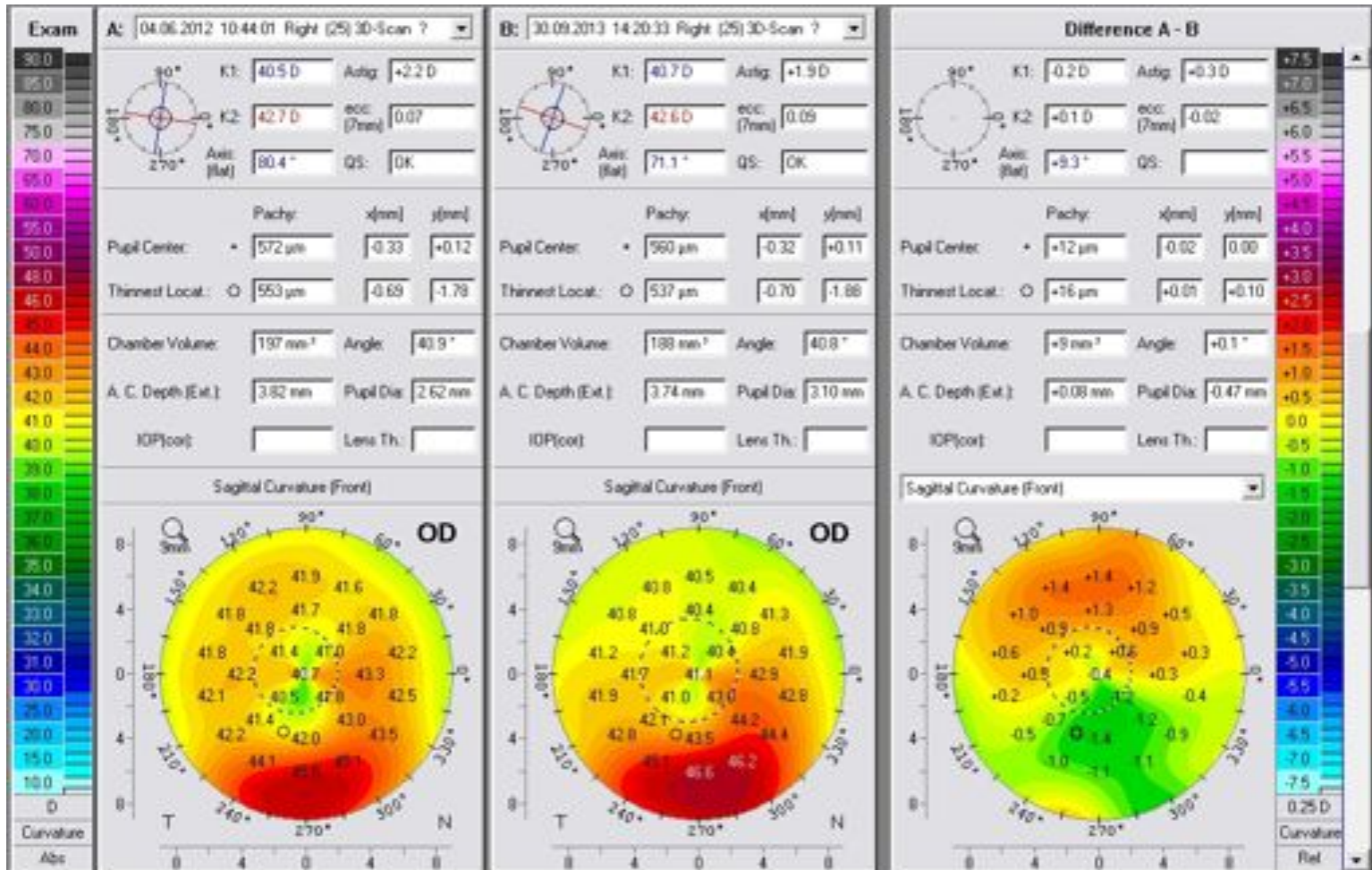
- Visual acuity
- Refraction
- Pachymetry
- Keratometry
- Anterior/inferior asymmetry
- Amsler-Krumeich criteria



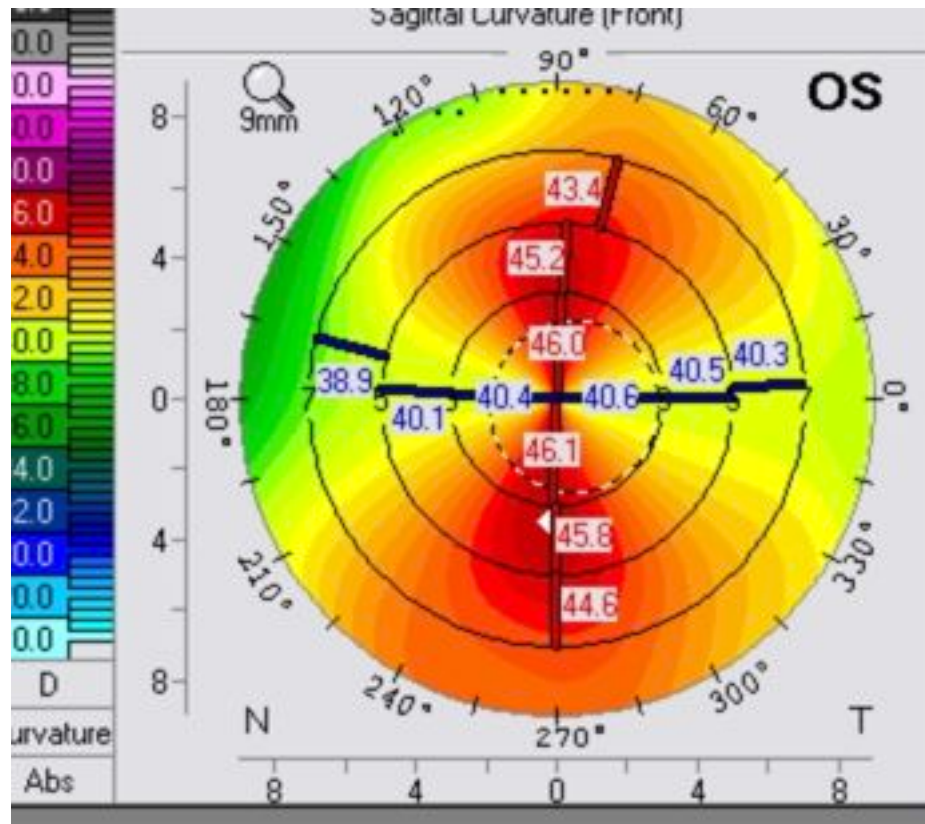
34y/o female MD with KCN:

