Novel Keratoconus Diagnosis and Progression Criteria Based on Multiple Anterior Segment Imaging Devices

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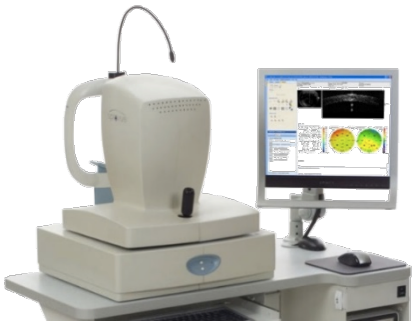
Purpose

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)



Methods

250 keratoconic and 160 control cases were evaluated for keratoconic grading and anterior surface indexing by

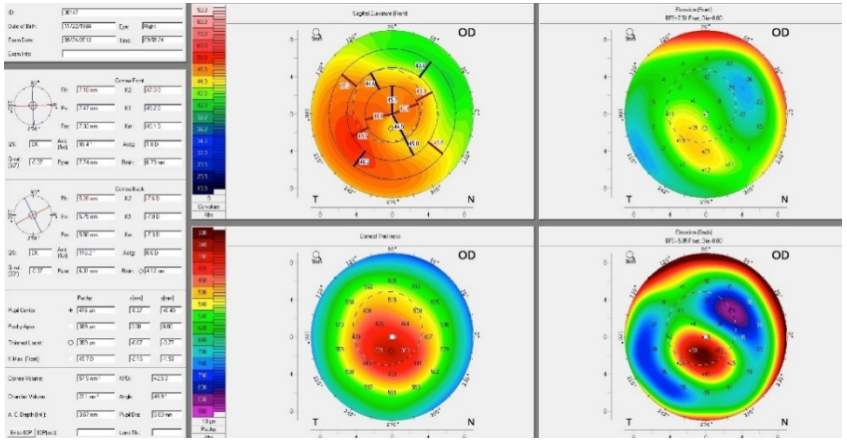
- Scheimpflug imaging (Oculyzer II, WaveLight AG, Erlagen, Germany)
- Placido Topography (Vario Topolyzer, WaveLight AG, Erlagen, Germany)
- AS-OCT (RTVue-100, Optovue Inc., Fremont, CA)

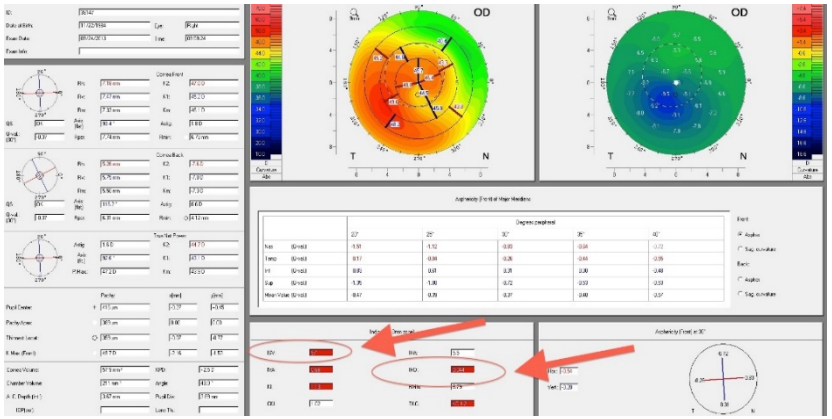
Correlation between Scheimpflug and Placido derived keratoconic grading and anterior-surface irregularity indices for keratoconus were assessed with AS-OCT derived keratoconus indices employing paired two-tailed t-tests, coefficient of determination (r^2), and trend line linearity.

Why Revisit the Diagnosis and Progression criteria of Keratoconus?

