GLOBAL EXPERT
ROUNDTABLE DISCUSSION

CRITICAL NEW STUDY: PREDICTING REFRACTIVE PATIENTS AT-RISK OF CORNEAL ECTASIA

Cynthia Roberts, USA

Renato Ambrósio Jr, Brazil

Riccardo Vinciguerra, Italy

George Waring, USA

Rohit Shetty, India

Bai Ji, China

Suphi Taneri, Germany

OCULUS®

Welcome and Introductions

Cynthia Roberts, USA

Renato Ambrósio Jr, Brazil

Riccardo Vinciguerra, Italy

George Waring, USA

Rohit Shetty, India

Bai Ji, China

Suphi Taneri, Germany

Importance of Early Detection

Renato Ambrósio Jr
Brazil

Why some patients currently missed

The newer methods of detecting at-risk patients

- Power of combining biomechanical and tomographical data
- Changes in the viscoelastic properties of the cornea

Enhancements to the AI algorithm

International Corneal and Biomechanics Study Group: TBI_v2 launch at ESCRS

AMERICAN JOURNAL OF OPHTHALMOLOGY

RESEARCH ARTICLE | ARTICLES IN PRESS

Optimized artificial intelligence for enhanced ectasia detection using Scheimpflug-based corneal tomography and biomechanical data

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METHODS
RESULTS
DISCUSSION
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Purpose

To optimize artificial intelligence (AI) algorithms to integrate Scheimpflug-based corneal tomography and biomechanics to enhance ectasia detection.

Design

Multicenter cross-sectional case-control retrospective study.

Methods

A total of 3886 unoperated eyes from 3412 patients had Pentacam and Corvis ST (Oculus Optikgeräte GmbH) examinations. The database included 1 eye randomly selected from 1680 normal patients (N) and from 1181 "bilateral" keratoconus (KC) patients, along with 551 normal topography eyes from patients with very asymmetric ectasia (VAE-NT), and their 474 unoperated ectatic (VAE-E) eyes. The current TBIv1 (tomographic-biomechanical index) was tested, and an optimized AI algorithm was developed for augmenting accuracy.

Results

The area under the receiver operating characteristic curve (AUC) of the TBIv1 for discriminating clinical ectasia (KC and VAE-E) was 0.999 (96.5% sensitivity; 98.6% specificity [cutoff: 0.5]), and for VAE-NT, 0.899 (76% sensitivity; 89.1% specificity [cutoff: 0.29]). A novel random forest algorithm (TBIv2), developed with 18 features in 156 trees using 10-fold cross-validation, had a significantly higher AUC (0.945; DeLong, $P < .0001$) for detecting VAE-NT (84.4% sensitivity and 90.1% specificity; cutoff: 0.43; DeLong, $P < .0001$) and a similar AUC for clinical ectasia (0.999; DeLong, $P = .818$; 98.7% sensitivity; 99.2% specificity [cutoff: 0.8]). Considering all cases, the TBIv2 had a higher AUC (0.985) than TBIv1 (0.974; DeLong, $P < .0001$).

Conclusions

AI optimization to integrate Scheimpflug-based corneal tomography and biomechanical assessments augments accuracy for ectasia detection, characterizing ectasia susceptibility in the diverse VAE-NT group. Some patients with VAE may have true unilateral ectasia. Machine learning considering additional data, including epithelial thickness or other parameters from multimodal refractive imaging, will continuously enhance accuracy. NOTE: Publication of this article is sponsored by the American Ophthalmological Society.

The International Corneal Biomechanical Study Group


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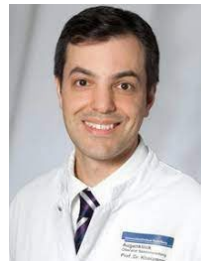
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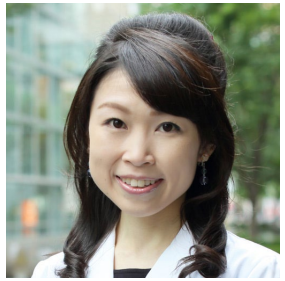
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Dr. Jens Bühren


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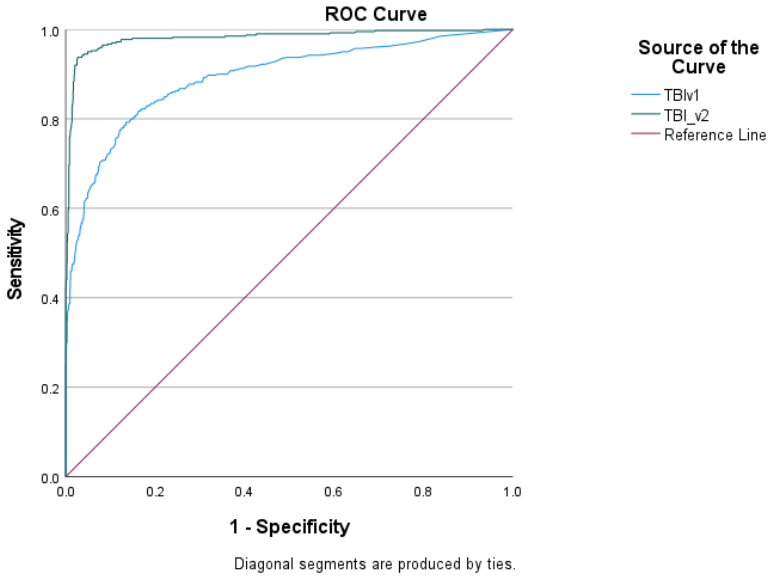
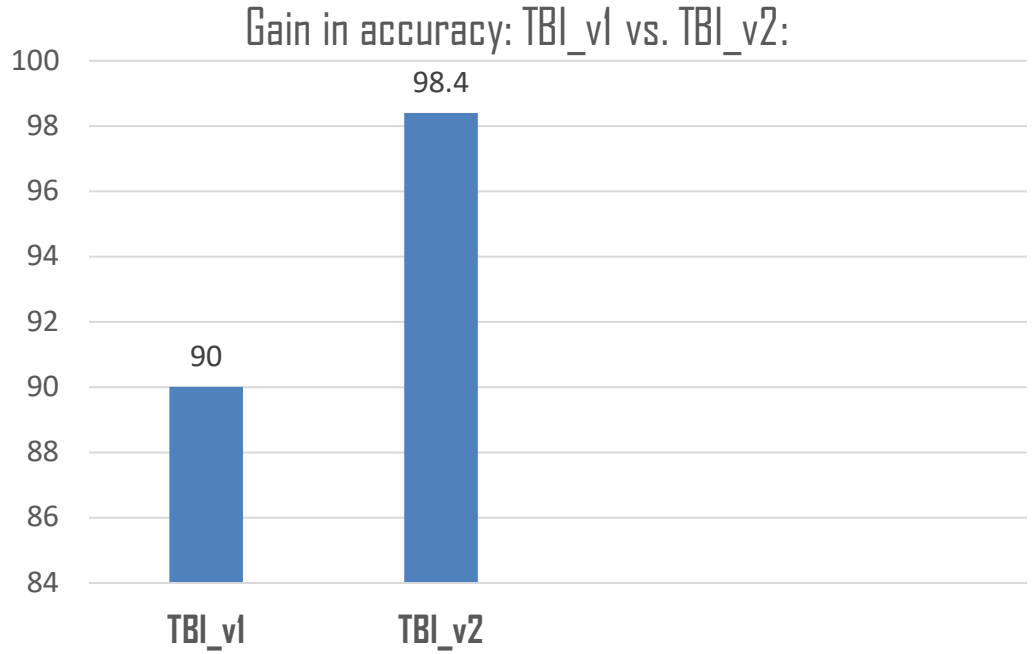
Dr. Bernardo Lopes

10 Years in evolution of early ectasia detection

Gain in accuracy in the detection of eyes with normal topography of Very Asymmetric Ectasia patients:

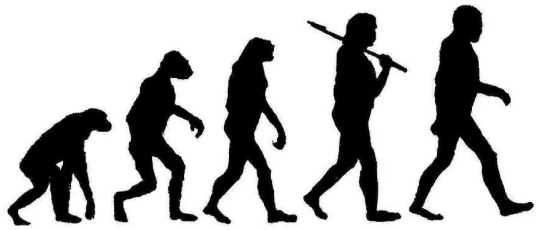




TBI_v2:
Specifity: 98.3 %
Sensitivity: 96.8 %

TBI_v1: 90.0 %

TBI_v2: 98.4 %



10 Years in evolution of early ectasia detection

Accuracy for „Forme Fruste Keratoconus“

2016: TI_v1: 90.0 %

2023: TBI_v2: 98.4 %

Spezifität: 98.3 %
Sensitivität: 96.8 %

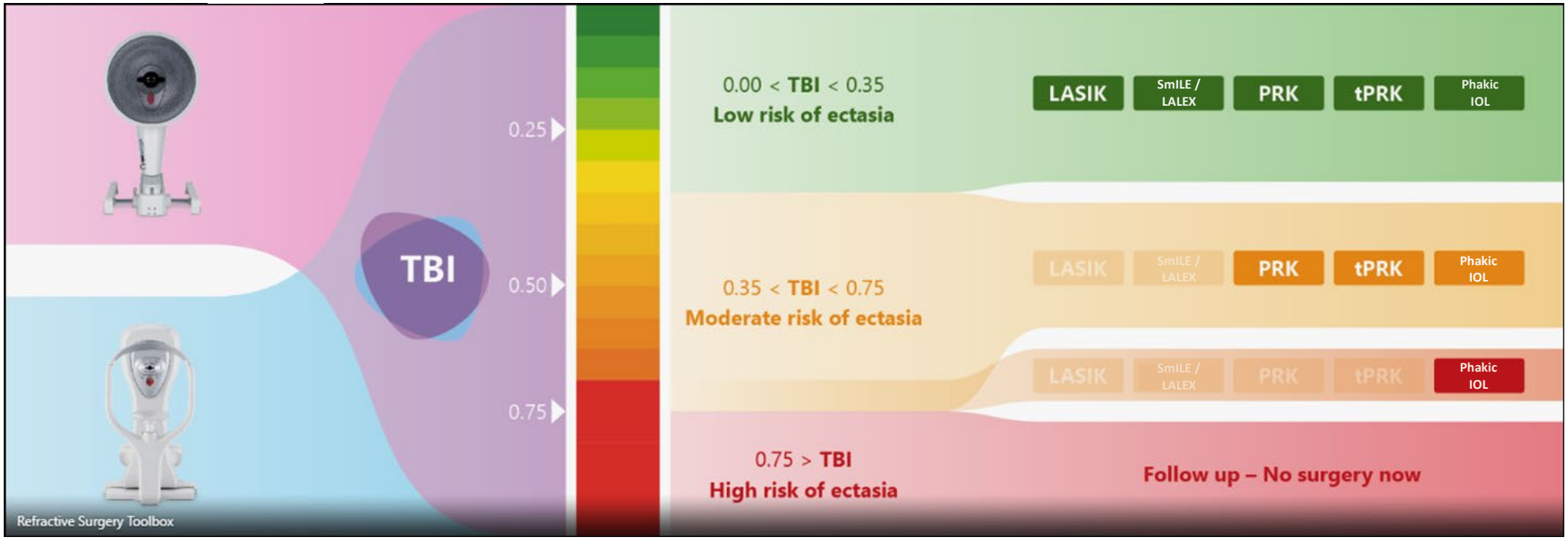
Will doctors be replaced by Artificial Inteligence in near future?

