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Mild topographic abnormalities that become more suspicious on Scheimpflug imaging

A. WOLF[1], W. ABDALLAT[2], A. KOLLIAS[1], S.J. FRÖHLICH[1], M. GRUETERICH[1], C.A. LACKERBAUER[1]

[1]Department of Ophthalmology, Ludwig-Maximilians-Universität, Munich - Germany
[2]Department of Ophthalmology, King Hussien Medical Center, Amman - Jordan

PURPOSE. *Although several screening methods exist, postoperative corneal ectasia after refractive surgery is a severe complication. One possibility for this might be the fact that screening methods may fail in detection of preoperative risk factors such as forme fruste keratoconus (FFKC).*
METHODS. *Retrospective evaluation of four cases that showed only mild changes of FFKC on placido-based topography but revealed indicative findings on Scheimpflug imaging (Pentacam®).*
RESULTS. *While in placido-based topography evaluation of corneal topography did not show a clear FFKC, the evaluation of corneal topography on Scheimpflug imaging together with the data of spatial corneal thickness revealed distinctive FFKC in all cases presented.*
CONCLUSIONS. *Although both methods bear the risk of not detecting pre-existing FFKC, Scheimpflug imaging seems superior to placido-based corneal topography alone. (Eur J Ophthalmol 2009; 19: 10-7)*

KEY WORDS. *Scheimpflug imaging, Placido-based corneal topography, Forme fruste keratoconus*

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INTRODUCTION

Keratectasia is among the most severe complications after laser-assisted in situ keratomileusis (LASIK). Several risk factors for the development of corneal ectasia after refractive surgery are known, among them high myopia (1-6), low residual stromal bed thickness (RSBT) (2, 7, 8), pre-existing keratoconus, and forme fruste keratoconus (FFKC) (9-11). Most of these risk factors can be evaluated reliably preoperatively.

Corneal thickness and thus RSBT can be assessed by ultrasound or optical pachymetry. In order to avoid corneal ectasia after LASIK surgery, Barraquer (7) recommended a RSBT of 300 µm.

Keratoconus and FFKC as a risk factor for postoperative corneal ectasia can be assessed by corneal topography. It is a pathologic condition which is characterized by structural weakening of the cornea that leads to thinning and protrusion (13, 14).

While standard pachymetry may not be used for detection of keratoconus (13, 14), several characteristic changes in topography exist and screening algorithms such as the Klyce/Maeda program or the inferior-superior value may also detect early forms of keratoconus or FFKC (12-15). However, some of these signs can also be found in normal eyes (16). Even though the majority of risk factors are therefore identifiable, Klein et al found several cases without apparent preoperative risk factors that consequently developed corneal ectasia after surgery (17). One reason for this might be the inability of topographic devices to detect FFKC preoperatively.

In this retrospective study, we present four patients who showed suspicious findings on placido-based corneal topography. All of the patients did not completely fulfill the criteria of FFKC when using the placido-based corneal topography alone.

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METHODS

Four patients presented for routine examination prior to corneal refractive surgery. All of the following cases followed a standard examination protocol consisting of manifest refraction, slit-lamp and fundus examination, pupillography, and optical pachymetry. All demonstrated cases had worn soft contact lenses before and thus contact lens abstinence for at least 3 weeks was mandatory.
As part of the routine examination, different topography systems – placido-based topography (keratograph [Oculus Optikgerate GmbH, Wetzlar, Germany] or Topolyzer [Wavelight Laser Technologie AG, Erlangen, Germany]) and the Scheimpflug imaging based system (Pentacam [Oculus Optikgerate GmbH]) – were applied.
For identification of keratoconus on topographic analysis, findings were analyzed concerning an asymmetric inferior steepening, an asymmetric bowtie pattern with skewed steep radial axes above and below the horizontal meridian as is recommended by the AAO/ISRS/ASCRS joint committee (18). Centralization of the astigmatic lobes was also interpreted as indicative for keratoconus.
As thinning of the cornea is a pathognomic condition for keratoconus, increase of corneal thickness of more than 20% at a distance of 4.8 mm from the thinnest measurement in a graphical analysis was interpreted as indicative for early keratoconus on spatial pachymetry. For keratoconus, a mean thickness increase of 28% has been found while normal eyes have an increase of 9% in the mean (19). We have chosen a lower thickness increase because before refractive surgery early forms of keratoconus have to be detected.