Traditional Approach

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





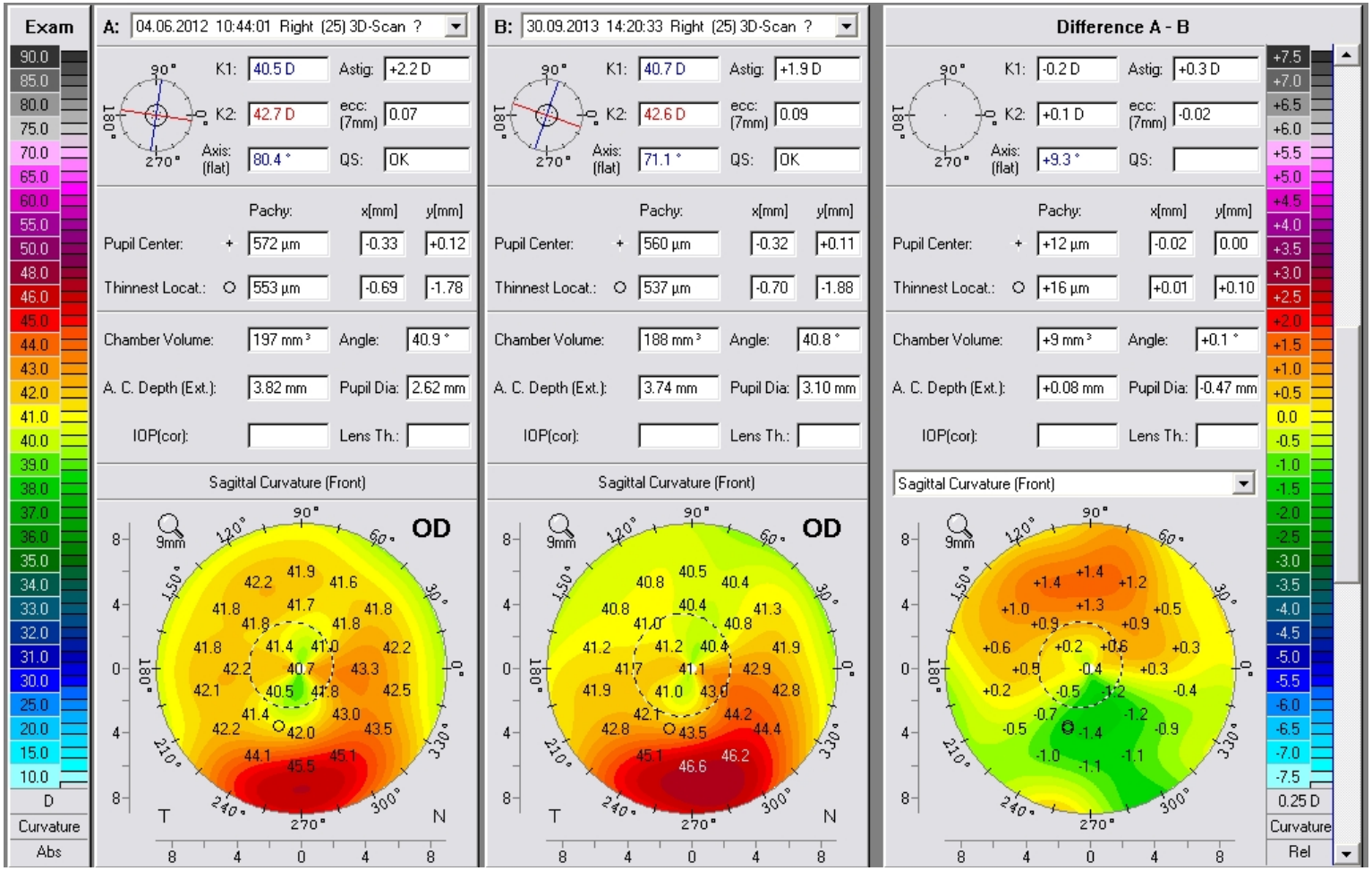
Clinical example:

34 y/o female MD with KCN

OS: treated with CXL 2 years ago for progression

OD: UCVA 20/20, asymptomatic

Has the cone changed in the past 2 years?



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Anterior-Surface Topometric Indices

- Anterior-surface curvature derived imaging topographical data from both the Pentacam and Placido-based topography
- Index of Height Decentration (IHD)
  - value of the decentration of elevation data in the vertical direction (expressed in μm)
  - 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
- Index of Surface Variance (ISV)
  - unitless standard deviation of individual corneal sagittal radii from the mean curvature.
  - expression of the corneal surface irregularity. ISV value larger than 37 degrees is considered abnormal and larger than 41 is pathological

Anterior Surface Indices and Keratoconus Grading

Clinical Ophthalmology

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ORIGINAL RESEARCH

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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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 ± 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

Video abstract

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

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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