NO! But doctors will be replaced by doctors that are using AI!

Combined Tomographic & Biomechanical Assessment

Refractive Surgery Toolbox

Prof. Ambrosio´s Guidance for the ideal solution for each patient



Disclaimer: The decision for any kind of surgery is always the decision of the surgeon. This graphic only illustrates a rule of thumb recommended by Renato Ambrosio. All other avaliable clinical information have to be considered for decision making.

Case #1 : Ectasia after SMILE

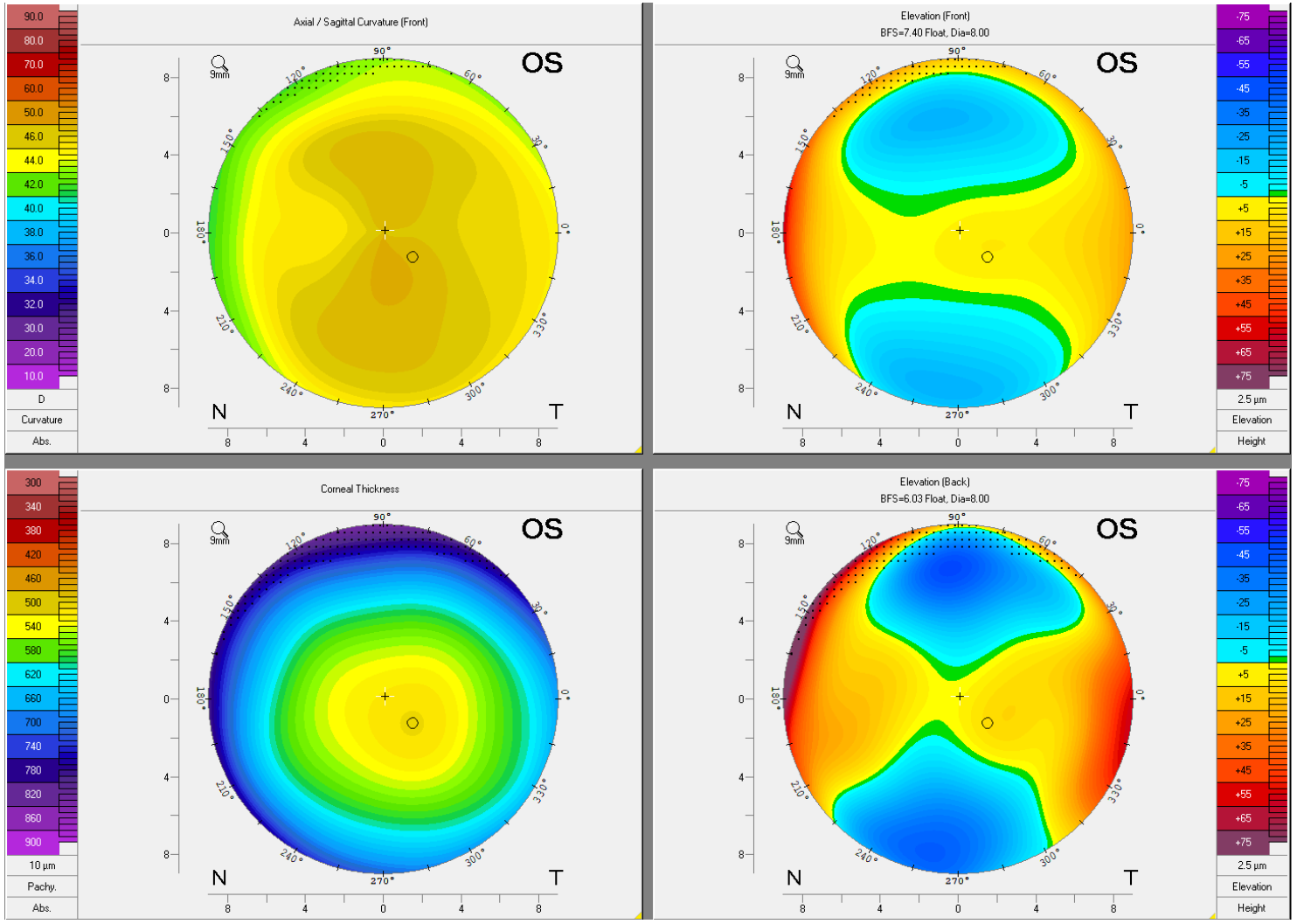
, Riccardo Vinciguerra, Italy

Provided by: Professor Renato Ambrosio, Brazil

Case 1: Corneal Ectasia after SMILE
Clinical Data

- 29 year old patient
- Normal pre-operative topographic and tomographic data
  - Subjective refraction:
    - OD -4,00 () -1,00 x 177°
    - OS -4,50 () -1,00 x 177°
  - Lenticule thickness:
    - OD 87 µm
    - OS 115 µm
- OS 20 month post-op reduced visual acuity (CDVA: 0.67)
  - OS corneal ectasia
  - OD first signs of corneal ectasia

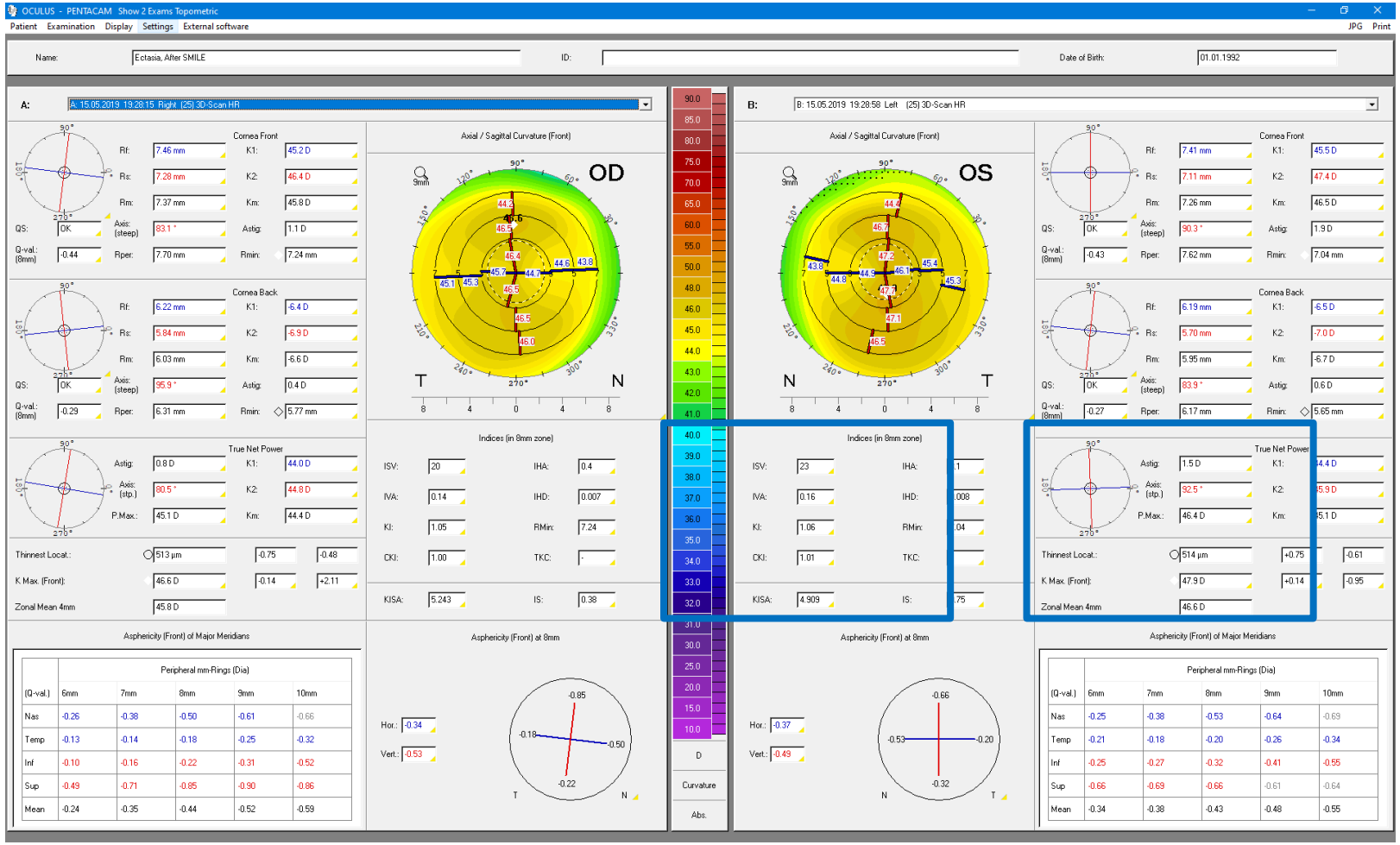
Corneal Ectasia after SMILE
4 Maps Refractive – pre-op, OS



