

Topography and Scheimpflug Imaging

Pearls for refractive surgery screening and keratoconus detection.

BY MICHAEL W. BELIN, MD

Detecting keratoconus and performing topographic screenings prior to refractive surgery are particularly timely topics in light of *Cataract & Refractive Surgery Today's* Anatomy of a Lawsuit II articles.¹⁻⁴ After reviewing those pieces, it would be inappropriate for me to comment on the trial and/or its merit. What I will review is the confusing and often unresolved issue of what is topographic evidence of keratoconus.

I perform LASIK on the majority of my patients, but I have always performed a higher percentage (approximately 20%) of surface ablation procedures than is the norm for my geographic area. I have been involved with keratoconus and topography for the better part of my professional life and have presented more than 100 papers at national and international meetings. I have been a proponent of elevation-based topography for more than 15 years. I believe I know more than most, but likely less than some, in terms of topography. I do acknowledge that my strong preference for elevation-based evaluation has not always been shared by others in the field.

SIMULATED KERATOMETRY

One of the earliest reliable signs of early keratoconus or other pathologic conditions of the cornea is irregular astigmatism, in which the principal meridians are not orthogonal (other than 90° apart). Unfortunately, in the majority of topographic systems in use today, simulated keratometry values are always measured 90° apart, regardless of the corneal surface. In other words, simulated K values should not be used to determine the degree of surface regularity. Many systems have other settings that allow the steep and flat axes to be identified without the constraint of forcing

them to be 90° apart. Often, these go by other names such as topometry or keratography. Users should be familiar with their topographer and its settings to allow the principal meridians to float when screening refractive patients.

FREQUENT MISTAKE

The most common errors in topography are a failure to understand exactly what is being measured and the assumption that curvature reflects shape. As ophthalmologists, we all understand that a spectacle lens can have multiple different shapes and yet still have the same power. This concept is partially true for corneal curvature. Curvature is a reference-based measurement, but it is not an innate property of the cornea, because it will change with the reference axis, positioning, or orientation.

If one views an eye the way Gullstrand⁵ did (simple reduced eye), determining the curvature and measurement of the cornea will not be a problem. The human eye, particularly the cornea, is not rotationally symmetric,

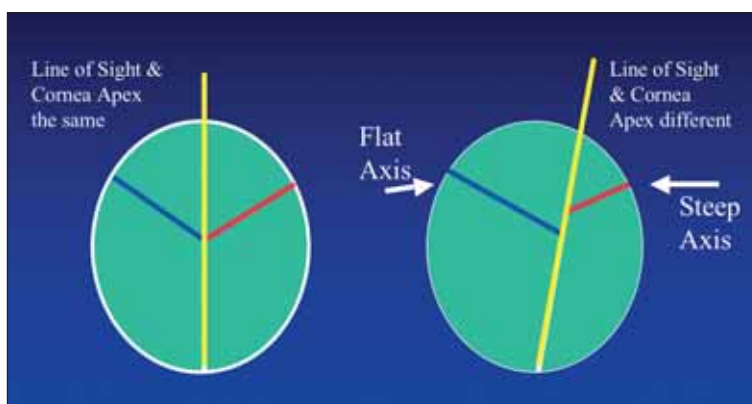


Figure 1. It is unreliable to depend on curvature to diagnose ectatic disorders. These patterns are often seen in what now is frequently called a *displaced corneal apex*: despite a normal corneal shape, the corneal apex does not line up with the reference axis. In overly simplistic terms, the patient is not looking through the apex of the cornea.

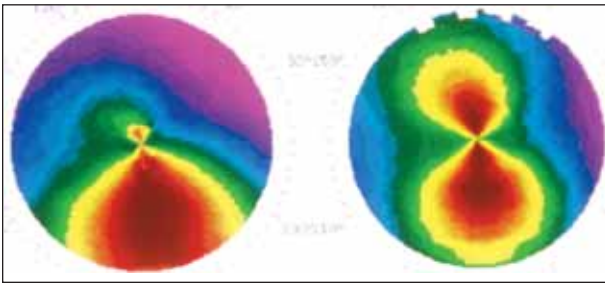


Figure 2. Most practitioners would consider the map on the right to represent a normal astigmatic cornea, whereas the map on the left is decidedly abnormal and highly suspicious of keratoconus. Both images are of the same eye taken minutes apart with a slight angular decentration.

however, and people typically do not look through its geometric center or its apex. The truth of this statement is evident in pediatric ophthalmology, when clinicians examine patients with pseudostrabismus due to a positive angle kappa. Curvature measurements are reference based, meaning the curvature map will change based on the reference axis. Typically, the reference axis is neither the corneal apex nor the line of sight but some arbitrary axis made by the normal line that the keratoscope makes with the corneal surface. For most people, the differences between these points (lines) are reasonably minute and a relatively small source of error. In some, however, the difference between the topographer's reference axis, the line of sight, and the corneal apex lead to curvature patterns that may be interpreted as abnormal (eg, asymmetric bowtie astigmatism, inferior steepening) (Figure 1).