RESULTS

In all four cases, the placido-based topography showed abnormalities within the central corneal area which could be found to a similar degree in the other eye. All patients revealed some degree of regular or irregular astigmatism. A distinctive keratoconus or FFKC could not be recognized clearly in any patient and none of the patients showed a distinctive asymmetric inferior corneal steepening or asymmetric bowtie patterns with skewed steep radial axes above and below the horizontal meridian.
In the same cases, the Scheimpflug-based topography (Pentacam®) data showed the presence of definite central corneal irregularities with peripheral steepening of the cornea – highly suspicious for FFKC. Calculating the spatial corneal thickness, all patients had an increase of corneal thickness of 20% or more at a circle about 4.8 mm around the thinnest measurement.
None of the patients underwent refractive surgery.

Case 1 (Fig. 1)

A 45-year-old Caucasian man presented for counseling for refractive surgery. Manifest refraction was –4.0/–0.75×162° diopters (D) (right eye [RE]) and –3.5/–0.5×42° D (left eye [LE]). BCVA was 20/20 in the right and 20/25 in the left eye. Placido-based topography showed regular astigmatism with the rule (–0.95 D×80.3° [RE] and –1.04 D×107° [LE]) and regular astigmatism but no off-centered steepening of corneal curvature. No characteristic asymmetric bowtie sign was evident. However, there was a centralization of the astigmatic lobes and there was a slight skewing of the radial axes above and below the horizontal meridian. There was no obvious steepening of the inferior cornea.
Scheimpflug-based imaging on the other hand revealed a clear inferior steepening. Both corneas showed thinning with thickness increase >20% at 4.8 mm distance from thinnest measurement (RE 21%, LE 25%).
The patient was advised to not undergo refractive surgery.

Case 2 (Fig. 2)

A 20-year-old woman with a manifest refraction of –1.75/–1.0×110° D in her RE and –2.00/–0.75×92° D in her LE presented for counseling before refractive surgery. Again, patient history and anterior and posterior segment findings did not show any contraindication for corneal laser surgery. BCVA was 20/20 in both eyes. Placido-based topography showed slight irregular astigmatism centrally and there was no marked difference between the two eyes. No inferior steepening or skewing of the radial axes above and below the horizontal median was evident.
Considering the Scheimpflug-based imaging results, an inferior steepening (RE>LE) as well as a thinning with thickness increase 20% at 4.8 mm distance from thinnest measurement was detectable (RE/LE 20%).

Case 3 (Fig. 3)

A 38-year-old Caucasian man presented for refractive surgery. The manifest refraction was –3.0/–4.25×9° D RE and –4.5/–3.25×175° D LE. Best-corrected visual acuity

