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Getting the Most From Topography

The challenge is to understand how best to use these technologies in clinical practice.

BY STEPHEN D. KLYCE, PhD

In the early 1980s, keratorefractive surgery was developing via a steady stream of incisional, excisional, and onlay techniques that changed the cornea's shape and thus its curvature. It became clear that simply measuring visual acuities and following keratometry (K) readings were not going to be adequate for examining the details of changes in the cornea's shape. That was the stimulus for surgeons' voyage into the development of corneal topography and the color-coded map that is the standard of care in corneal and lenticular refractive surgical practice today.

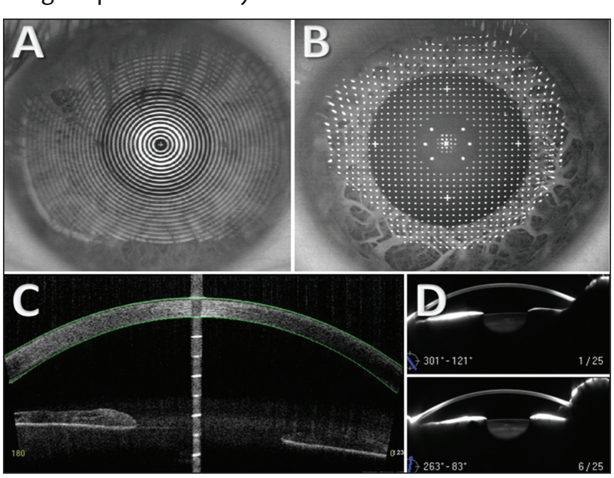

Figure 1. Three technologies are commercially available for measuring corneal topography. The Placido disk target continues to be the most popular approach (A). The grid-style reflection method was introduced with some success (B). Swept-source spectral-domain OCT (C). Slit-scan devices are the most capable of measuring aberrated corneas, and they can also measure corneal thickness (D).

Much progress has been made with corneal topographers. We now embrace devices that can reliably measure corneal curvature, shape, and thickness and even corneal and ocular aberrometry. The challenge now is to understand how best to use these technologies in clinical practice.

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THE TECHNOLOGIES

At least three technologies are commercially available for measuring corneal topography (Figure 1). The reflection-based corneal topographers have the longest history and the widest spectrum of models from which to choose. The Placido disk target continues to be the most popular approach (Figure 1A), although the grid-style reflection method has been introduced with some success (Figure 1B). Interferometric techniques have been pursued in the past, but recently, an instrument based on swept-source spectral-domain optical coherence tomography (OCT) was introduced to measure corneal curvature (Figure 1C). This is a technology to watch, as OCT resolution continues to improve. Finally, slit-scan devices offer the best measurements of aberrated corneas and can measure corneal thickness (Figure 1D).

The relative sensitivity and fidelity[1] of the different approaches to measuring corneal curvature are illustrated in Figure 2. When high sensitivity and resolution are important, such as for topography screening applications, the grid-style reflection approach may have a slight edge over the traditional Placido target. Elevation-measuring slit-scan methods are less faithful in rendering

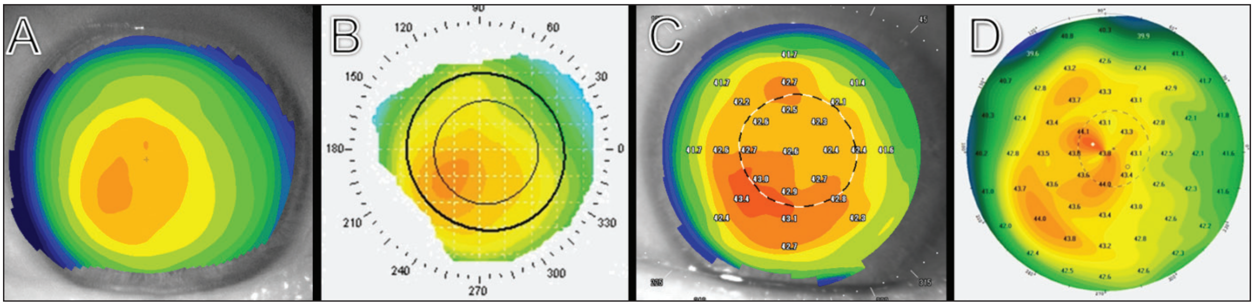

Figure 2. The relative sensitivity and fidelity of the different approaches: Placido (A), grid-style reflection (B), OCT (C), and slit scan (D).

corneal curvature with high sensitivity. On the other hand, for studies in which evaluating the reduction in corneal aberrations is paramount, as when documenting the progression of keratoconus and its amelioration after cross-linking, the slit-scan devices are essential. The reflection devices cannot follow rapid changes in corneal curvature. Swept-source OCT performs remarkably well on relatively normal corneas, but it remains to be seen how it will handle aberrated corneas.