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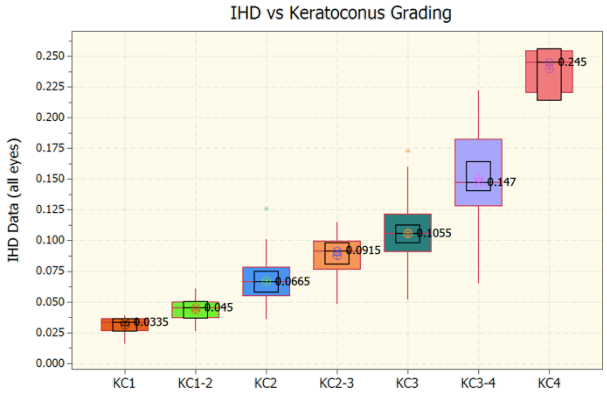
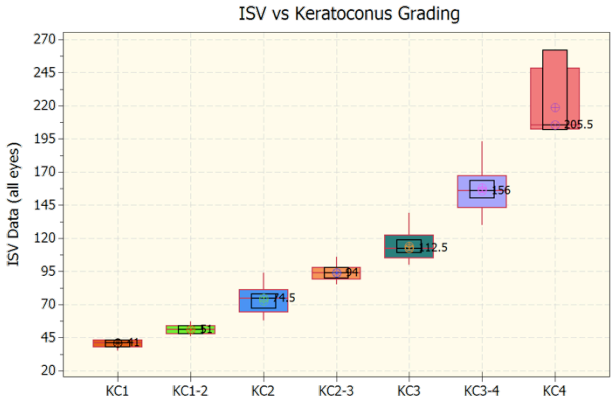


IHD



ISV

Clin Ophthalmol 2013:7
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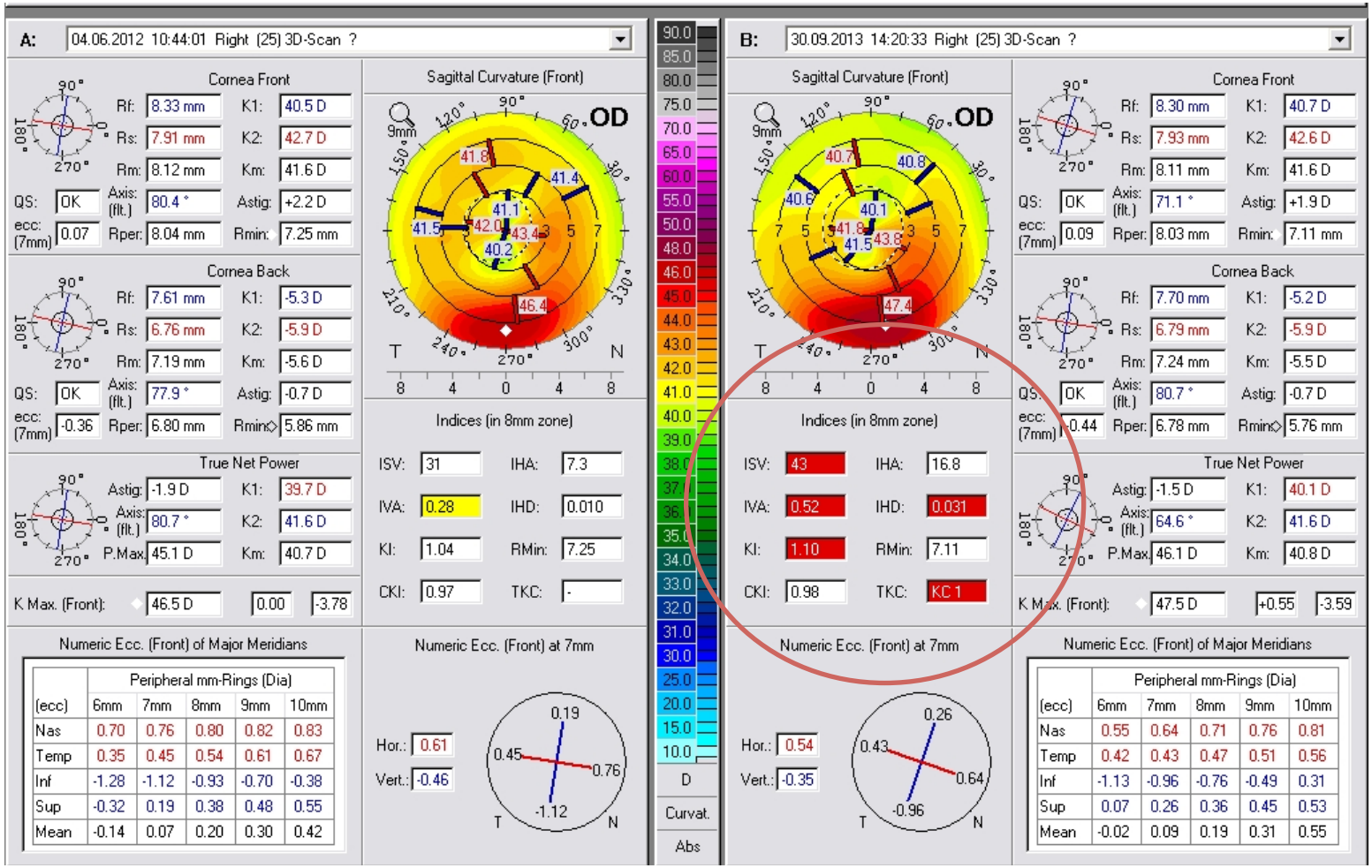
Clinical Example:

Second look with anterior surface indices

IHD and ISV deterioration suggesting KCN progression



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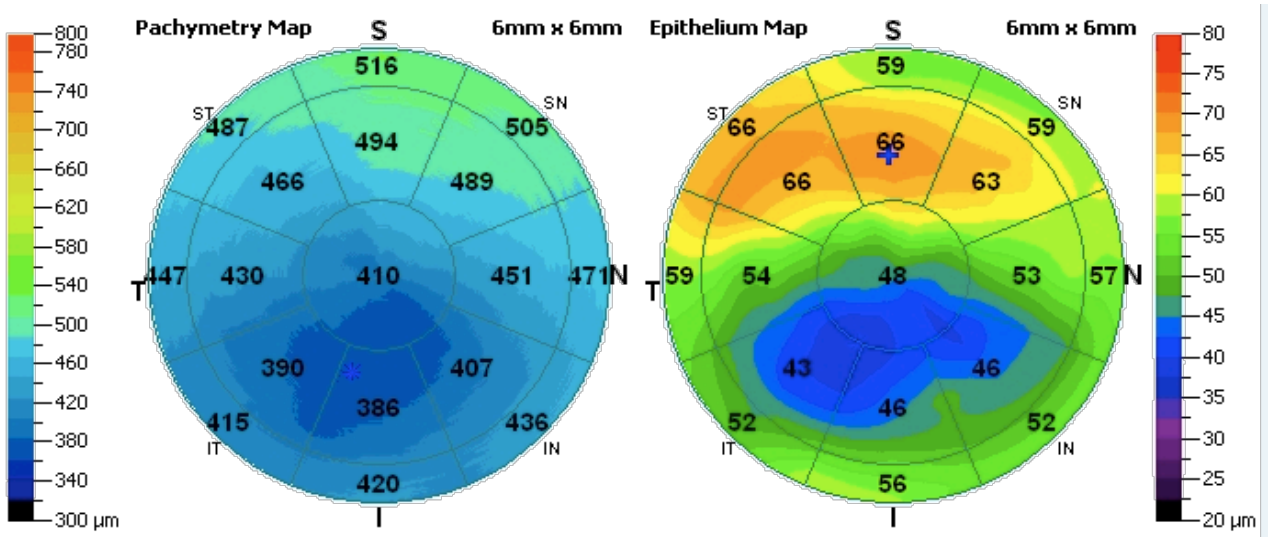
AS-OCT Epithelial Thickness Indices

- Epithelial thickness asymmetry indices
  - Thickness range (Max – Min)
  - Topographic variability
  - Mean epithelial thickness
  - Superior & Inferior quadrant