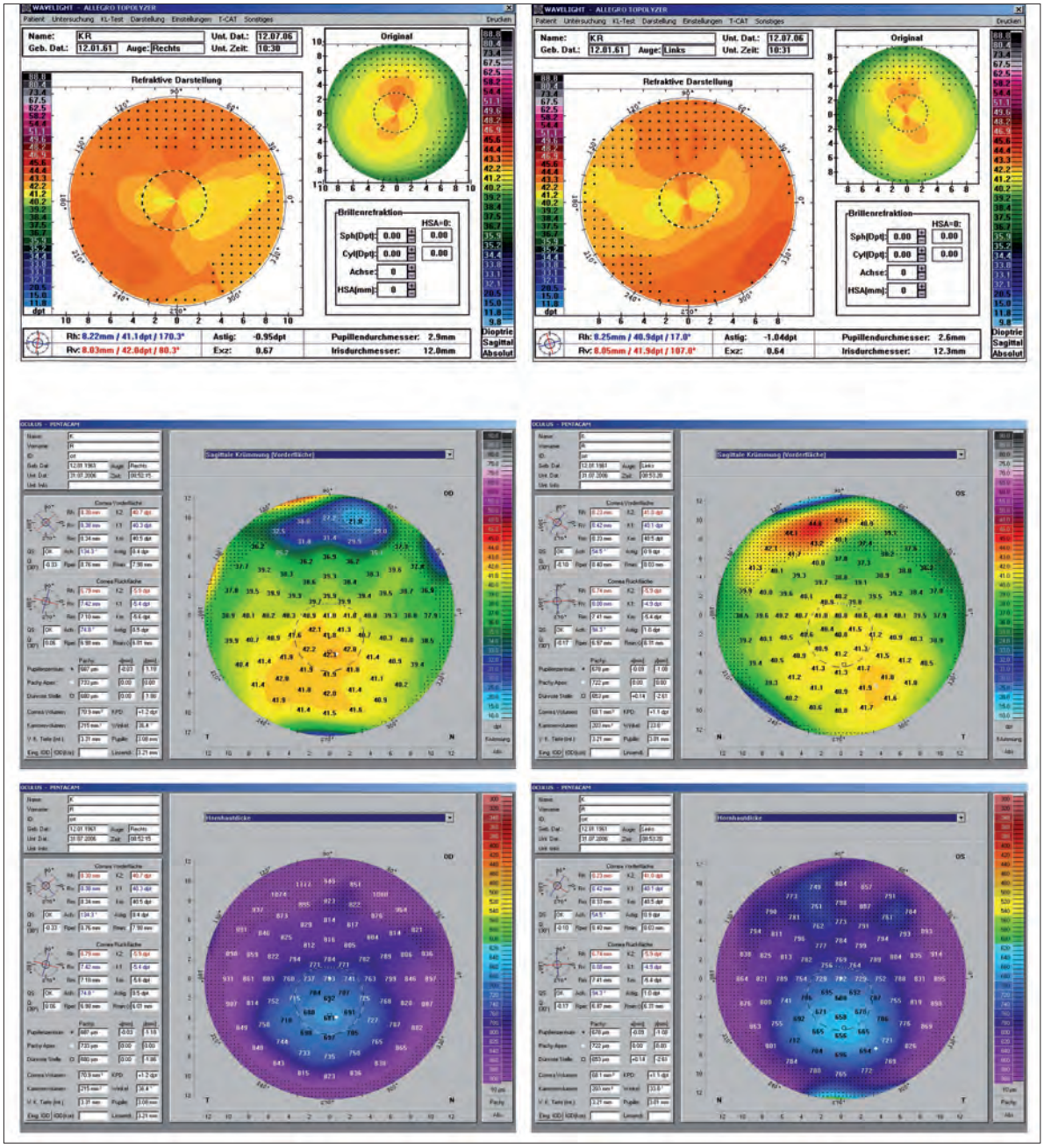

Fig. 1 - *Placido-based topography of a 45-year-old Caucasian man indicating regular astigmatism. No characteristic asymmetric bowtie sign was evident. However, there was a centralization of the astigmatic lobes and there was a slight skewing of the radial axes above and below the horizontal meridian* (upper line)*. On additional Scheimpflug imaging a clear inferior steepening was found* (middle line)*. Both corneas showed thinning with thickness increase >20% at 4.8 mm distance from thinnest measurement* (bottom line)*.*

(BCVA) was 20/32 RE and 20/25 LE. Routine examinations in both eyes were unremarkable. Placido-based topography showed regular, with the rule astigmatism in both eyes (RE –2.76 D; LE –2.52 D) and no signs of corneal irregularity. On the placido-disk imaging a slight inferior-nasal steepening of curvature was evident. Bowtie pattern was present with only slight difference between the two eyes.