Relatively Normal tomography OS

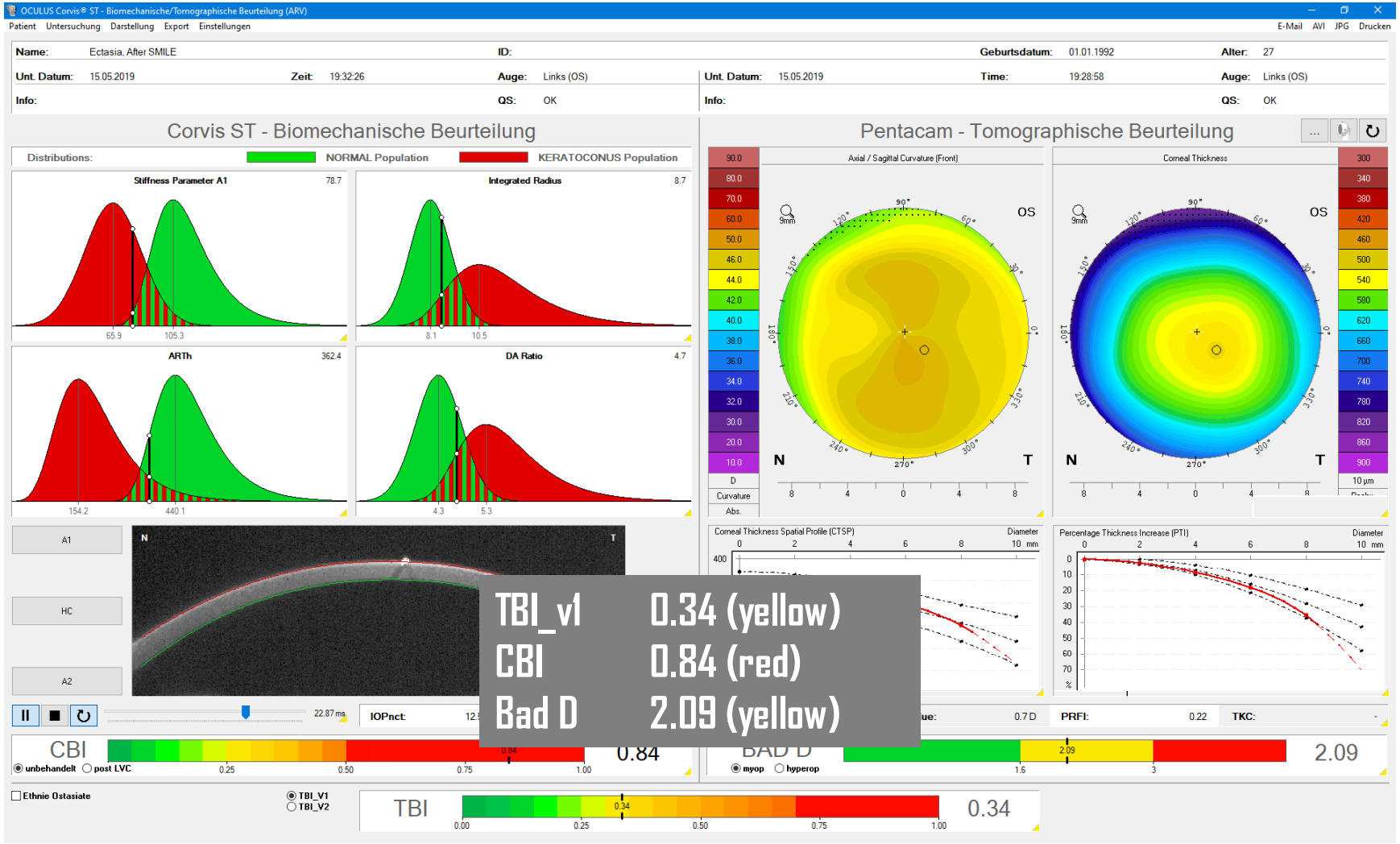
Corneal Ectasia after SMiLE

Topometric / KC Staging – pre-op, OU



Normal topography OU

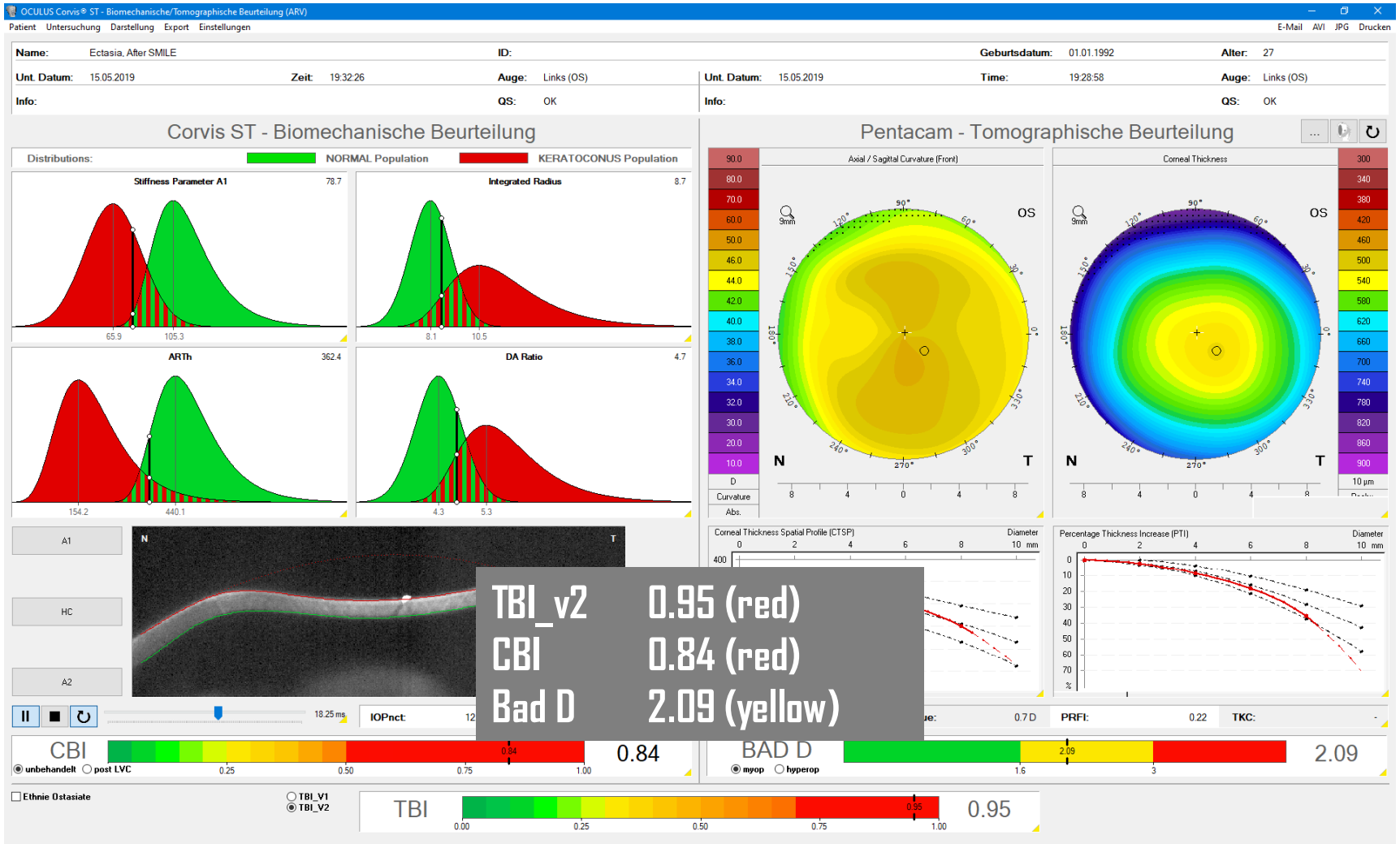
Corneal Ectasia after SMiLE
TBI-v1 – pre-op, OS



TBI_v1	0.34 (yellow)
CBI	0.84 (red)
Bad D	2.09 (yellow)

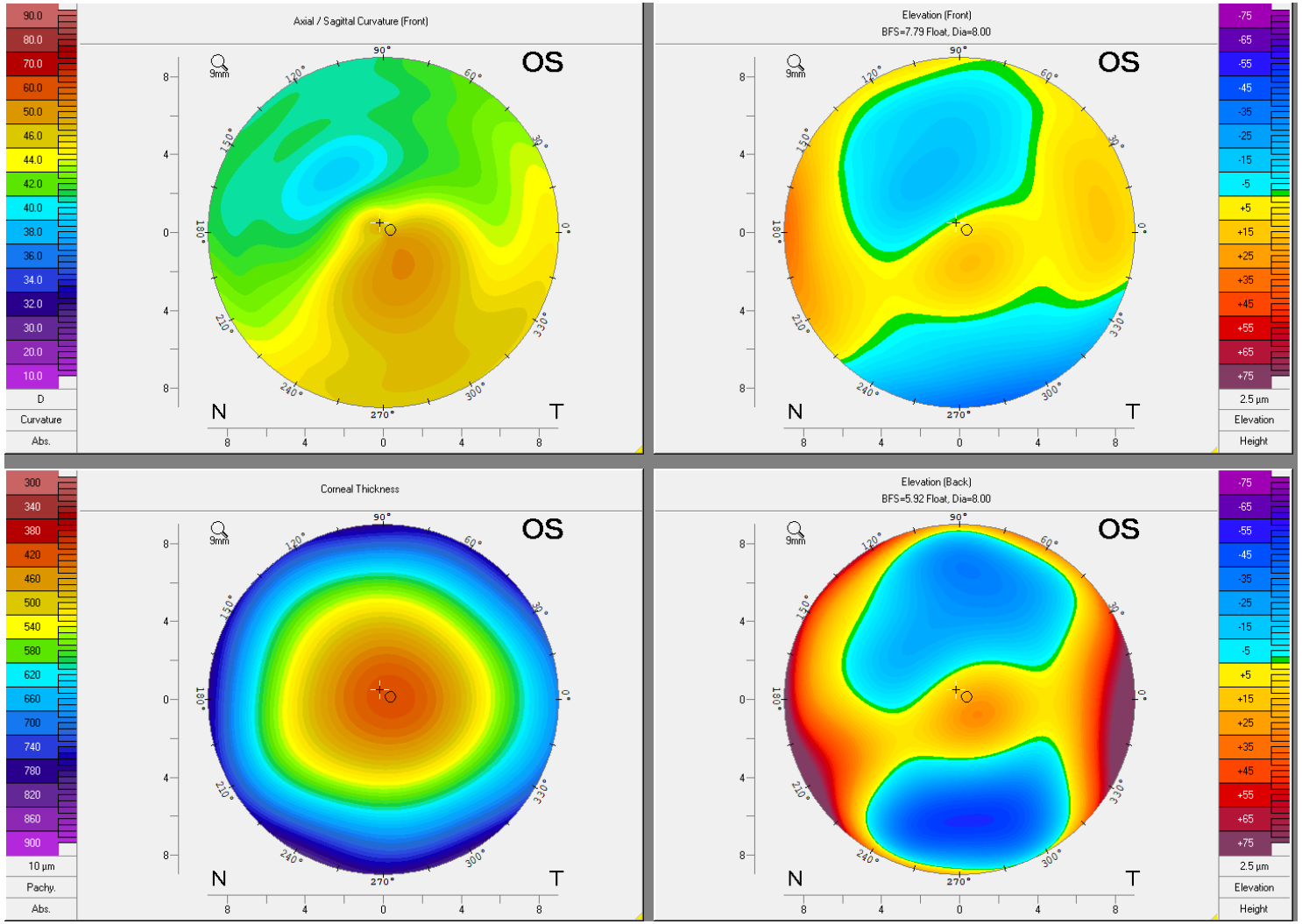
Abnormal biomechanics, slightly suspicious TBI_v1 OS