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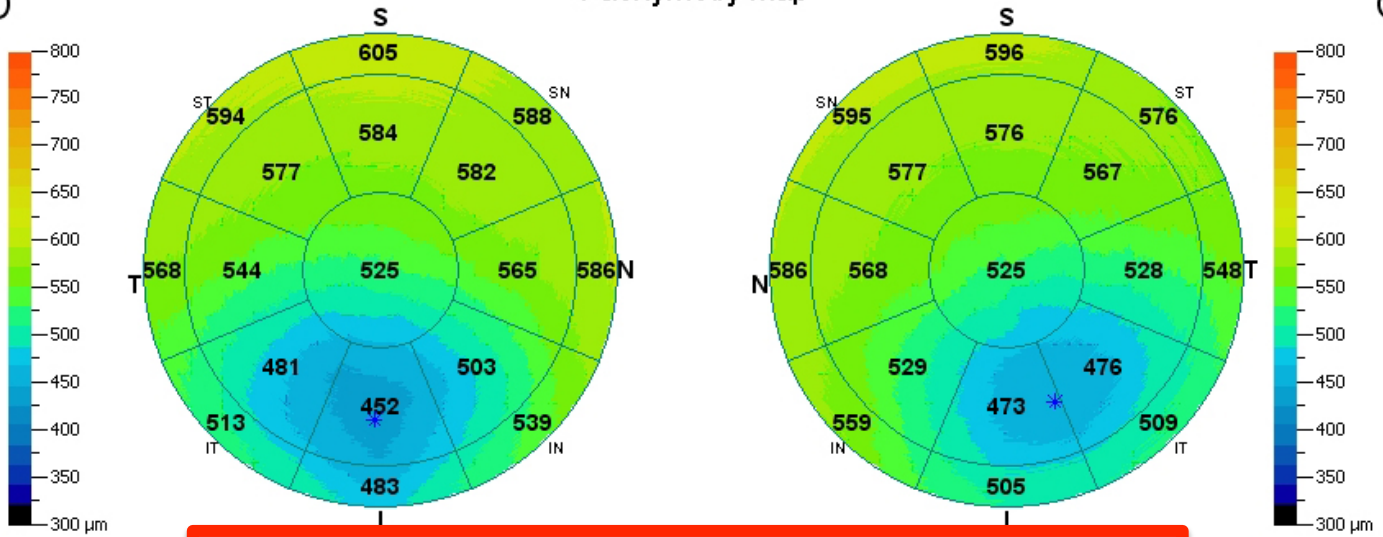
OD

Pachymetry Map

OS



Pachymetry

Pachymetry statistics within central 5mm zone

	OD	OS		OD	OS
SN-IT(2-5mm):	101	101	S-I(2-5mm):	132	103
Min:	438	455	Location Y:	-1804	-1585
Min-Median:	-96	-79	Min-Max:	-160	-130

Min thickness indicated as *

Epithelium

Epithelium statistics within central 5mm zone

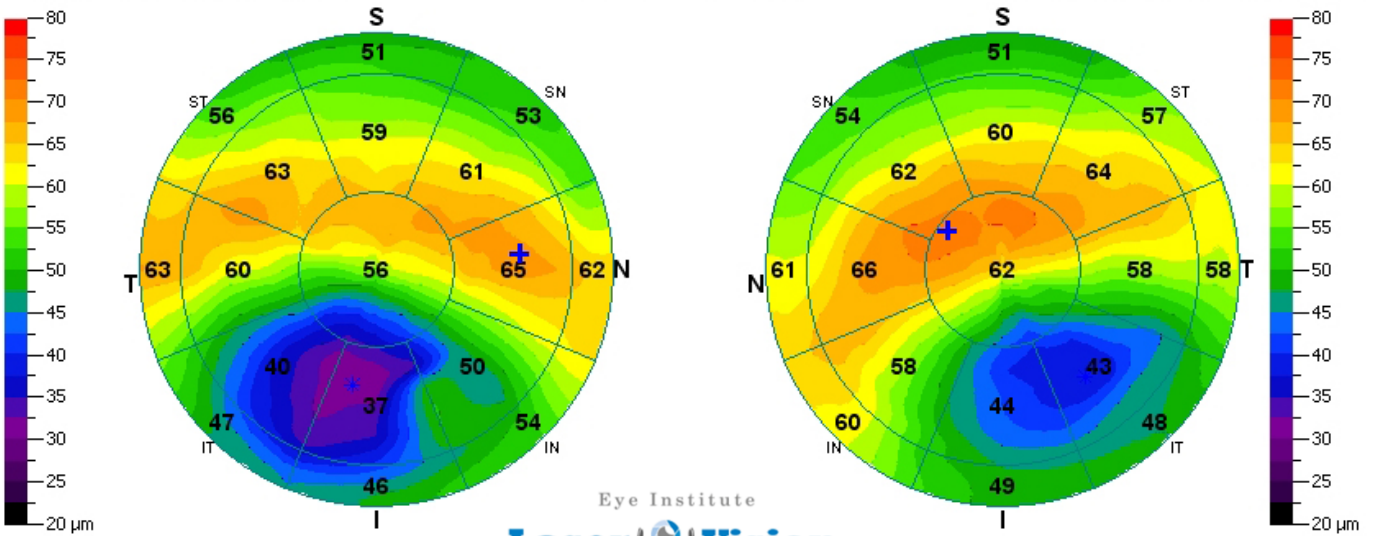
	OD	OS		OD	OS
Superior:	62	63	Inferior:	47	51
Min:	32	39	Max:	68	71
Std Dev:	11.0	9.3	Min-Max:	-37	-32