Pentacam® examination revealed the presence of central corneal irregularities in both eyes. An inferior steepening of more

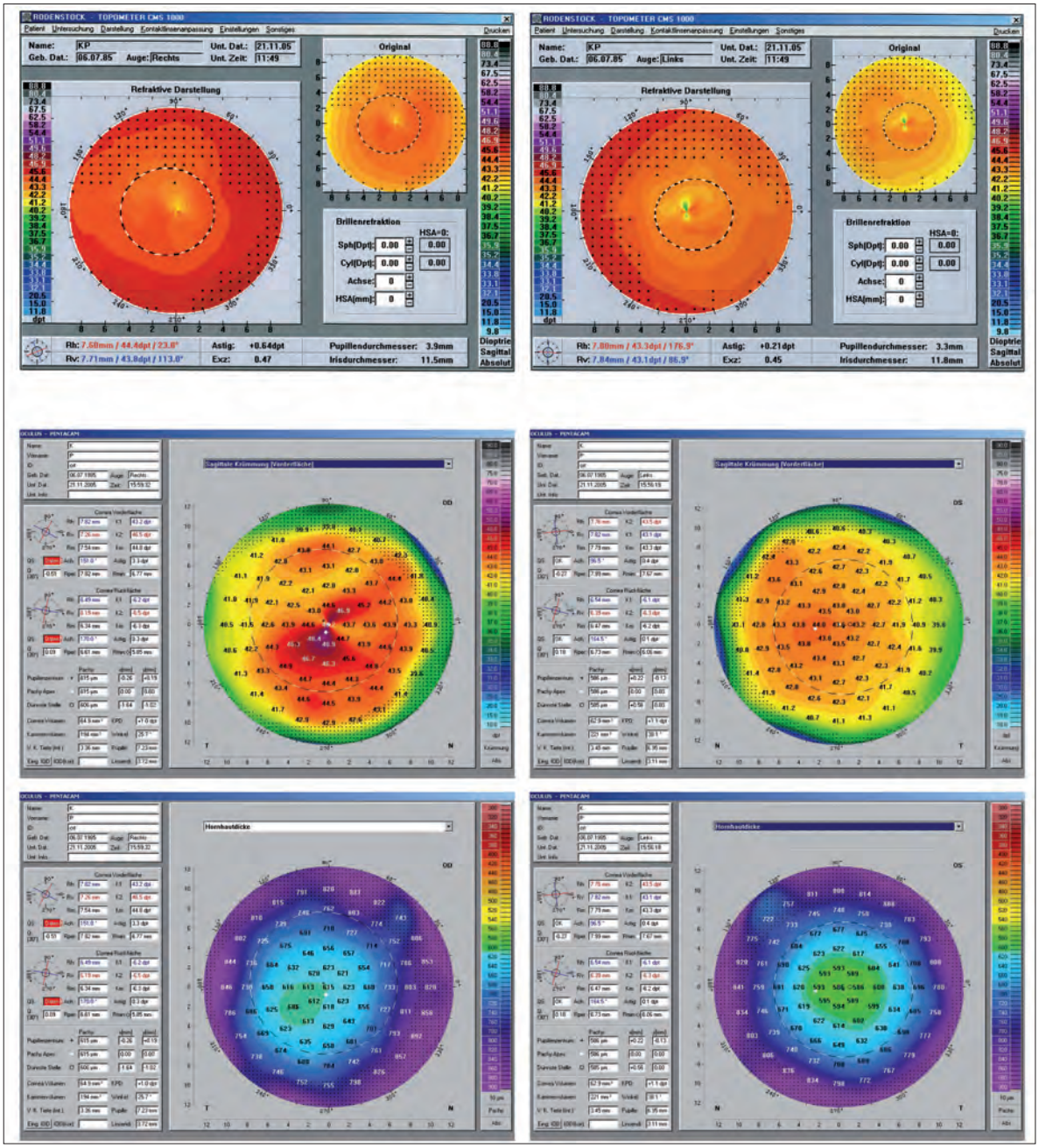

Fig. 2 - *Placido-based topography and Scheimpflug imaging of a 20-year-old Caucasian woman. Placido-based topography showed slight irregular astigmatism centrally and there was no marked difference between the two eyes. No distinctive forme fruste keratoconus (FFKC) was detectable on placido-based corneal topography* (upper line)*. On Scheimpflug imaging, an inferior steepening* (middle line) *as well as a thinning with thickness increase >20% at 4.8 mm distance from thinnest measurement* (bottom line) *indicated FFKC.*