Corneal Ectasia after SMiLE
TBI_V2 – pre-op, OS



Abnormal biomechanics, abnormal TBI_v2 OS

Corneal Ectasia after SMiLE
corneal ectasia OS



Corneal Ectasia after SMILE: Conclusions

- Post-SMILE ectasia, despite:
  - pre-operatively normal Topo- and Tomography
  - only moderate refractive correction
- Biomechanics: high CBI values pre-operatively indicate ectasia risk
- Tomographic Biomechanical Assessment:
  - TBI_v1 only moderate ectasia risk
  - TBI_v2 high ectasia risk OU
- Ectasia could have been prevented based on modern AI approach based on tomographic & biomechanical data

Case #2 : Ectasia after PRK

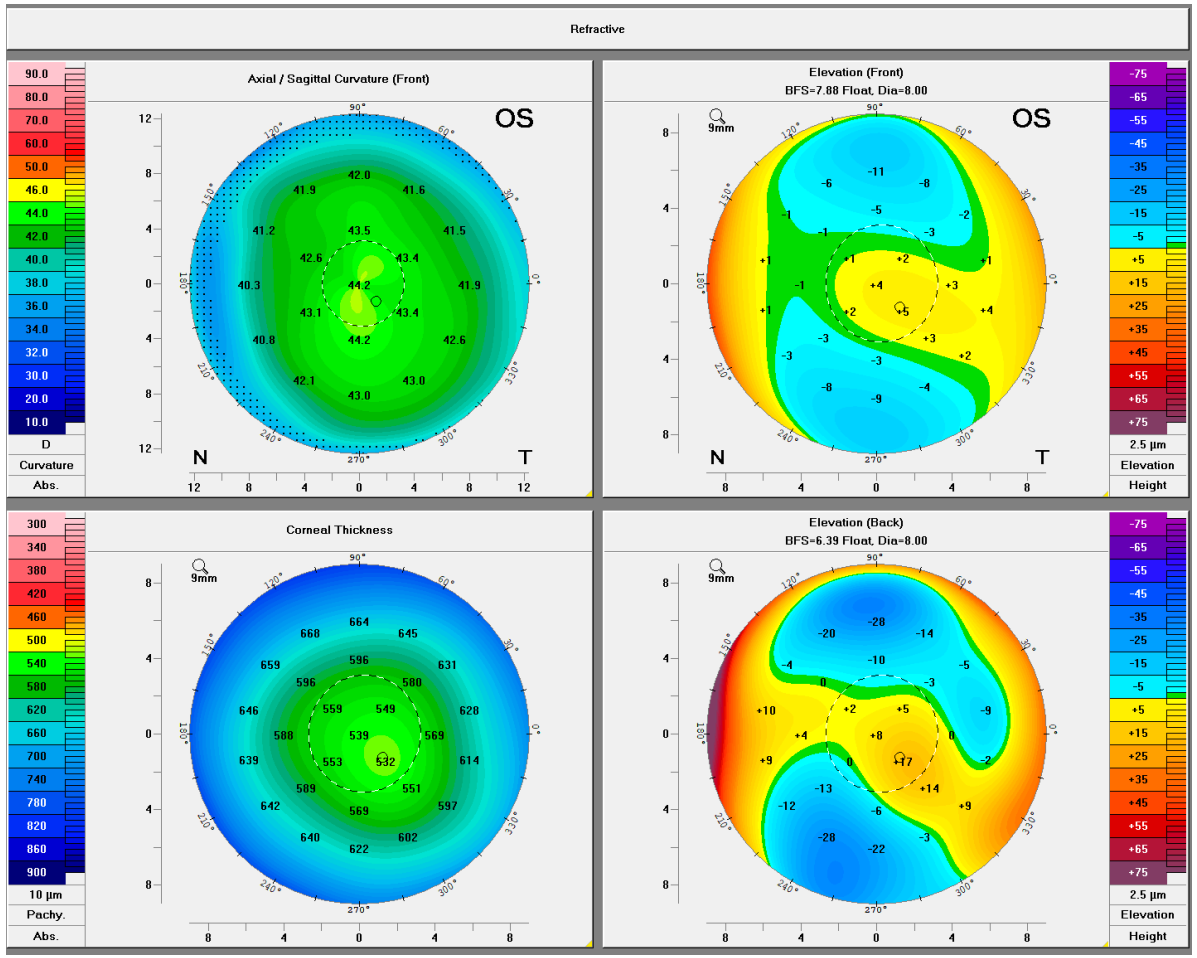
, Riccardo Vinciguerra, Italy

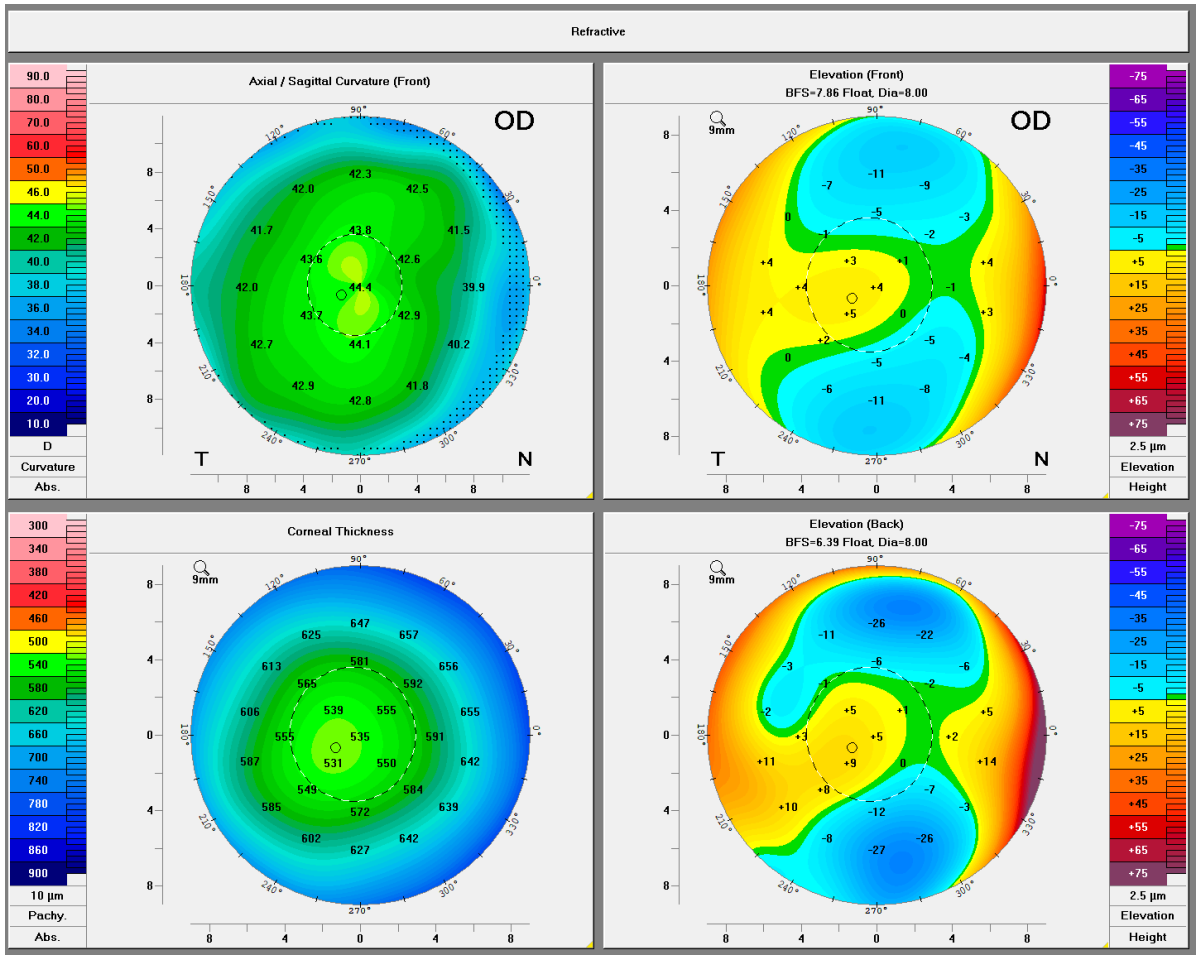
Provided by Dr. Sedaghat, Turkey

Ectasia after PRK
clinical data

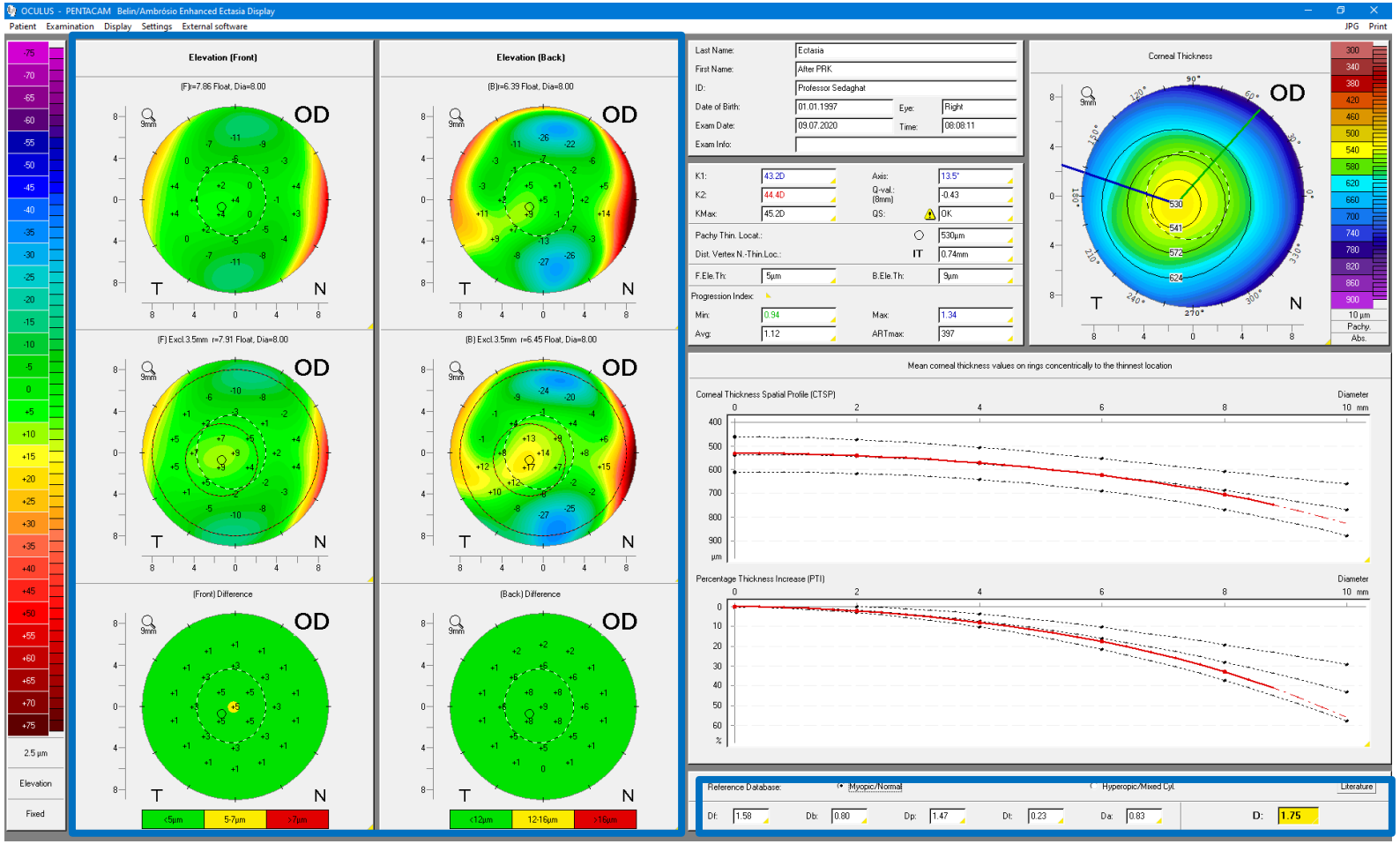
- 23-year old patient
- normal pre-operative topography and only slightly suspicious tomography
- Best corrected visual acuity : OU 1.0
  - OD -2,00
  - OS -2.25