Min/Max thickness indicated as */+

Exam Date: 11/04/2013, SSI= 36.8

Epithelium Map

Exam Date: 11/04/2013, SSI= 38.9



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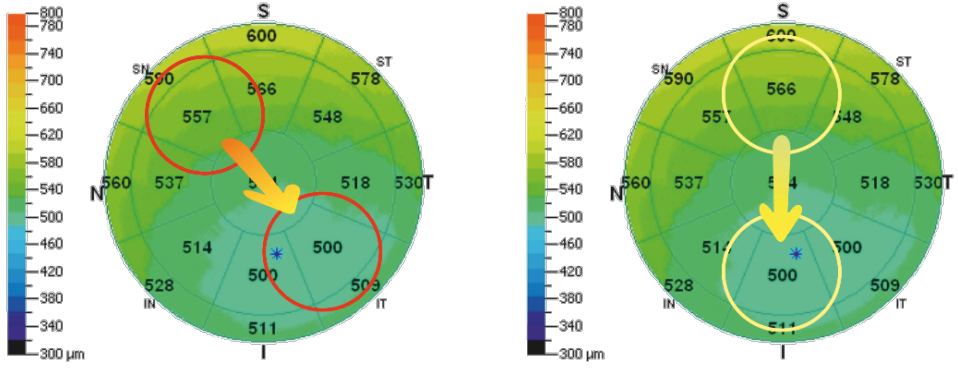
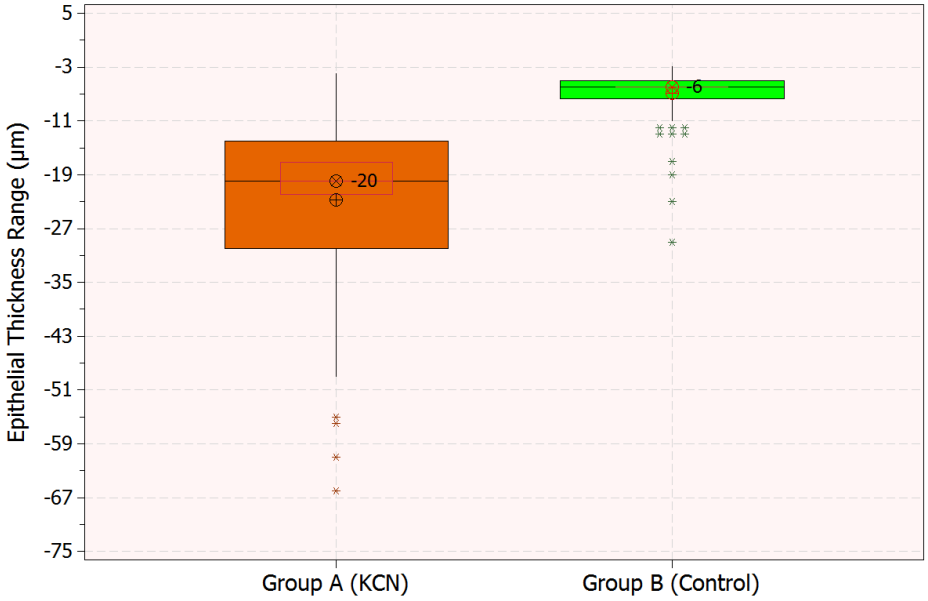
AS-OCT Corneal Thickness indices