ASYMMETRIC TOPOGRAPHY

Asymmetric topography can be present, and almost always is, in abnormal eyes (eg, keratoconus, contact lens warpage), but it may also be present in completely normal eyes with a displaced apex. These eyes will typically have a normal elevation map but often exhibit orthogonal principal meridians. Some programs for keratoconus detection utilize the principal meridian detection feature to differentiate normal from abnormal asymmetry (Figure 2).

Low amounts of astigmatism may appear asymmetric or variable without being abnormal, as anyone can attest who has tried to obtain repeatable refractions from a patient with very low levels of astigmatism.

PELLUCID MARGINAL DEGENERATION

Pellucid marginal degeneration is a rare condition in which the cornea has a linear band of thinning 1 to 2mm from the inferior limbus. The cornea is typically flat above the band and then undergoes a rapid increase

in curvature and change in shape in the area of thinning. The condition was first described by Schlaeppli⁶ in 1957 and was extensively reviewed by Krachmer et al.⁷ Currently, someone describes multiple cases of pellucid marginal degeneration based on topographic evidence at every ophthalmic meeting. Almost all cases currently being called *pellucid marginal degeneration* are standard keratoconic eyes for which the physician incorrectly located the cone based on axial curvature analysis (Figure 3).

Additionally, placido-based systems cannot image the entire corneal surface. These systems are reflective and require a mirror image of the placido pattern to be processed by a centrally placed camera. Due to both the optical properties of the anterior corneal surface and the physical properties of the patient (anatomy), it is physically impossible to obtain limbal-to-limbal readings. In other words, placido-based systems cannot image the area where the greatest pathology exists in classic pellucid marginal degeneration. The frequent diagnosis of pellucid marginal degeneration is based on the incorrect assumption that curvature (axial) maps reflect shape. Axial curvature maps are inherently inaccurate in the corneal periphery and will exaggerate the size and incorrectly locate the area of thinning. Most of the cases, when viewed with an accurate elevation map, will be typical of inferior keratoconus and will not share the features classically attributed to pellucid marginal degeneration.

Recently, newer technology has greatly aided the imaging of irregular corneas and the diagnosis of the very early stages of ectatic disease. The Pentacam (Oculus, Inc., Lynnwood, WA) utilizes a rotating

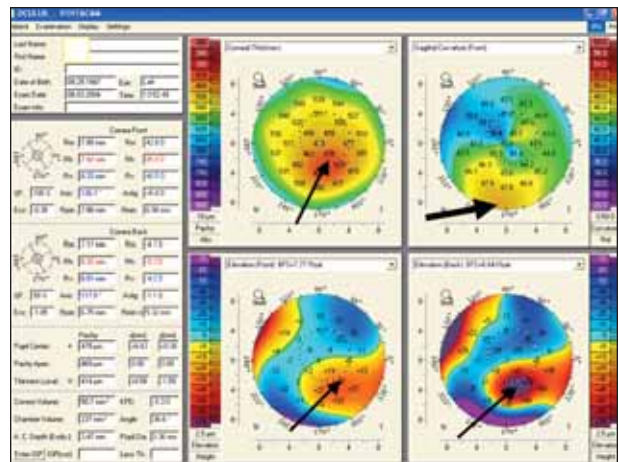


Figure 3. In this example, the curvature map incorrectly locates the cone in the far periphery, whereas the elevation maps (anterior and posterior) and pachymetric maps correctly locate the cone slightly below the pupillary border.

Scheimpflug imaging system to directly measure both anterior and posterior corneal elevations as well as image the entire anterior segment and determine lens transmission. Because the device is recording an optical slice, it can measure the amount of light that is transmitted through each optical part of the system. By measuring the loss of light due to the lens, one can determine the optical density of the lens. The Pentacam appears to accurately evaluate clinical situations in which other elevation systems have been historically inaccurate (post-LASIK, corneal haze). Posterior elevation changes have often been overlooked as possibly one of the earliest changes in forme fruste keratoconus, partially due to the fact that placido systems cannot measure the posterior surface, and other elevation systems were notoriously inaccurate in measuring subtle changes to the posterior corneal surface. The combination of anterior elevation, accurate posterior elevation, and pachymetric distribution has greatly aided the diagnosis of early keratoconus and the differentiation of true post-LASIK ectasia from earlier aberrant diagnoses.

CONCLUSION

Although topography was developed more than 20 years ago, the means by which to determine the cornea's true shape is still evolving and has proven more problematic than some more recent developments such as wavefront analysis. Although there is little disagreement on diagnosing clinically evident keratoconus, agreement on what constitutes forme fruste or preclinical keratoconus remains elusive. The analysis of both anterior and posterior corneal surfaces and the corneal pachymetry distribution appears to have significantly enhanced clinicians' ability to identify eyes at risk, although level-one evidence for the type of detection is and will likely remain lacking.

Refractive surgeons need to understand topography in order to screen patients properly and may at times have to choose a procedure (LASIK, surface ablation, conductive keratoplasty, phakic IOL) or elect not to proceed based on topographic findings. Newer technologies that look at other physical properties of the cornea are evolving, and their potential usefulness is unknown. Refractive surgery, like all medical procedures, will never be risk free. The physician's job is to offer patients the best possible care. It is the legal system's role not to hold ophthalmologists to the unattainable goal of totally risk-free surgery. ■

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