2 years now asymptomatic:

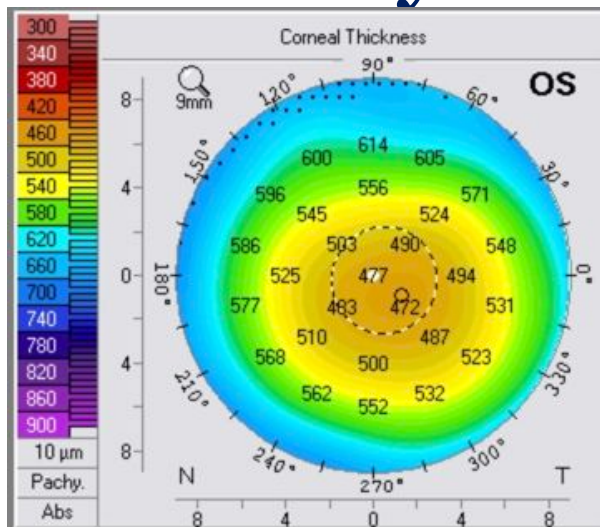
No change? 20/20, no K change



Current criteria may be inadequate



Current criteria may be inadequate



Pachymetry

Pachymetry statistics within central 5mm zone

SN-IT(2-5mm): 35 S-I(2-5mm): 30
 Min: 450 Location Y: -489
 Min-Median: -24 Min-Max: -76

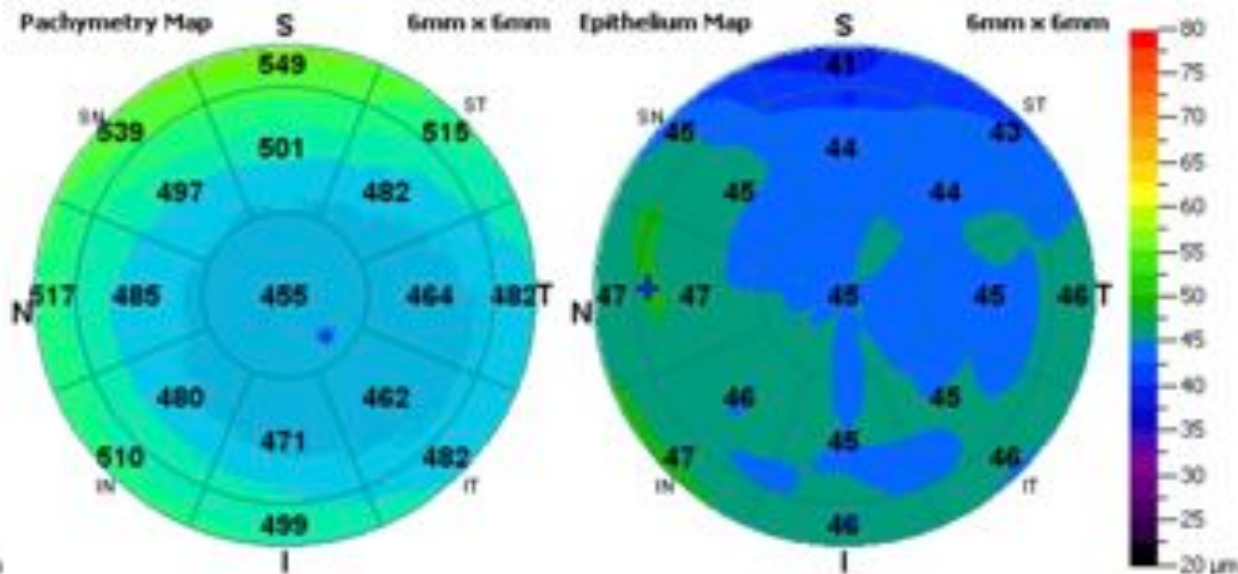
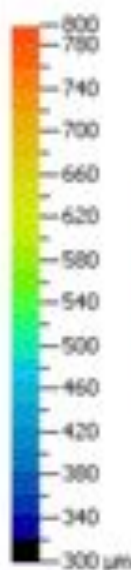
Min thickness at(0.495mm, -0.489mm) indicated as *

Epithelium

Epithelium statistics within central 5mm zone

Superior: 45 Inferior: 46
 Min: 42 Max: 48
 Std Dev: 1.1 Min-Max: -6

Min/Max thickness indicated as */+



Revisiting keratoconus diagnosis and progression classification based on evaluation of corneal asymmetry indices, derived from Scheimpflug imaging in keratoconic and suspect cases

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→ Video abstract



Point your smartphone at the code above. If you have a QR code reader the video abstract will appear. Or visit: <http://dx.doi.org/10.2147/OPTH.S44741>

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Purpose: To survey the standard keratoconus grading scale (Pentacam[®]-derived Amsler-Krumeich stages) compared to corneal irregularity indices and best spectacle-corrected distance visual acuity (CDVA).

Patients and methods: Two-hundred and twelve keratoconus cases were evaluated for keratoconus grading, anterior surface irregularity indices (measured by Pentacam imaging), and subjective refraction (measured by CDVA). The correlations between CDVA, keratometry, and the Scheimpflug keratoconus grading and the seven anterior surface Pentacam-derived topometric indices – index of surface variance, index of vertical asymmetry, keratoconus index, central keratoconus index, index of height asymmetry, index of height decentration, and index of minimum radius of curvature – were analyzed using paired two-tailed *t*-tests, coefficient of determination (r^2), and trendline linearity.

Results: The average \pm standard deviation CDVA (expressed decimally) was 0.626 ± 0.244 for all eyes (range 0.10–1.00). The average flat meridian keratometry was (K1) 46.7 ± 5.89 D; the average steep keratometry (K2) was 51.05 ± 6.59 D. The index of surface variance and the index of height decentration had the strongest correlation with topographic keratoconus grading ($P < 0.001$). CDVA and keratometry correlated poorly with keratoconus severity.

Conclusion: It is reported here for the first time that the index of surface variance and the index of height decentration may be the most sensitive and specific criteria in the diagnosis, progression, and surgical follow-up of keratoconus. The classification proposed herein may present a novel benchmark in clinical work and future studies.