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

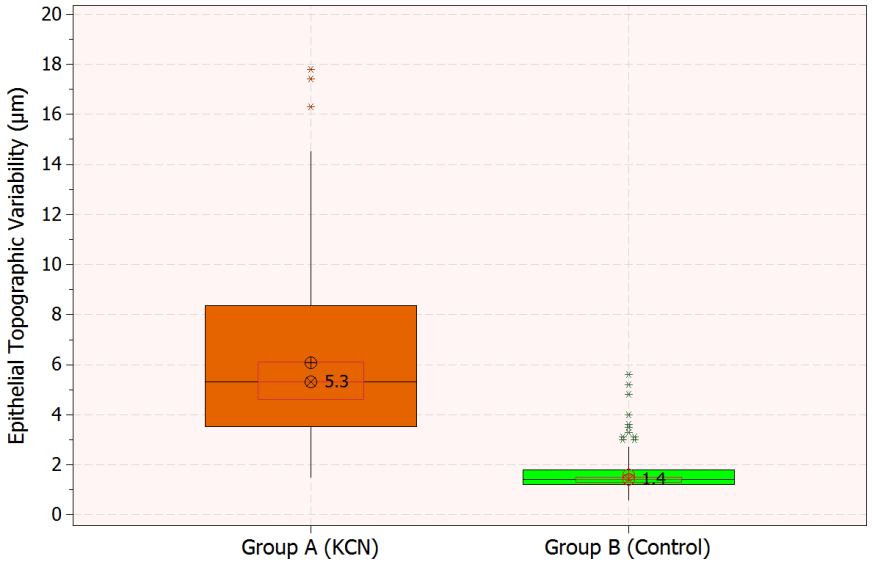
- Focal thinning indices
  - Min-Median focal thinning: minimum minus median thickness
  - Min-Max thickness range: minimum minus maximum thickness



AS-OCT Epithelial Indices
Epithelial thickness range & topographic variability



epithelial thickness range



epithelial topographic variability

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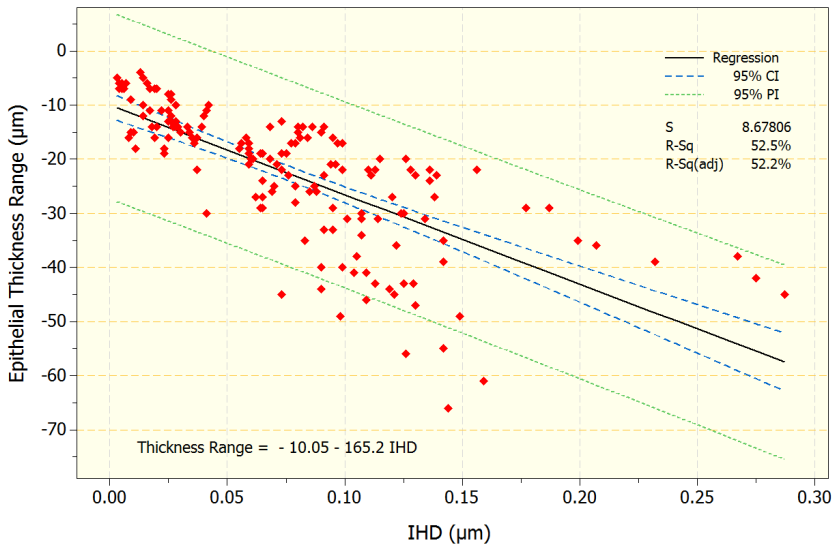
AS-OCT Epithelial thickness range Correlation to IHD & ISV



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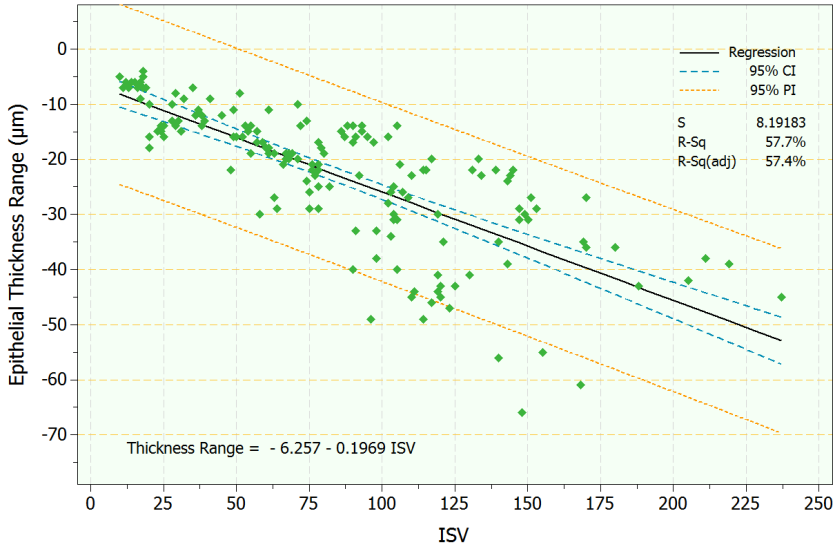