than 2.9 diopters was detected in the RE which leads to the assumed diagnosis of FFKC. Spatial pachymetry showed a thinning with thickness increase >20% at 4.8 mm distance from thinnest measurement (RE 29%, LE 30%).
The patient was counseled not to undergo refractive surgery.

Case 4 (Fig. 4)

A 37-year-old Asian man presented for consultation on refractive surgery. Manifest refraction was –5.75/–2.75×0° D RE and –2.0/–1.75×9° D LE. BCVA

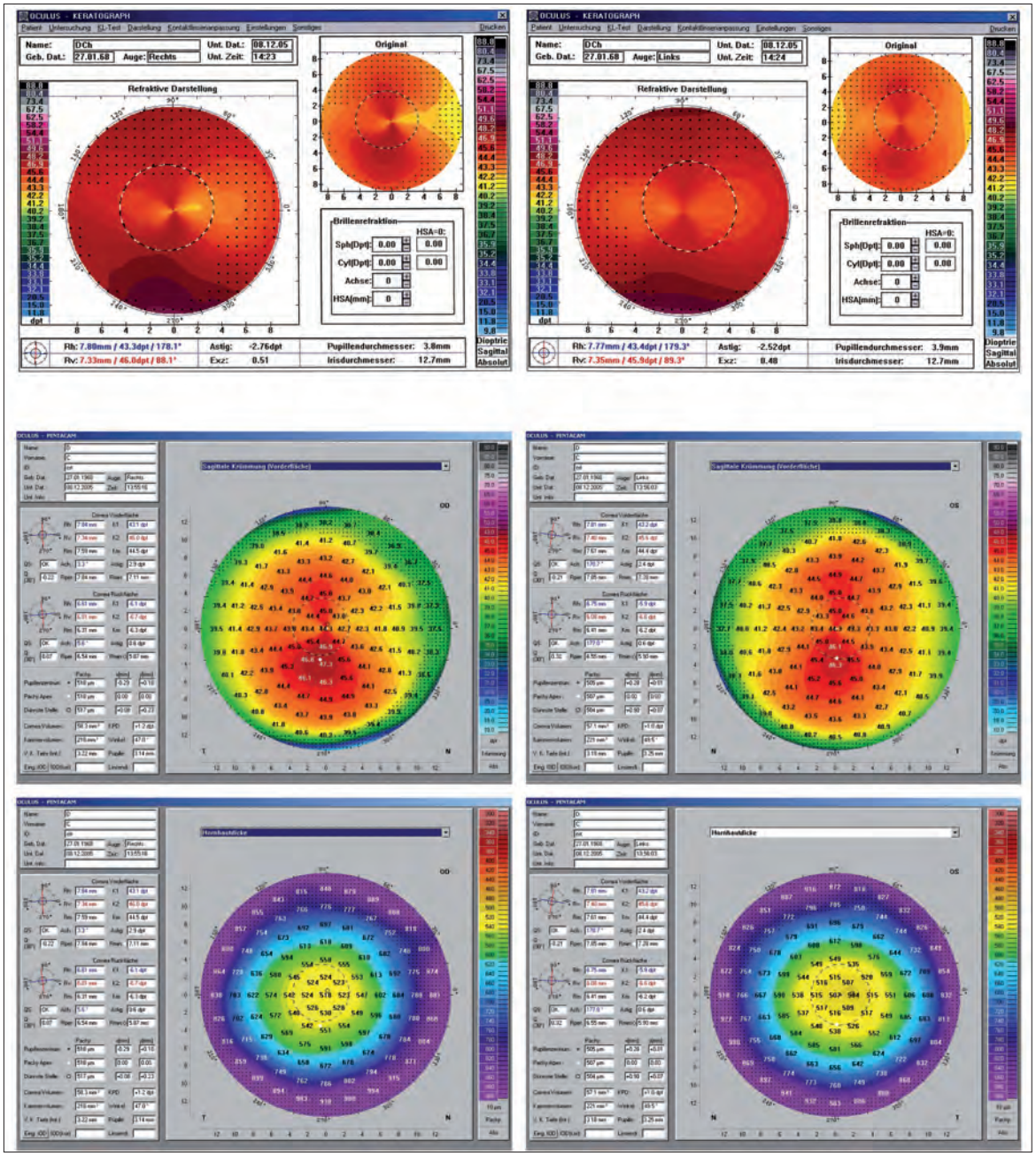

Fig. 3 - *Placido-based topography of a 38-year-old Caucasian man showed regular astigmatism in both eyes with no signs of corneal irregularity. On the placido-disk imaging no obvious inferior-nasal steepening of curvature was evident. Bowtie pattern was present with only slight difference between the two eyes and eccentricity was within normal range* (upper line)*. Scheimpflug imaging showed central corneal irregularities in both eyes and an inferior steepening* (middle line)*. Spatial pachymetry showed a thinning with thickness increase >20% at 4.8 mm distance from thinnest measurement* (bottom line)*.*

was 20/20 in both eyes. Preoperative examination was uneventful. Placido-based topography showed astigmatism with the rule (RE –2.3 D, LE –4.1 D). Bowtie pattern was detectable in both eyes and asymmetry raised suspicion of FFKC.

Scheimpflug-based imaging showed an inferior steepening inferior in the left eye and thinning with thickness increase >20% at 4.8 mm distance from the thinnest measurement was detectable in both eyes (RE 28%, LE 24%). Refractive surgery was not performed in this patient.