Keywords: diagnosis and classification, Pentacam topometric indices, Amsler-Krumeich keratoconus grading, surface variance, vertical asymmetry, keratoconus index, central keratoconus index, height asymmetry, height decentration, minimum radius of curvature

Introduction

Keratoconus is described as a degenerative bilateral, progressive, noninflammatory corneal disorder characterized by ectasia, thinning, and increased curvature.^{1,2} It is associated with loss of visual acuity particularly in relation to progressive cornea irregularity,^{3,4} and usually is manifested asymmetrically between the two eyes of the same patient.^{5,6} Occasionally, the patient may present with symptoms of photophobia, glare, and monocular diplopia.

The problem of specificity and sensitivity of keratoconus assessment, particularly the diagnosis of early signs of ectasia and/or subclinical keratoconus, and for monitoring the progression of the disease, has been extensively studied.⁷ The commonly used

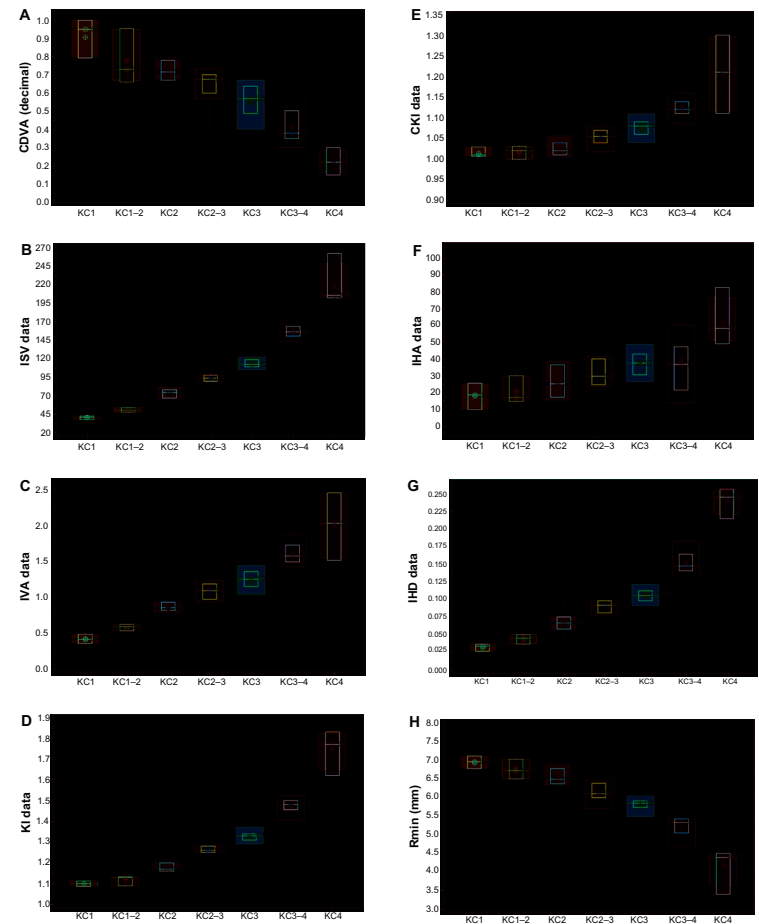


Figure 2 Box plots of measured parameters versus keratoconus grading, as produced by the Oculyzer[™] software, showing median level (indicated by □), average symbol (□), 95% median confidence range box (black line boxes), and interquartile intervals range box (red line boxes). (A) CDVA versus keratoconus grading. (B) ISV versus keratoconus grading. (C) IVA versus keratoconus grading. (D) KI versus keratoconus grading. (E) CKI versus keratoconus grading. (F) IHA versus keratoconus grading. (G) IHD versus keratoconus grading. (H) Rmin versus keratoconus grading.

Abbreviations: CDVA, best spectacle-corrected distance visual acuity; CKI, central keratoconus index; IHA, index of height asymmetry; IHD, index of height decentration; ISV, index of surface variance; IVA, index of vertical asymmetry; KC1, keratoconus grading Stage I–II; KC2, keratoconus grading Stage II; KC2–3, keratoconus grading Stage II–III; KC3, keratoconus grading Stage III; KC3–4, keratoconus grading Stage III–IV; KC4, keratoconus grading Stage IV; KI, keratoconus index; PI, prediction interval; Rmin, minimum radius of curvature.



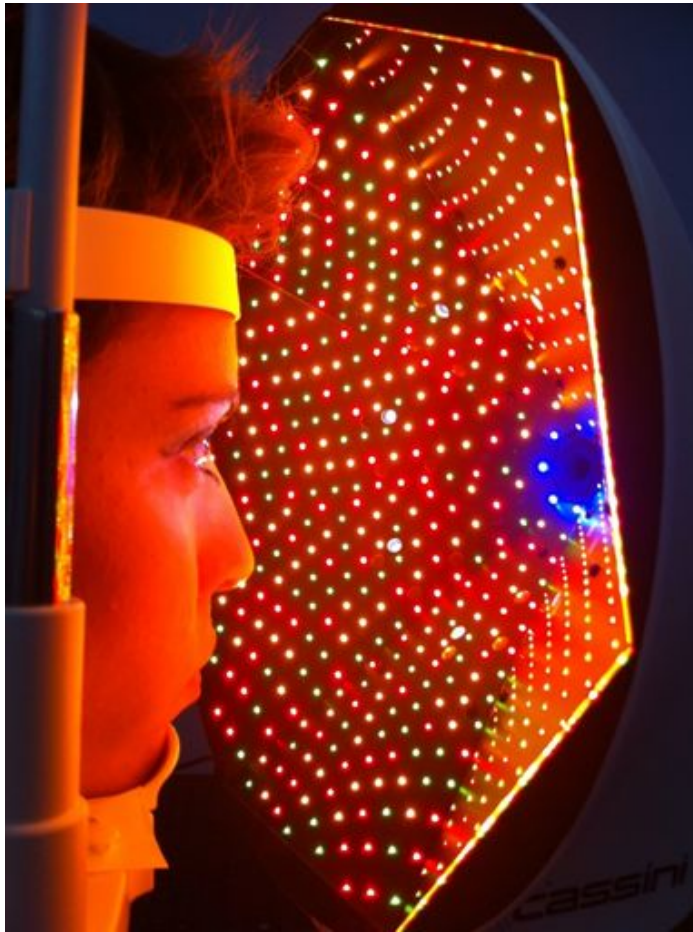
Purpose

To evaluate Keratoconus Diagnosis and Progression Assessment based on modern anterior segment imaging modalities:

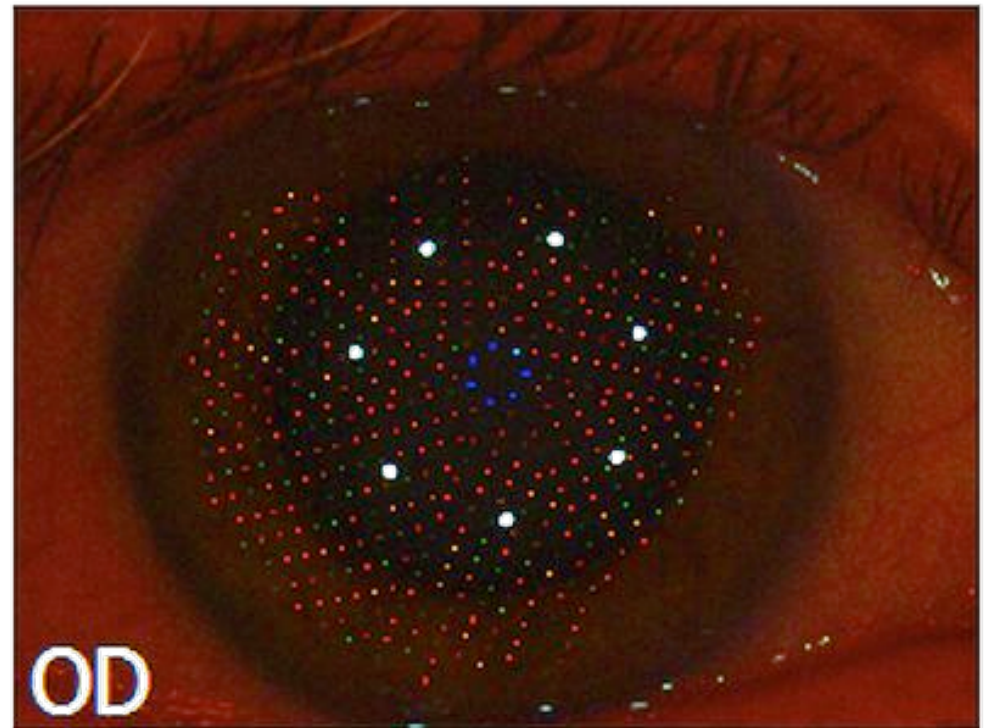
- Scheimpflug imaging,
- Placido Topography,
- Anterior-Segment Optical Coherence Tomography (AS-OCT), and
- novel Multi-colored Spot Reflection Topography (MSRT).



Cassini



Recorded image



Methods

Two hundred fifty (250) keratoconic cases were evaluated for keratoconic grading and anterior surface indexing by

- Scheimpflug imaging (Oculus II, WaveLight AG, Erlagen, Germany),
- Placido Topography (Vario Topolyzer, WaveLight AG, Erlagen, Germany),
- AS-OCT (RTVue-100, Optovue Inc., Fremont, CA) and
- a newly-introduced MSRT (Cassini, i-Optics, the Hague, The Netherlands).

The correlations between Scheimpflug- and Placido- derived keratoconic grading and anterior-surface irregularity indices for keratoconus were assessed with the AS-OCT and the PCT- derived keratoconus indices employing paired two-tailed t-tests, Bland-Altman plots, coefficient of determination (r^2), and trend line linearity.



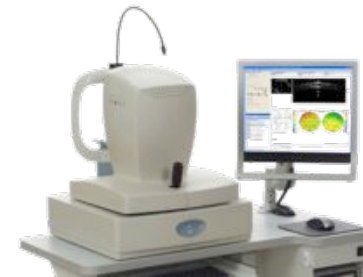
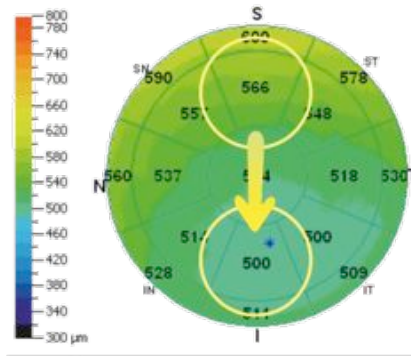
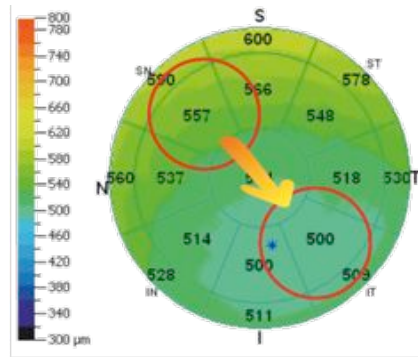
Anterior-Surface Indices

- ISV: the unitless standard deviation of individual corneal sagittal radii from the mean curvature.
 - ISV is thus an expression of the corneal surface irregularity.
- IHD: the value of the decentration of elevation data in the vertical direction (expressed in μm), and is calculated from a Fourier analysis.
 - This index provides the degree of decentration in the vertical direction, calculated on a ring with radius 3 mm. An IHD value larger than 0.014 is considered abnormal, and larger than 0.016 is pathological.
- Objective anterior-surface imaging topographical data



AS-OCT-derived Indices

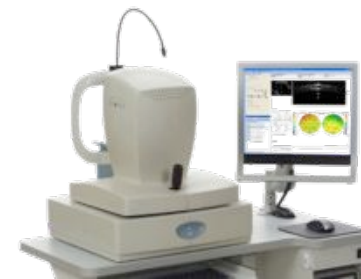
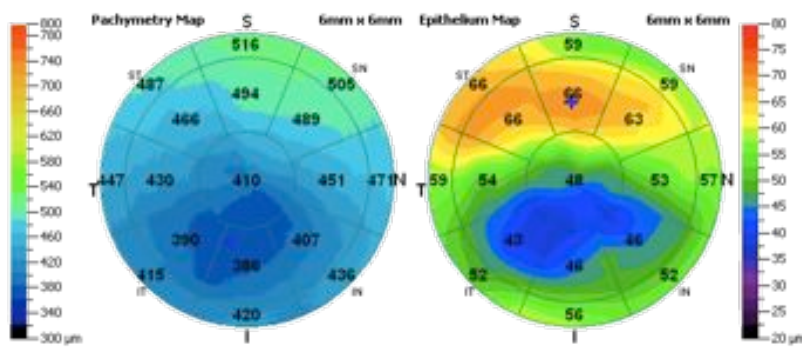
- Corneal thickness asymmetry indices
 - SN-IT, average superior-nasal octant thickness minus inferior-temporal;
 - S-I, superior minus inferior thickness



- Focal thinning indices
 - Min-Med focal thinning, minimum minus median thickness;
 - Min-Max thickness range, minimum minus maximum thickness.