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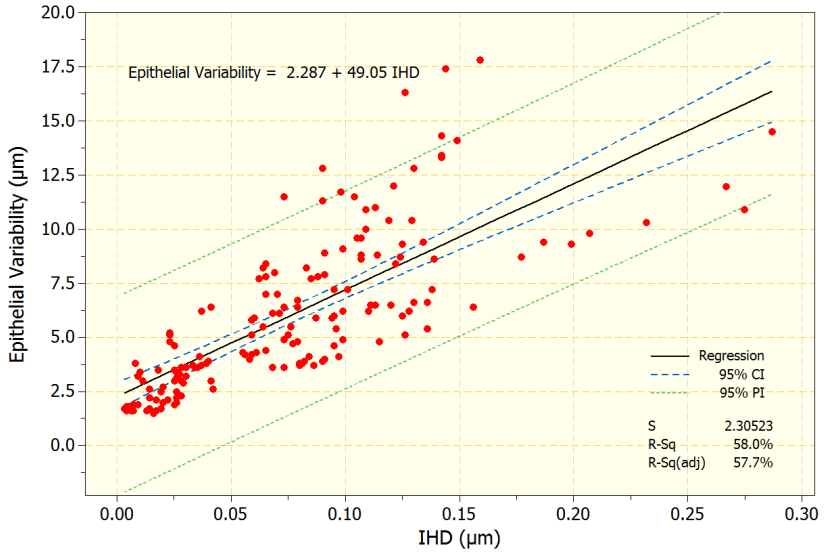
AS-OCT Epithelial variability Correlation to IHD & ISV



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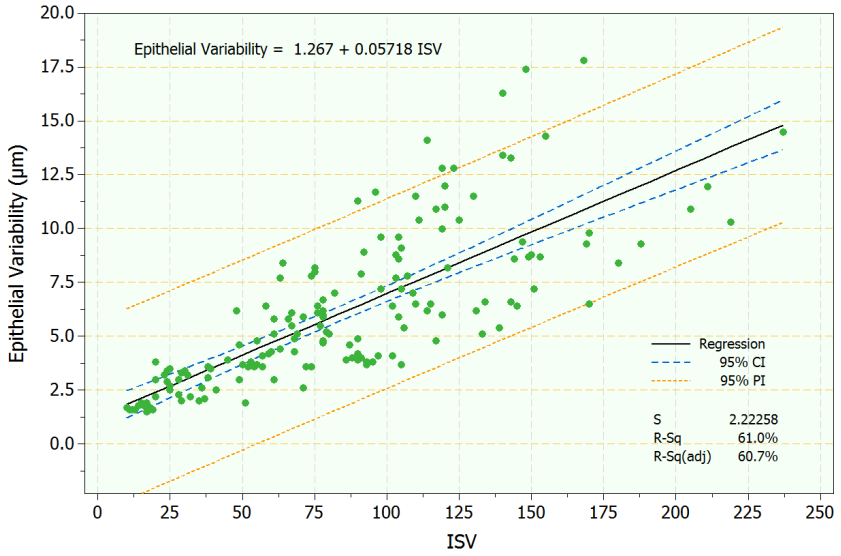

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Results

- Excellent agreement among the Scheimpflug and Placido derived keratoconic grading and anterior-surface irregularity indices for keratoconus

- AS-OCT epithelial and total corneal thickness indices we introduce herein show similar tight correlation

Conclusion

- Limited use in the rare central (nipple) cone KCN variability
- Anterior-segment topometric and epithelial thickness irregularity indices maybe valuable in early KCN for progression and diagnosis
- We introduce a possible epithelial and total corneal thickness benchmark for future studies