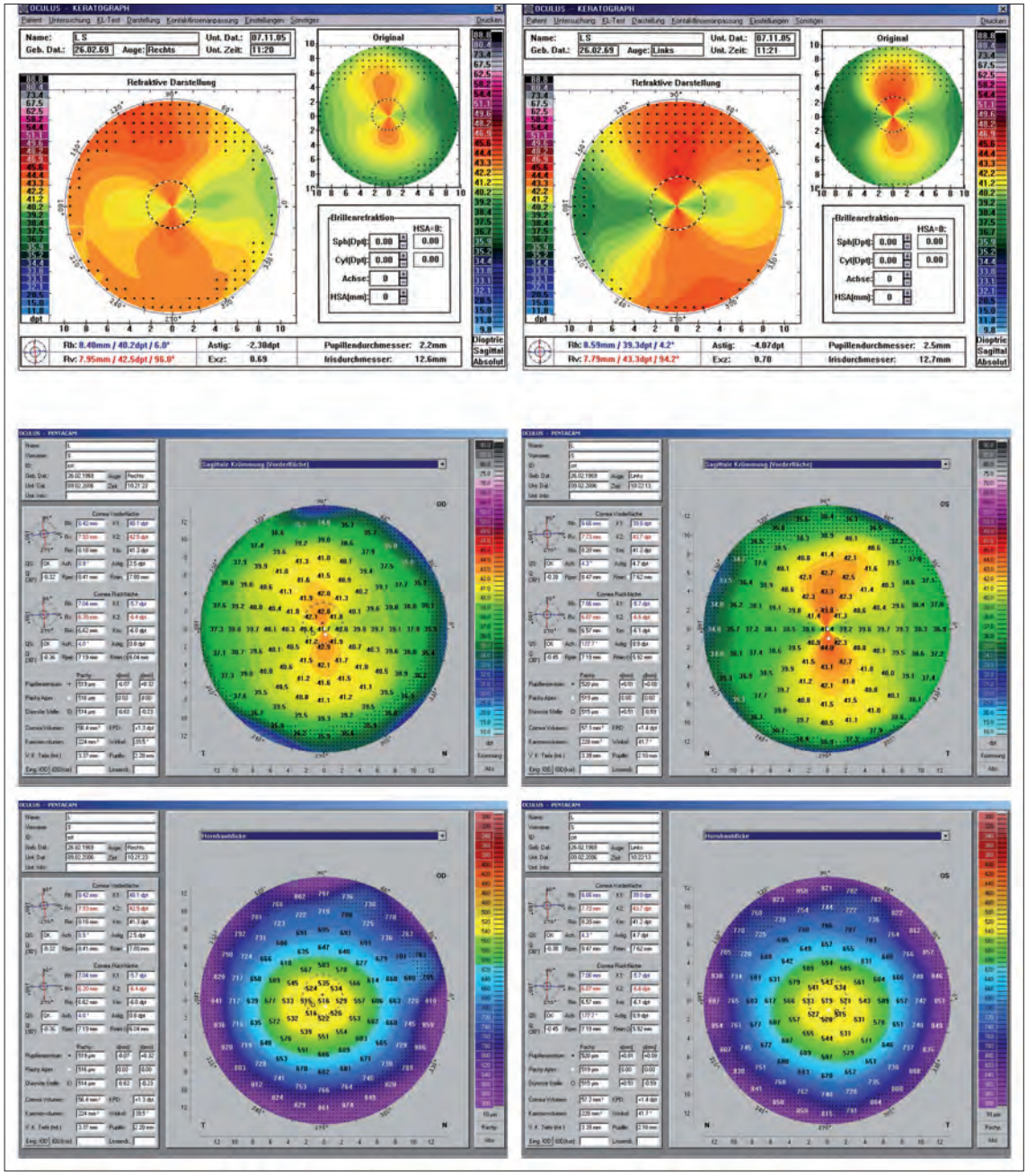

Fig. 4 - *Placido-based topography of a 37-year-old Asian man showed regular astigmatism but eccentricity was within normal range. An asymmetric bowtie pattern was detectable in both eyes and raised suspicion of forme fruste keratoconus* (upper line)*. Scheimpflug-based imaging showed an inferior steepening inferior in the left eye* (middle line) *and thinning with thickness increase >20% at 4.8 mm distance from the thinnest measurement was detectable in both eyes* (bottom line)*.*

DISCUSSION

The presented cases demonstrate differences of placido-based topography and Scheimpflug-based imaging of the cornea in detecting FFKC. These differences range from slight (Case 4) to considerable (Case 1). As in Case 1, on placido-based topography, only a suspicion with skewing of radial axis of bowtie above and below the horizontal axes as well centralization of the lobes was raised. In this case, Scheimpflug-based imaging revealed a marked in-

ferior steepening on topographic analysis and a thinning with increase of corneal thickness more than 20% at 4.8 mm distance from the thinnest measurement on spatial pachymetry. Thus, FFKC was highly suspicious.

In Case 2 the central irregular astigmatism that was revealed by placido-based topography did not raise moderate suspicion for FFKC. However, the inferior steepening as well as the thinning with spatial increase of corneal thickness led to suspicion of FFKC on Scheimpflug-based imaging.

Similarly, in Case 3 both eyes showed similar findings in placido-based imaging. Scheimpflug-based imaging showed a marked difference in inferior corneal steepening and the thinnest corneal measurement was surrounded by an increase of corneal thickness of more than 20%. Differences for detection of FFKC between placido-based and Scheimpflug-based imaging were less marked in Case 4. In this case, placido-based topography revealed a significant difference of bowtie sign between right and left eye. However, the additional information on spatial corneal thickness variation confirmed the suspicion of FFKC.