Ectasia after PRK: 4 Maps Refractive pre-op

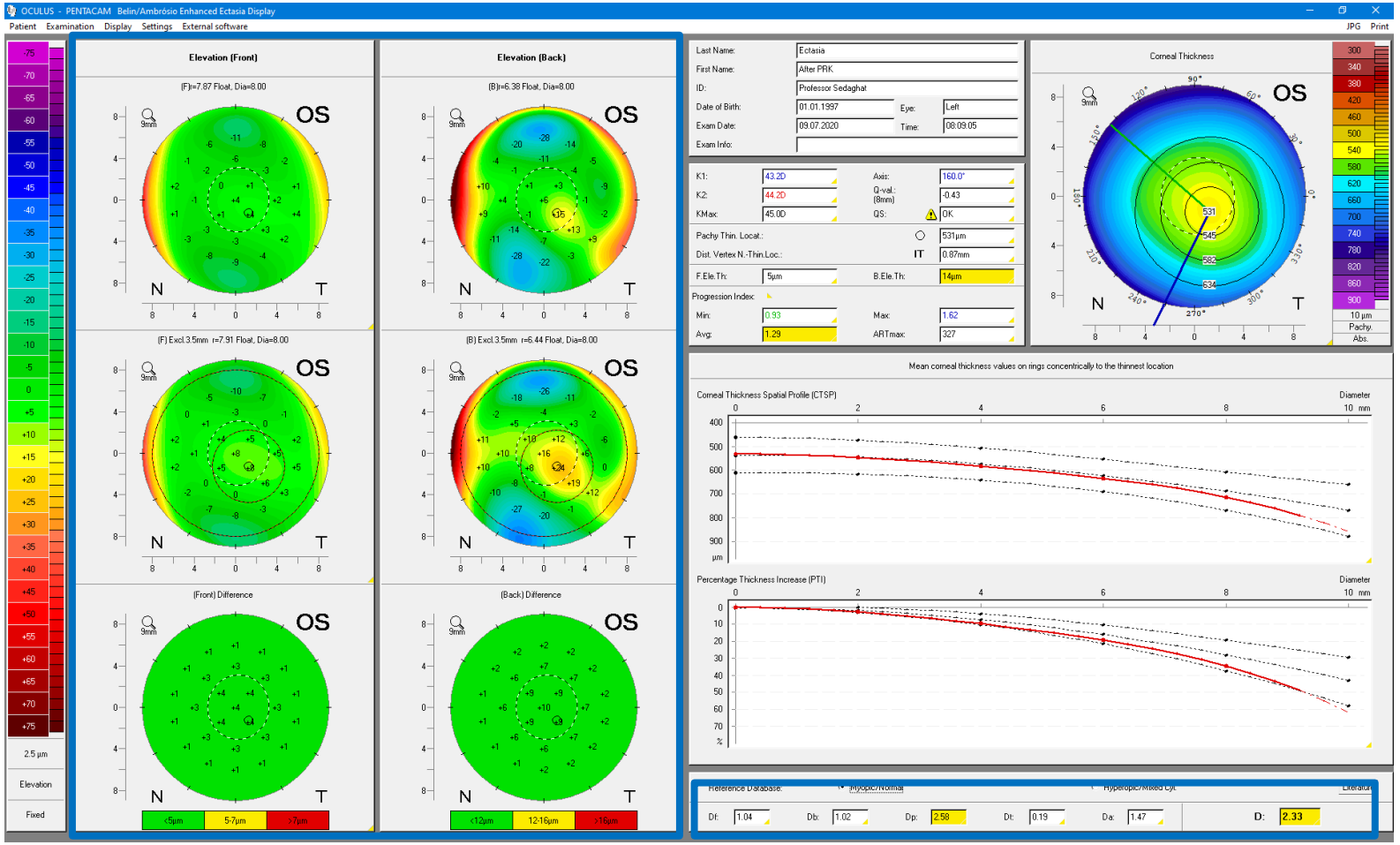




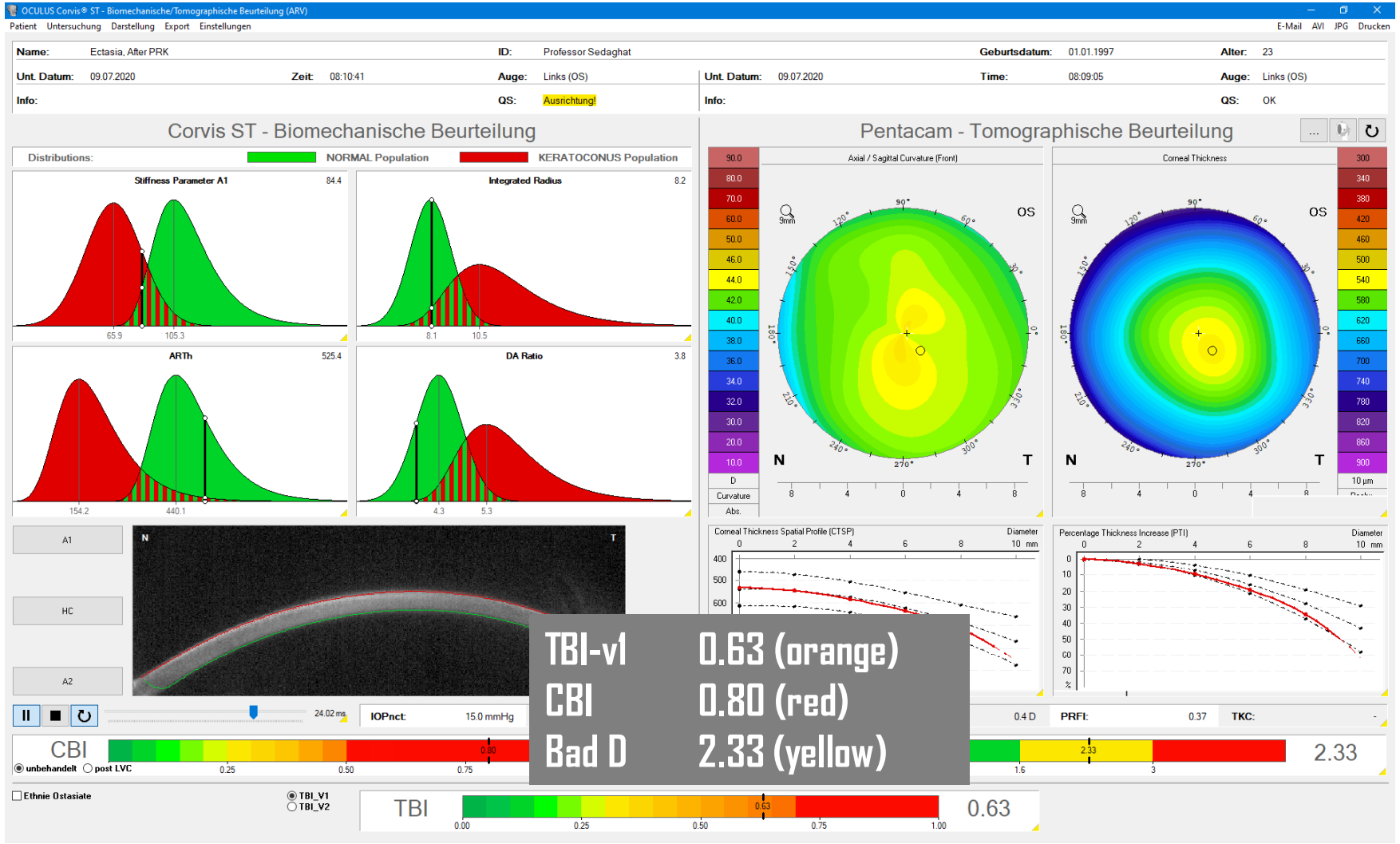
Ectasia after PRK
BAD-D – pre-op, OD



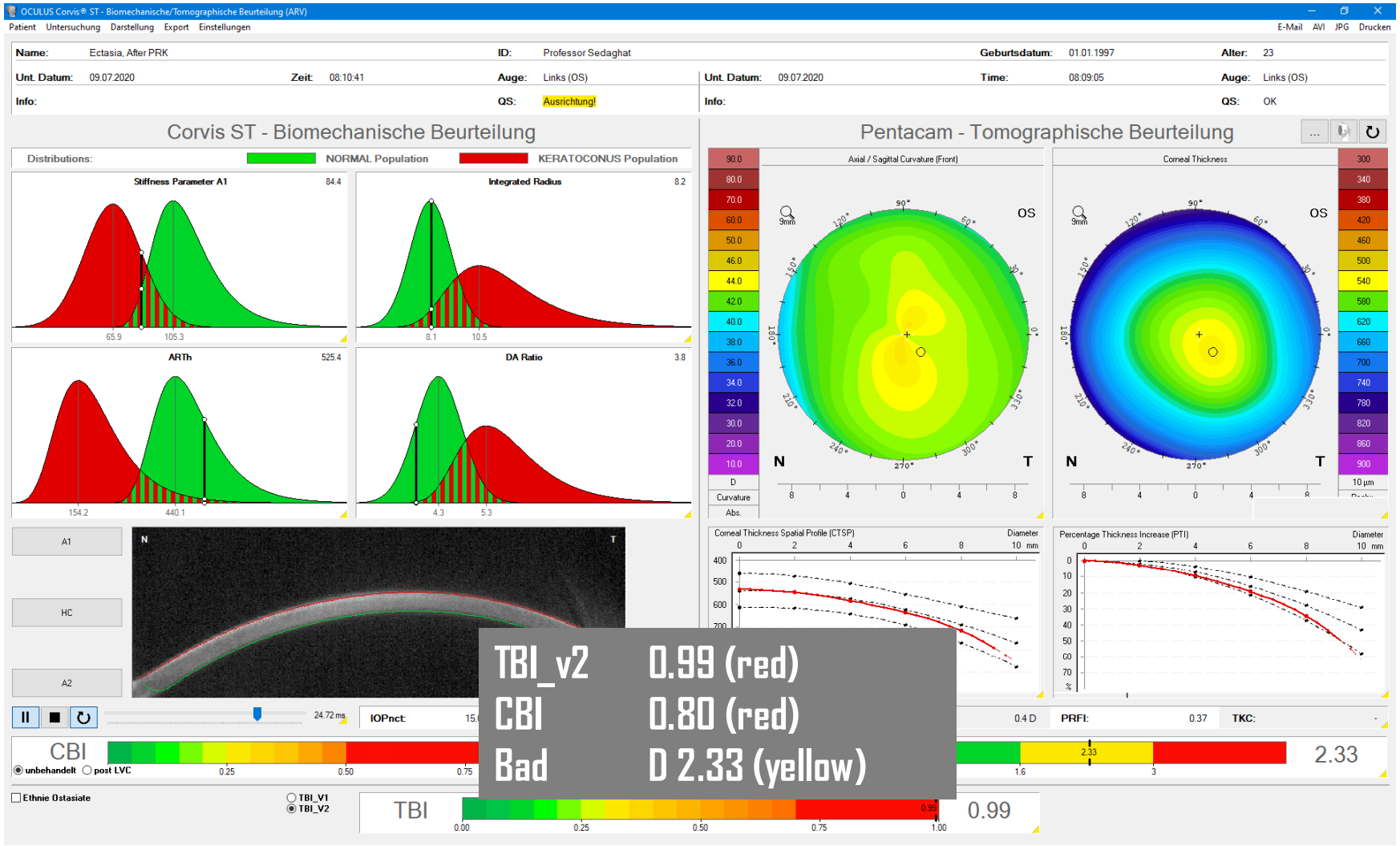
Ectasia after PRK
BAD-D – pre-op, OS



Ectasia after PRK
TBI-V1 – pre-op, OS



Ectasia after PRK
TBI_V2 – pre-op, OS