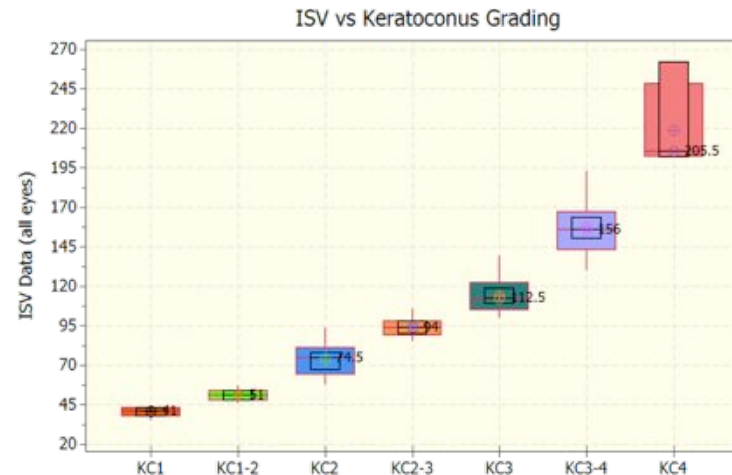
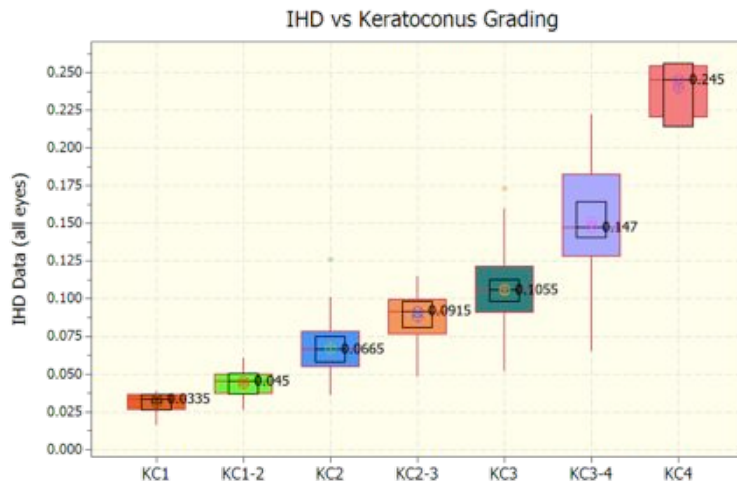
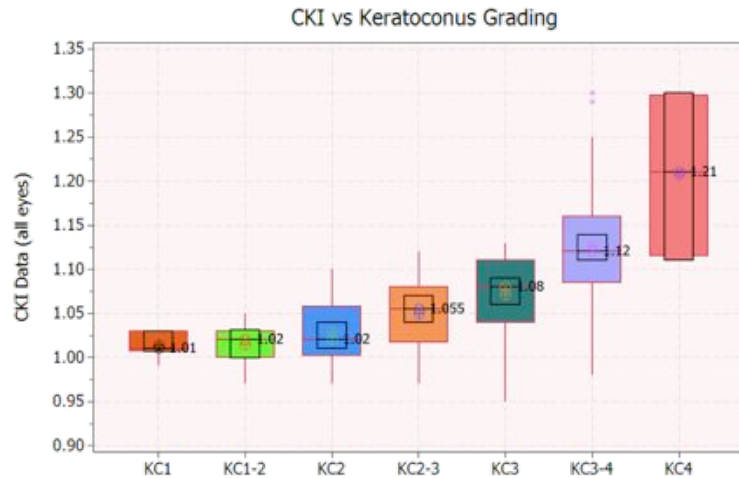
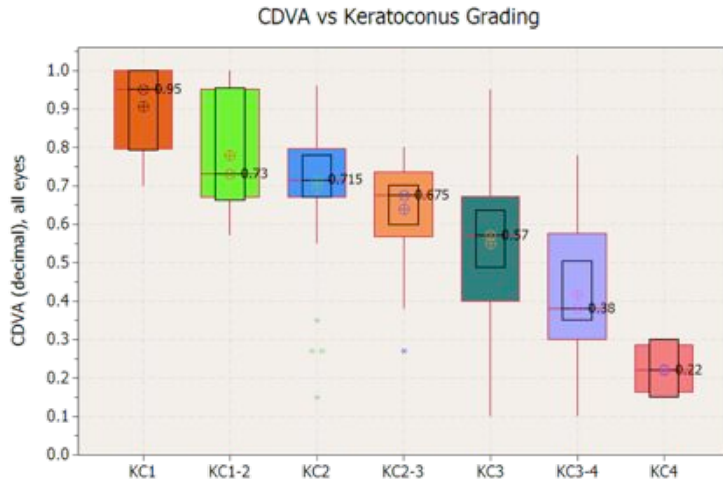
AS-OCT-derived Indices

- Epithelial thickness asymmetry indices
 - Topographic variability (Stdev of 17 points);
 - Thickness range (Max – Min)