All of these cases demonstrate that placido-based topography may mask the presence of FFKC. To our experience, differences could be due to additional information and technical differences in data acquisition of these two corneal topography systems:

While placido-based topography gives only topographic information of anterior corneal curvature, Scheimpflug-based systems (Pentacam®, Orbscan®) generate a complete topographic map of the anterior corneal surface and the posterior corneal curvature. The measurements are based on approximately 25,000 true elevation points, including the pupil's center, the apex, the thinnest local point of the cornea, and its deviation from the apex. Based on these data, the Pentacam® examination gives additional information on topographic corneal thickness. Therefore, to increase power to detect early forms of keratoconus, a spatial thickness variation as described by Ambrósio et al (19) may be additionally used as a criterion in Pentacam® examinations. There are no data available on early forms of keratoconus. Therefore, we adopted the data found by Ambrósio and colleagues for manifest keratoconus. In our setting, we use a spatial thickness increase of only 20% for detection of very early forms of keratoconus before refractive surgery.

Using placido-disk topography, there is a lack of information on central corneal curvature due to the central positioning of the camera with a diameter of 1 mm to 2.1 mm, depending on the K-values of the cornea. Although keratoconus may also start inferiorly, changes within the central cornea are frequent. With placido-based imaging techniques, due to K-reading interpolation of the central corneal refractive power, central corneal irregularities cannot be detected sensitively. The data acquisition, used in placido-based topography, relies on indirect measurements of the x, y, and z coordinates of elevation points referring to the anterior corneal surface.

For this data acquisition, the Pentacam® system uses a rotating Scheimpflug camera to obtain 50 slit images with a very high density of real measurement points in the central corneal area. Using this data acquisition, the central cornea can be measured directly.

The processing of keratometric data in both systems is based on the Zeiss formula for the calculation of the axial curvature. Therefore, the differences for detection of FFKC cannot be due to a difference in data processing but must be within the data acquisition as mentioned above.

For placido-based topography as well as for Scheimpflug-based imaging, several disadvantages exist. While there is no obvious difference in duration of examination (20), both systems are susceptible to certain conditions. Placido-based topography has been shown to be susceptible to tear film instability (15). Pentacam® is vulnerable to distortions in a similar way. Huebscher et al have demonstrated several physical phenomena leading to fallacies in Scheimpflug-based imaging (21). But due to the physical principle, especially the measurement of the anterior curvature is least susceptible to large distortions (21). Since this is the most significant indicator for FFKC, the detection of preoperative FFKC should be less influenceable in the Pentacam® system.

A weakness of our study is the fact that since placido-based topography is the standard, we cannot prove that our cases indeed present clear FFKC. This will be only possible by raising data in a long-term study showing the progression of findings. However, the pachymetry findings we adopted to identify FFKC have been shown in a comparative study previously (19). In this, the authors found an average increase of spatial thickness of 9% in normal eyes and 28% in keratoconic eyes. In order to detect very early forms of keratoconus – as is important before refractive surgery – a spatial thickness increase of only 20% was interpreted as suspicious for keratoconus.

Additionally, concerning the topographic findings, both systems use the same formula and since only the mode

of data acquisition differs, the characteristics on topography should not differ. Our cases (especially 1 and 2) do not present a clear inferior-superior steepening on placido-based topography while this was evident in all cases on Scheimpflug imaging using the Pentacam® system.

In conclusion, our cases provide data that FFKC leading to corneal ectasia can be overlooked by placido-based topography. Corneal topography measurements, based on Scheimpflug imaging (Pentacam®), are able to detect FFKC in cases in which placido-based imaging failed or delivered only suspicion of FFKC. Using the Pentacam® system, the creation of a topographic pachymetry map is useful complementary information for the detection of FFKC. Thus, to prevent our refractive patients with FFKC or not yet manifest keratoconus from corneal surgical procedures, we do not only rely on placido-based corneal topography results. In addition, we perform Scheimpflug-based imaging in order to avoid any surgical induced corneal ectasia.

The authors have no proprietary interest in any of the equipment or materials used in this study.

Reprint requests to:
Armin Wolf, MD
Department of Ophthalmology
Ludwig-Maximilians-Universität
Mathildenstr. 8
80336 Muenchen, Germany
armin.wolf@med.uni-muenchen.de

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