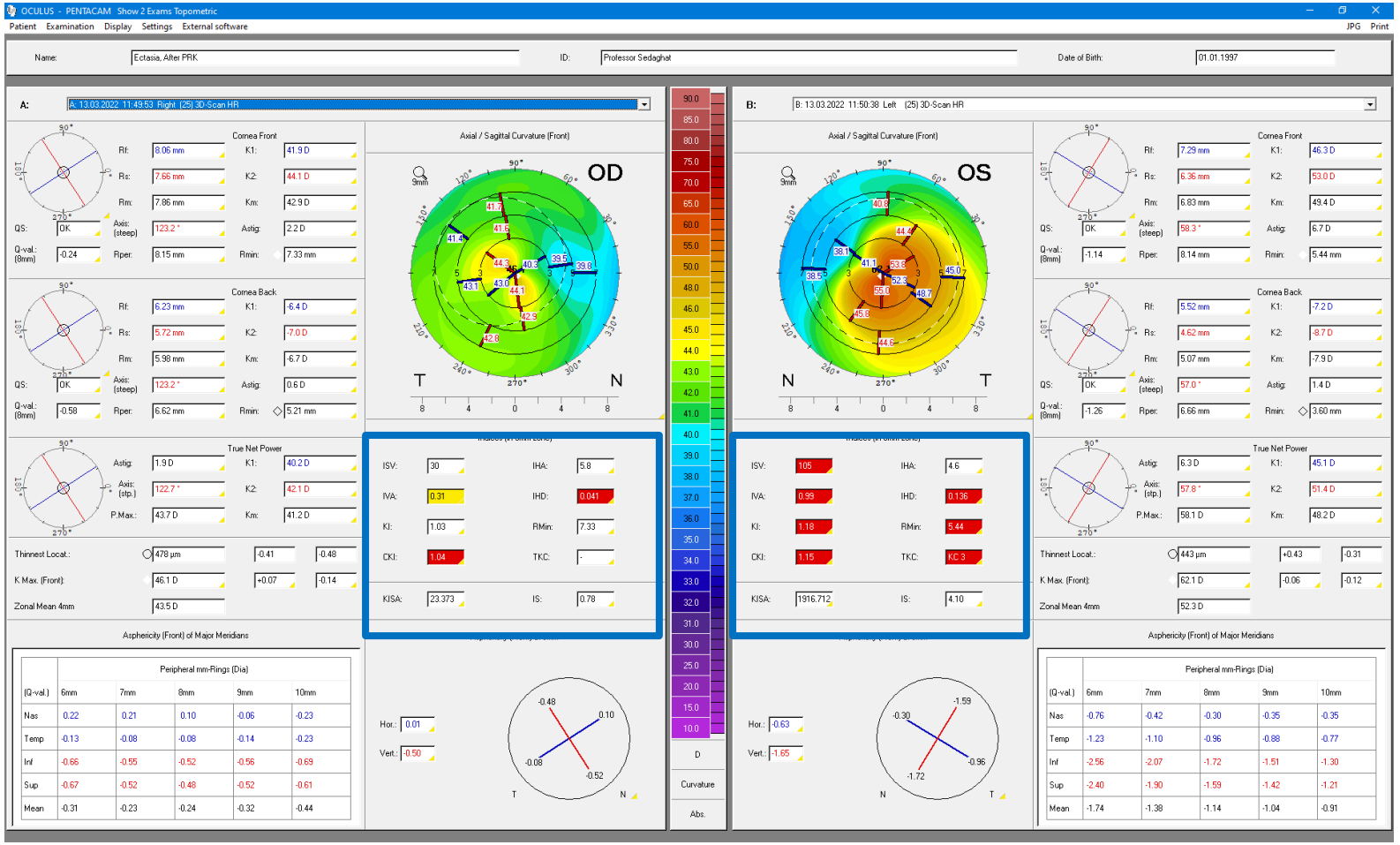


Ectasia after PRK
1.5 years post-op

1.5 years after PRK

- Uncorrected visual acuity:
  - OD 10/ 10 (1.0)
  - **OS 1/ 10 (0.1)**
- Best-corrected visual acuity
  - OD 10/ 10 (1.0)
  - **OS 3/ 10 (0.3)**
- Subjective Refraction:
  - RA -0.75 () -1.25 x 40°
  - **LA -2.25 () -6.75 x 150°**