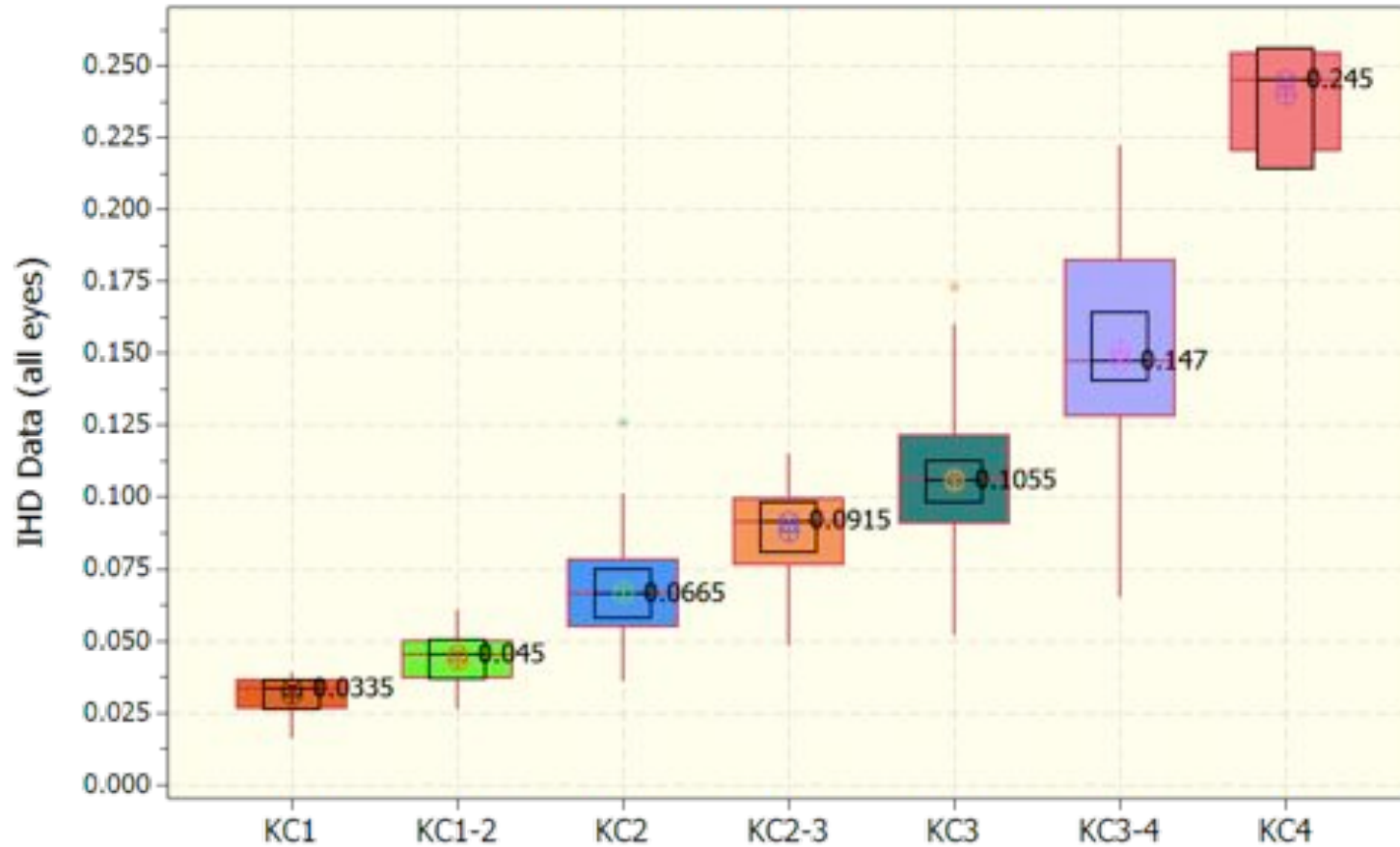
- Overall epithelial thickness
 - Mean epithelial thickness;
 - Superior - Inferior.

Vision, Ks, pachymetry = almost irrelevant in KCN cases test ISV and IHD



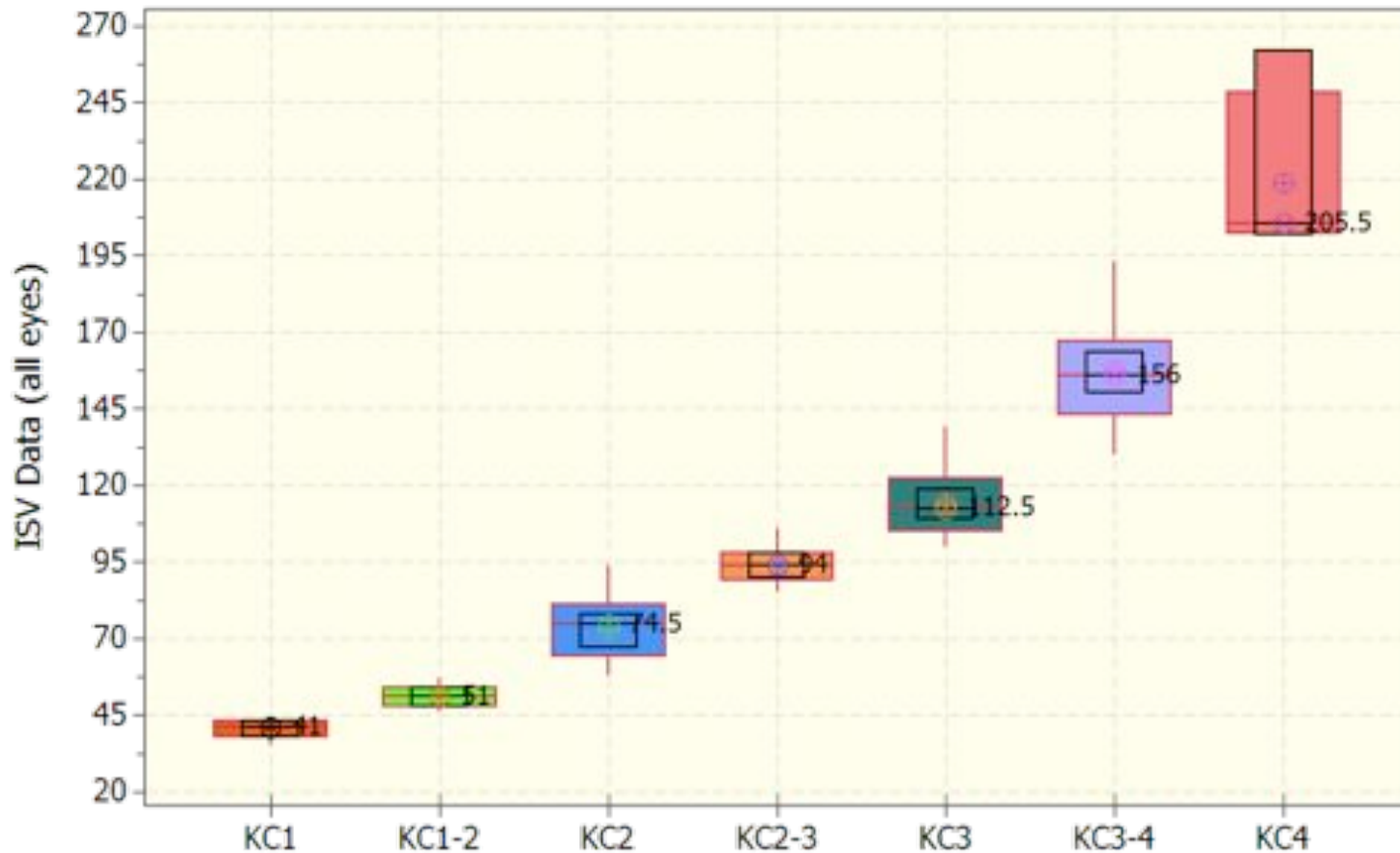
IHD vs. A-K Criteria

IHD vs Keratoconus Grading



ISV vs. A-K Criteria

ISV vs Keratoconus Grading



A: 04.06.2012 10:44:01 Right (25) 3D-Scan ?