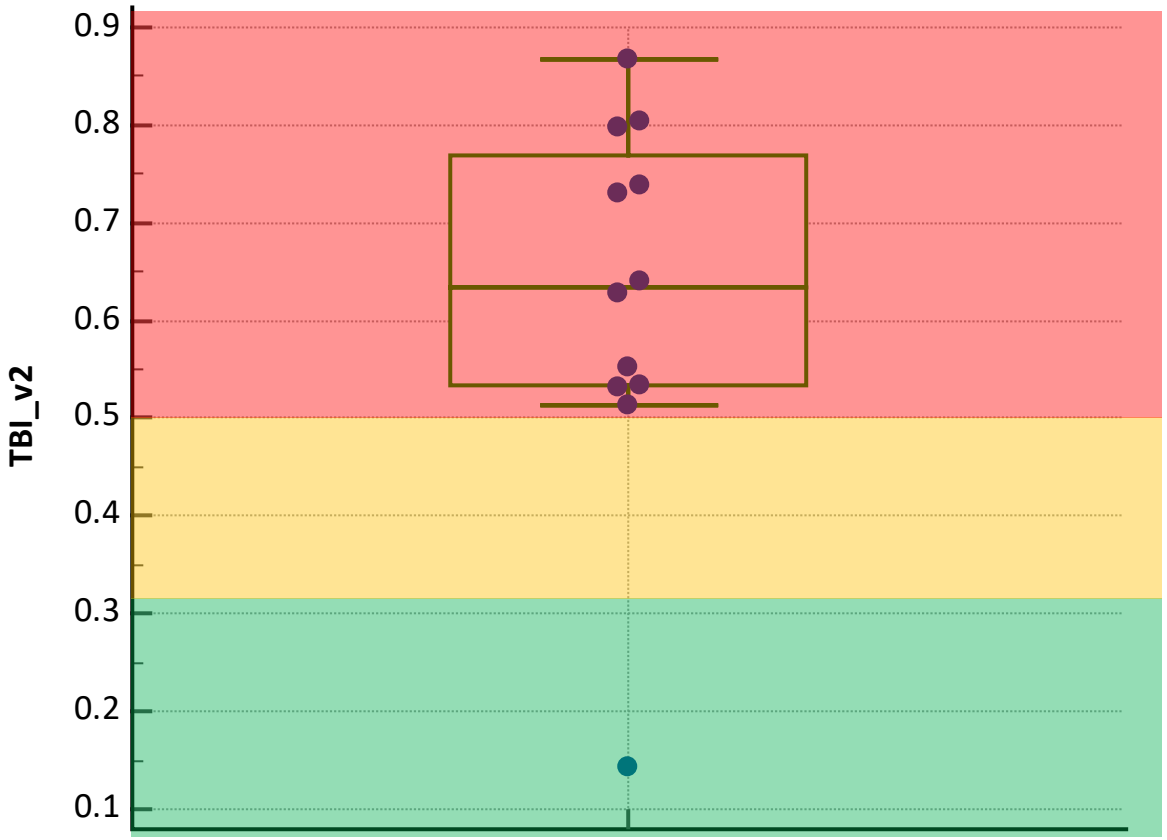
Ectasia nach PRK
topometric – postop, OU



Ectasia after PRK: Conclusions

- OU PRK, due to only slightly abnormal tomography
- Pentacam® - BAD D -> slightly suspicious
- Corvis®ST – CBI-> high ectasia risk pre-operatively
- TBI-v1 reveals high and TBI-v2 reveals very high ectasia risk pre-operatively
- Despite the lower ectasia risk after PRK, ectasia can still occur in cases with predisposition
- TBI helps to identify these patients

Case series: 7 pre-operative cases with ectasia after LVC



- 13 out of 14 eyes with abnormal TBI_v2
- In all cases tomography was assessed as normal and thus LVC was performed
- All 14 eyes with ectasia after LVC
- In all 7 patients at least one eye was indicated as abnormal by TBI!
- Thus all ectasia cases might have been prevented!

Motivation for cCBI: Biomechanical differences between Chinese and Caucasian Healthy Subjects

Bai Ji,
China

frontiers in Medicine

ORIGINAL RESEARCH
published: 25 February 2022
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Corneal Biomechanics Differences Between Chinese and Caucasian Healthy Subjects

Riccardo Vinciguerra[1], Robert Herber[2], Yan Wang[3,4], Fengju Zhang[5], Xingtao Zhou[6], Ji Bai[7], Keming Yu[8], Shihao Chen[9], Xuejun Fang[10], Frederik Raiskup[2] and Paolo Vinciguerra[11,12]*

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Purpose: The aim of this study was to evaluate the difference between Caucasian and Chinese healthy subjects with regards to Corvis ST dynamic corneal response parameters (DCRs).

Methods: Two thousand eight hundred and eighty-nine healthy Caucasian and Chinese subjects were included in this multicenter retrospective study. Subsequently, Chinese eyes were matched to Caucasians by age, intraocular pressure (IOP), and Corneal Thickness (CCT) using a case-control matching algorithm. The DCRs assessed were Deformation Amplitude (DA) Applanation 1 velocity (A1v), integrated radius (1/R), deformation amplitude ratio (DAratio), stiffness parameter at applanation 1 (SPA1), ARTh (Ambrósio's Relational Thickness to the horizontal profile), and the novel Stress Strain Index (SSI).

Results: After age-, CCT-, and IOP- matching, 503 Chinese were assigned to 452 Caucasians participants. Statistical analysis showed a statistical significant difference between Chinese and Caucasian Healthy subjects in the values of SPA1 ($p = 0.008$), Arth ($p = 0.008$), and SSI ($p < 0.001$). Conversely, DA, A1v, DAratio, and 1/R were not significantly different between the two ethnical groups ($p > 0.05$).

Conclusion: We found significant differences in the values of the DCRs provided by the Corvis ST between Chinese and Caucasian healthy subjects.

Keywords: biomechanics, cornea, keratoconus, CBI, IOP (intraocular pressure)

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Conclusions:

- Corneal stiffness parameters SPA1 and SSI were statistical significant different
- Thickness profile related ARTh parameter was mostly influenced by East Asian ethnicity
- Differences were small but could have an impact on AI-based algorithm

→ CBI and TBI were optimized for East Asian eyes

Ethnicity matters.
The new cCBI (for east Asian ethnicity)

Detection of Keratoconus With a New Corvis Biomechanical Index Optimized for Chinese Populations

RICCARDO VINCIGUERRA, RENATO AMBROSIO, YAN WANG, FENGJU ZHANG, XINGTAO ZHOU, JI BAI, KEMING YU, SHIHAO CHEN, XUEJUN FANG, AND PAOLO VINCIGUERRA

• PURPOSE: The aim of this study was to introduce an optimized version of the Corvis Biomechanical Index for Chinese populations (cCBI).
• DESIGN: Retrospective, multicenter clinical validity enhancement study.
• METHODS: Patients were included from 7 clinics in Beijing, Shenyang, Guangzhou, Shanghai, Wenzhou, Chongqing, and Tianjin, China. Logistic regression was used to optimize the values of the constants of the CBI, based on database 1 as the development dataset (6 of 7 clinics), to create a new version of the index named cCBI. The factors of the CBI (A1Velocity, ARTh, Stiffness Parameter-A, DARatio2mm, and Inverse Integrated Radius) and the cutoff value were kept the same (0.5). With the formation of cCBI determined, it was validated on database 2 (1 of the 7 clinics).
• RESULTS: Two thousand four hundred seventy-three patients (healthy and keratoconus) were included. In database 2, the area under the curve of the cCBI was 0.985 with 93.4% specificity and 95.5% sensitivity. In the same dataset, the original CBI produced an area under the curve of 0.978 with 68.1% specificity and 97.7% sensitivity. There was a statistically significant difference between the receiver operating characteristic curve of cCBI and CBI (De Long $P = .0009$)
• CONCLUSION: The new cCBI for Chinese patients was shown to be statistically significantly better when compared with CBI to separate healthy from keratoconic eyes. The presence of an external validation dataset confirms this finding and suggests the use of cCBI in everyday clinical practice to aid in the diagnosis of keratoconus in patients who are of Chinese ethnicity. (Am J Ophthalmol 2023;252: 182–187. © 2023 The Authors. Published by Elsevier Inc. This is an open access article under the CC BY license (http://creativecommons.org/licenses/by/4.0/))

ETHNIC DIFFERENCES IN OCULAR MEASUREMENTS HAVE been widely studied, and previous reports showed dissimilarities in corneal thickness,[1] corneal curvature,[2] Belin–Ambrósio enhanced ectasia display (BAD display) parameters,[3] anterior chamber depth[4] and axial length.[5]

A recent advance in ocular diagnostics came from the possibility to measure in vivo corneal biomechanics with the aid of an ultra-high speed Scheimpflug camera, which was shown to play an important role for the diagnosis and management of keratoconus (KC),[6–11] iatrogenic ectasia,[12] cross-linking stiffening,[13] measurement of intraocular pressure,[14,15] and glaucoma.[11,16,17]

The Corvis ST (OCULUS Optikgeräte GmbH, Wetzlar, Germany) measures the deformation of the cornea to an air pressure pulse with an ultra-high speed Scheimpflug camera and uses the acquired frames sequence to produce estimates of intraocular pressure and deformation response parame-

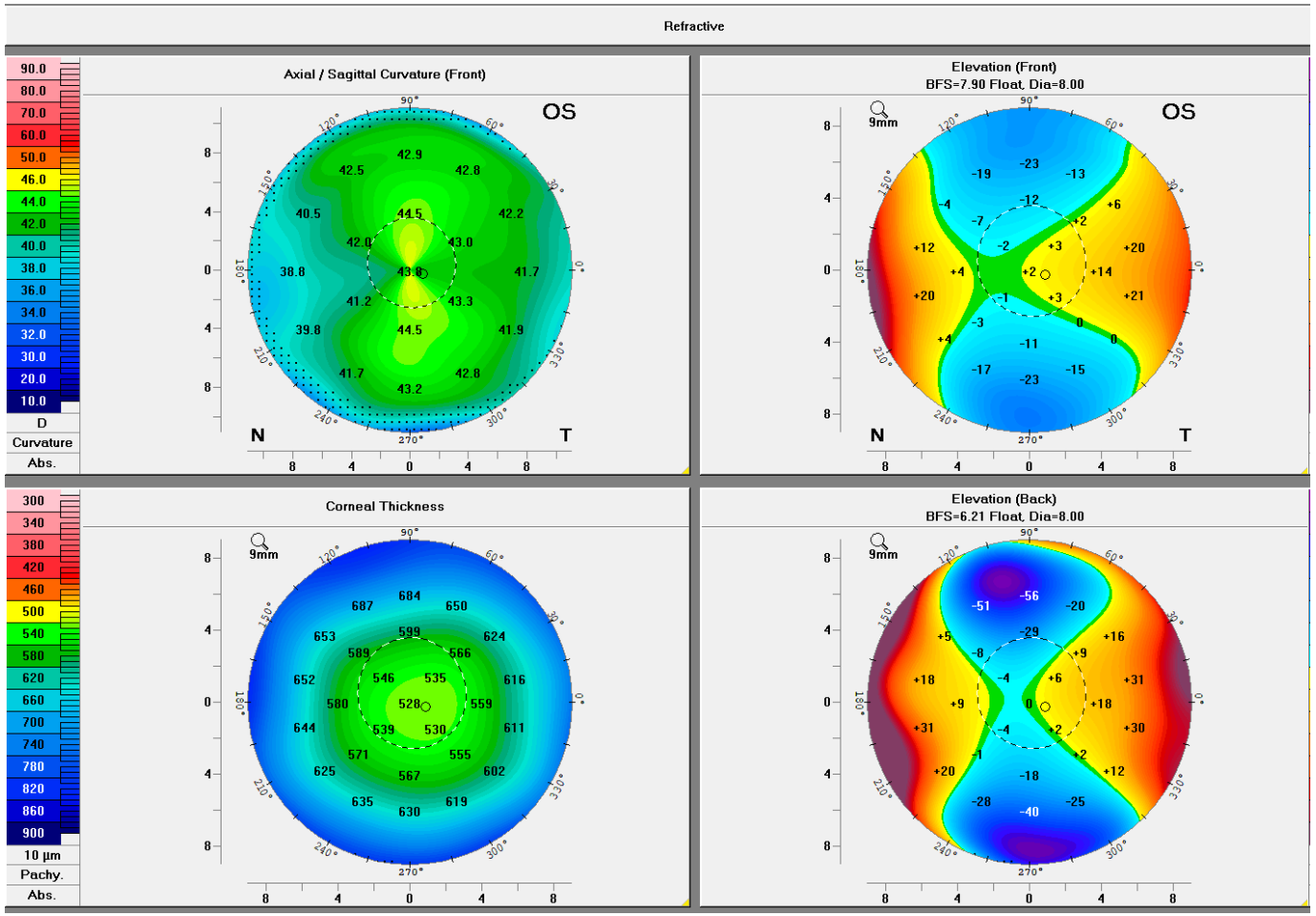
AJO.com Supplemental Material available at AJO.com.
Accepted for publication April 5, 2023.

Highlights:

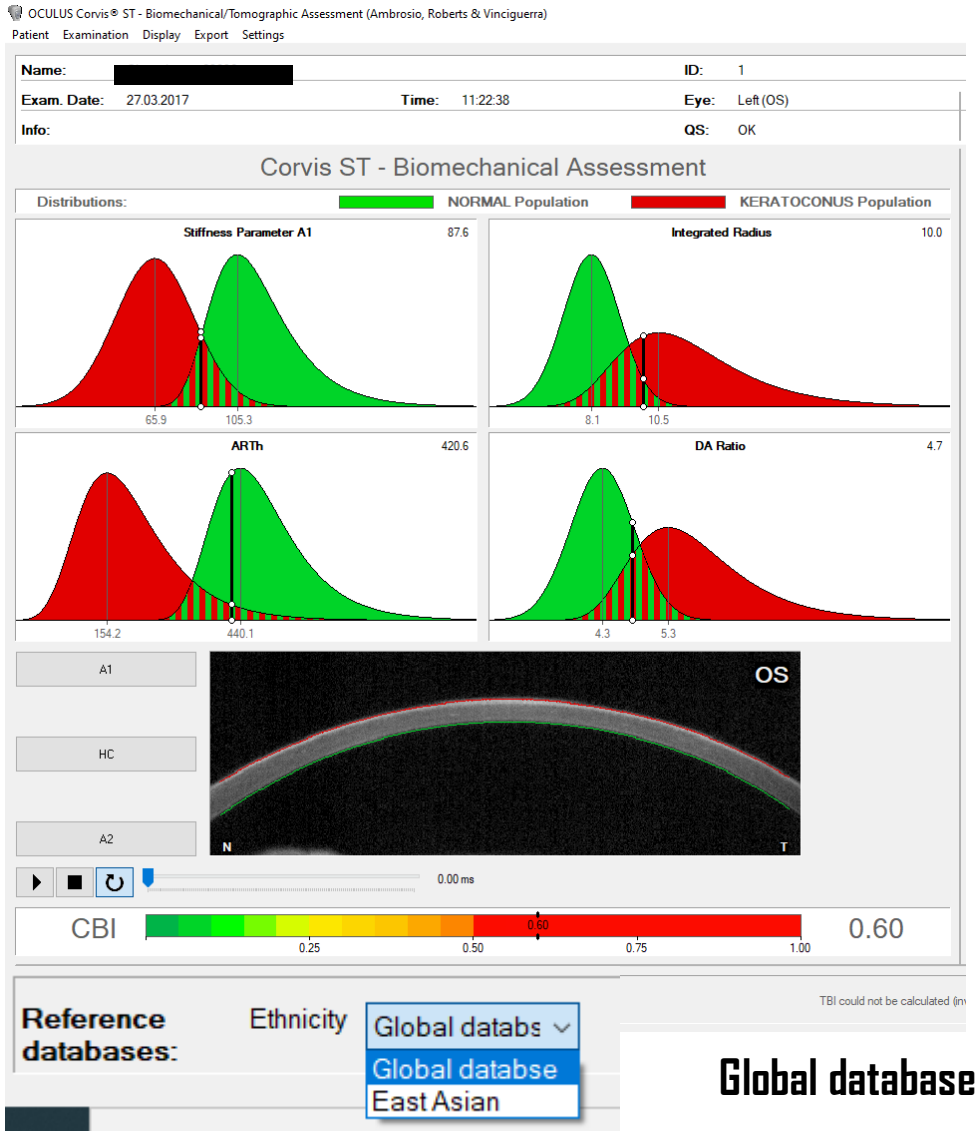
- The Corvis Biomechanical Index is known to be sensitive and specific to detect keratoconus
- CBI was created using a mixed South American and white population
- There is a significant difference in the values of SPAI and SSI between Chinese and white populations
- cCBI is a new index optimed for Chinese patients
- cCBI was superior to CBI for keratoconus detection in Chinese patients

Software with cCBI and cTBI launch at ESCRS!

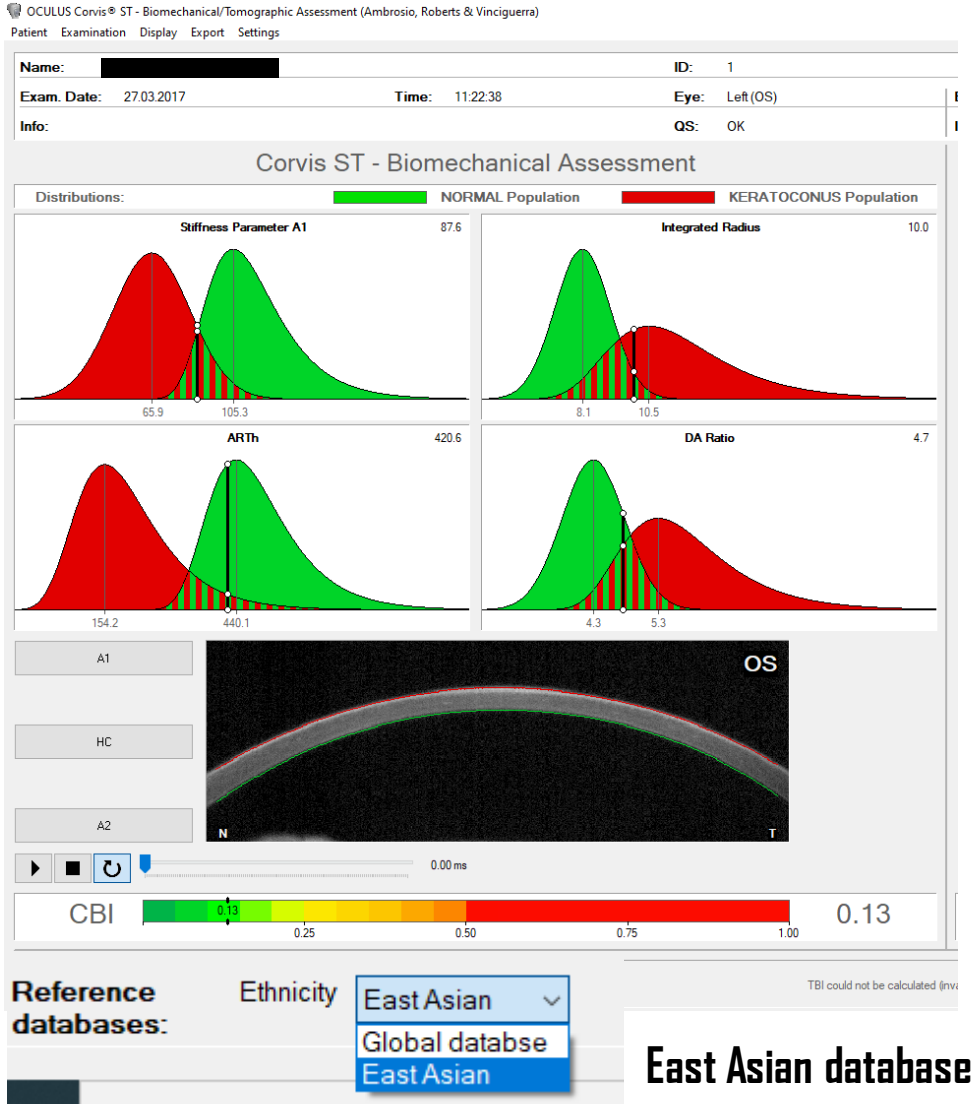
Case example: pre-op exam 4 Maps Refractive: pre-op exam of stable cornea after LVC



Difference between CBI and cCBI



Global database



East Asian database

GLOBAL EXPERT
ROUNDTABLE DISCUSSION

THANK YOU!

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