Cornea Front

Rt: 8.33 mm K1: 43.5 D
 Rc: 7.91 mm K2: 42.7 D
 Rm: 8.12 mm Km: 41.6 D

QS: OK Axis: 80.4° Astig: +2.2 D
 ecc: (7mm) 0.07 Rper: 8.04 mm Rmin: 7.25 mm

Cornea Back

Rt: 7.61 mm K1: 5.3 D
 Rc: 6.76 mm K2: 5.9 D
 Rm: 7.19 mm Km: 5.6 D

QS: OK Axis: 77.9° Astig: -0.7 D
 ecc: (7mm) -0.36 Rper: 6.80 mm Rmin: 5.86 mm

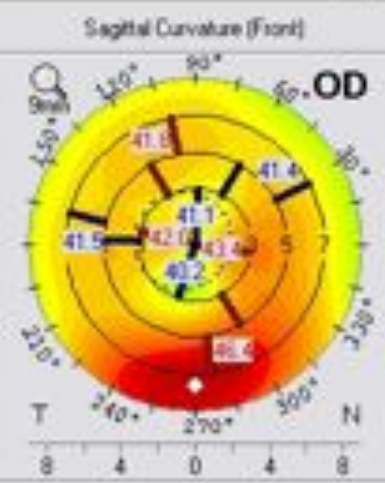
True Net Power

Astig: -1.9 D K1: 39.7 D
 Axis: 80.7° K2: 41.6 D
 P.Max: 45.1 D Km: 40.7 D

K Max (Front): 46.5 D 0.00 -3.78

Numeric Ecc. (Front) of Major Meridians

[ecc]	Peripheral mm-Rings (Dia)				
	6mm	7mm	8mm	9mm	10mm
Nas	0.70	0.76	0.80	0.82	0.83
Temp	0.35	0.45	0.54	0.61	0.67
Inf	-1.28	-1.12	-0.93	-0.70	-0.38
Sup	-0.32	0.19	0.38	0.48	0.55
Mean	-0.14	0.07	0.20	0.30	0.42



Indices (in Brn zone)

ISV: 31 IHA: 7.3
 IVA: 0.28 IHD: 0.010
 KI: 1.04 RMin: 7.25
 OK: 0.97 TKC: -

Numeric Ecc. (Front) at 7mm

Hor: 0.61
 Vert: 0.46

B: 30.09.2013 14:20:33 Right (25) 3D-Scan ?

Cornea Front

Rt: 8.30 mm K1: 40.7 D
 Rc: 7.93 mm K2: 42.6 D
 Rm: 8.11 mm Km: 41.6 D

QS: OK Axis: 71.1° Astig: +1.9 D
 ecc: (7mm) 0.09 Rper: 8.03 mm Rmin: 7.11 mm

Cornea Back

Rt: 7.70 mm K1: 5.2 D
 Rc: 6.79 mm K2: 5.9 D
 Rm: 7.24 mm Km: 5.5 D

QS: OK Axis: 80.7° Astig: -0.7 D
 ecc: (7mm) -0.44 Rper: 6.78 mm Rmin: 5.76 mm

True Net Power

Astig: -1.5 D K1: 40.1 D
 Axis: 64.6° K2: 41.6 D
 P.Max: 46.1 D Km: 40.8 D

K Max (Front): 47.5 D -0.55 -3.58

Numeric Ecc. (Front) at 7mm

Hor: 0.54
 Vert: 0.35

Cornea Front

Rt: 8.30 mm K1: 40.7 D
 Rc: 7.93 mm K2: 42.6 D
 Rm: 8.11 mm Km: 41.6 D

QS: OK Axis: 71.1° Astig: +1.9 D
 ecc: (7mm) 0.09 Rper: 8.03 mm Rmin: 7.11 mm

Cornea Back

Rt: 7.70 mm K1: 5.2 D
 Rc: 6.79 mm K2: 5.9 D
 Rm: 7.24 mm Km: 5.5 D

QS: OK Axis: 80.7° Astig: -0.7 D
 ecc: (7mm) -0.44 Rper: 6.78 mm Rmin: 5.76 mm

True Net Power

Astig: -1.5 D K1: 40.1 D
 Axis: 64.6° K2: 41.6 D
 P.Max: 46.1 D Km: 40.8 D

K Max (Front): 47.5 D -0.55 -3.58

Numeric Ecc. (Front) of Major Meridians

[ecc]	Peripheral mm-Rings (Dia)				
	6mm	7mm	8mm	9mm	10mm
Nas	0.55	0.64	0.71	0.76	0.81
Temp	0.42	0.43	0.47	0.51	0.56
Inf	-1.13	-0.96	-0.76	-0.49	0.31
Sup	0.07	0.26	0.36	0.45	0.53
Mean	-0.02	0.09	0.19	0.31	0.55

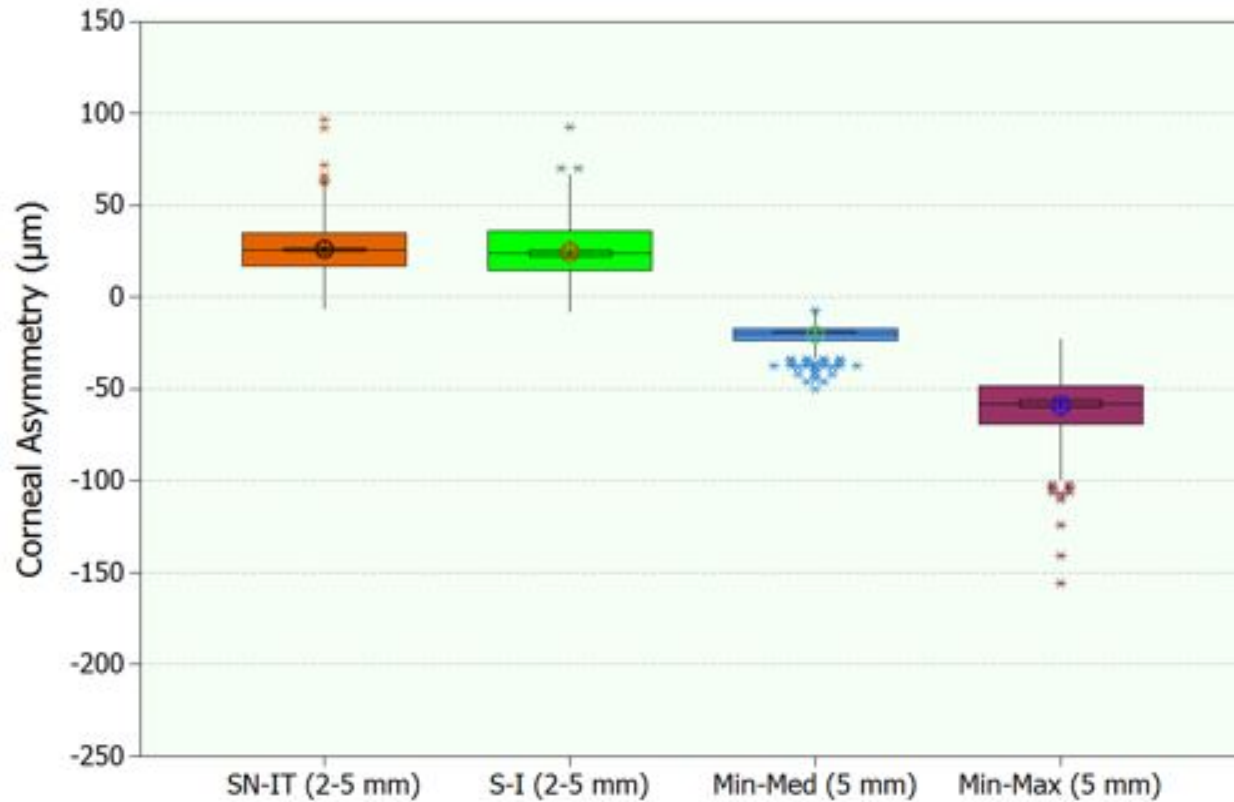


ISV & IHD vs Keratometry & Visual Acuity

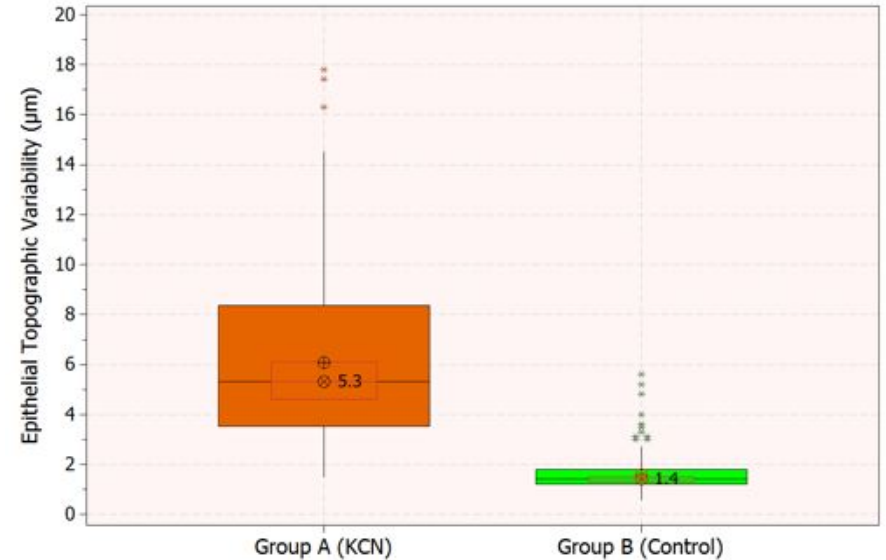
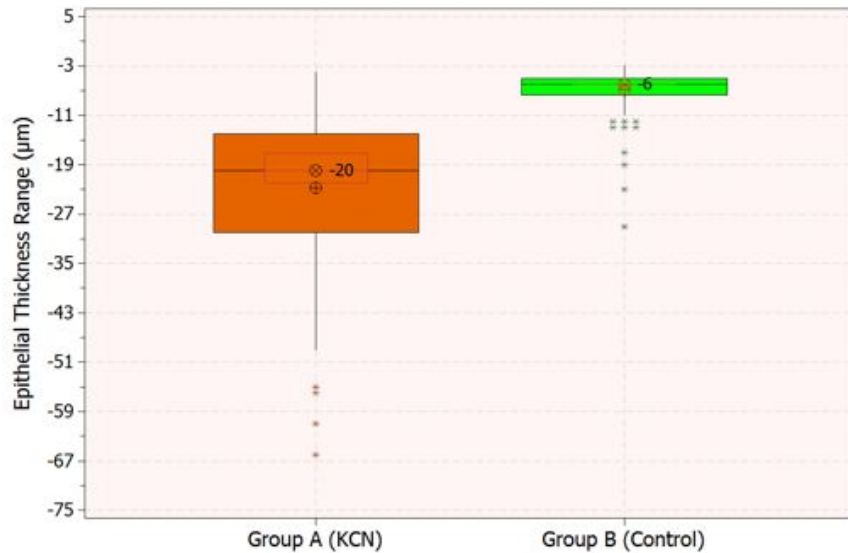
- ISV The index of surface variance and the
- IHD index of height decentration had the strongest correlation with topographic keratoconus grading (P , 0.001).
- CDVA and keratometry correlated poorly with keratoconus severity.
- These are compelling data and suggest, we have to reconsider the KCN diagnosis and progression benchmark parameters.



OCT Corneal Indices in KCN



OCT Epithelial Indices



Results

- Excellent agreement among the Scheimpflug- and Placido- derived keratoconic grading and anterior-surface irregularity indices for keratoconus with the AS-OCT and the Cassini – derived keratoconus was observed.
- **Increased topographic thickness variability and range was found to be in correlation with keratoconus severity**, quantitatively expressed with Scheimpflug imaging-derived anterior-surface irregularity indices.



Conclusions

- The quantitative anterior-segment topographic indices may help aid in early diagnosis,
- proper-monitoring and surgical follow-up in keratoconus by providing quantitative measure of ectasia progression.
- We present a benchmark for future studies for the development of keratoconus diagnosis, possibly providing an effective tool for early diagnosis of ectasia in order to offer cross-linking or other ectasia-management and procedures monitoring.



Thank you!