CORNEAL TOPOGRAPHY SCREENING 101

Based on studies of preoperative corneal topography of patients who developed ectasia after keratorefractive surgery, researchers have developed a better understanding of who may be at risk.[2] Thankfully, the incidence of iatrogenic ectasia appears to be on the decline, owing to several basic premises. The use of fixed standardized color scales[3,4] is perhaps most important for clinical discrimination between normal and abnormal topography. The latter has been singled out as the most important risk factor for postoperative ectasia.[2] Keratoconus is an established contraindication to refractive surgery, but in its earliest expression, the condition is difficult to detect.

A number of screening programs have been developed to help the clinician recognize the signs present in corneal topography that suggest keratoconus. The earliest test might be ascribed to Rabinowitz and McDonnell.[5] They showed that, because keratoconus is often expressed as an inferior steepening on corneal topography, a screening variable (I-S) could be calculated to measure its extent. The I-S value was calculated from superior and inferior averages of corneal power at a 3-mm radius. Values greater than 1.40 D of asymmetry were said to be suspicious for the presence of keratoconus. Subsequently, Rabinowitz broadened the scope of his detection method to include another sign of keratoconus: skewing of the radial axes.[6]

Various strategies for screening have been developed, but perhaps the most advanced method used the development of a neural network-based system that could not only discriminate keratoconus from normal corneal topography but also a variety of other common clinical conditions. That program, the Corneal Navigator (Nidek), is the only validated screening system to differentiate a number of corneal conditions (Figure 3).[7] Perhaps one of the most useful aspects of such screening systems is that they foster clinical understanding of corneal topographic abnormality.

There is more to screening than corneal topography. Currently, a wide variety of corneal topographers is available, some with screening programs, but few of

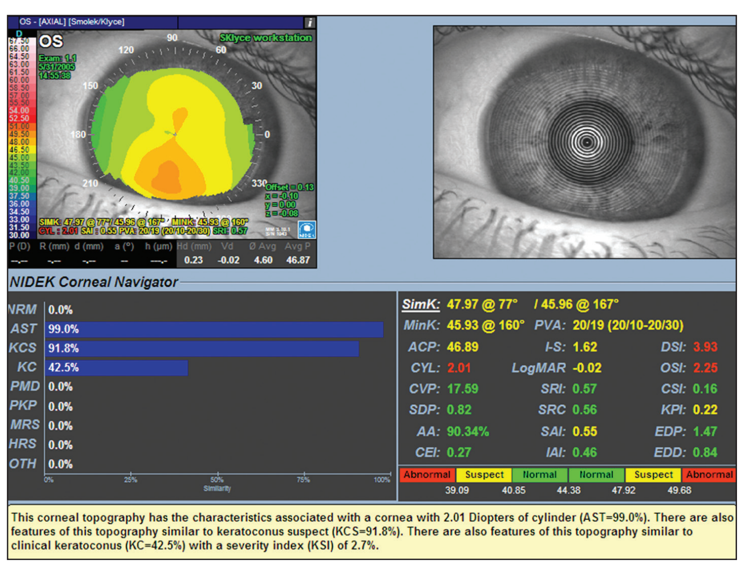

Figure 3. The Corneal Navigator is a validated screening system with which to differentiate among a number of corneal conditions.

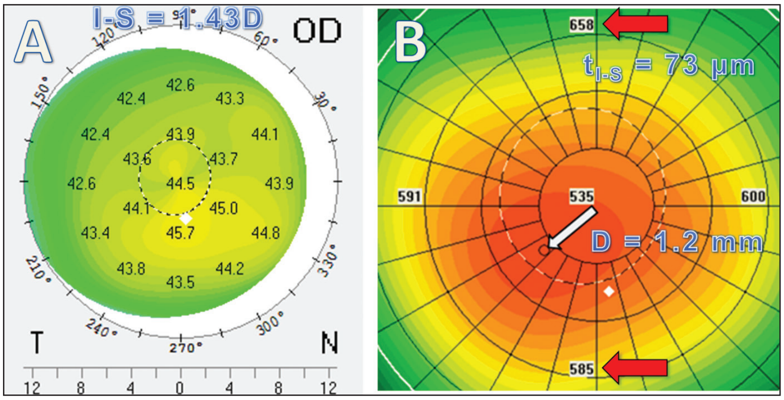

Figure 4. A cornea judged to be normal developed ectasia after refractive surgery: preoperative topography (A). Anomalies in pachymetry: large displacement of the thinnest point and a 73-um difference in superior and inferior thicknesses (B).

these have been validated in the literature. As a consequence, automatic detection of corneal topographic abnormality is not widely used. Furthermore, anecdotal reports of keratectasia after refractive surgery on corneas that are judged to have normal topography are routinely presented at meetings. Fortunately, today's slit-scan corneal tomographers provide a wealth of pachymetric data that can be used along with corneal topography to screen out suspicious corneas.

For example, Figure 4 shows a cornea with an anterior corneal curvature that was judged to be normal but that developed ectasia after refractive surgery. The corneal curvature (calculated from the elevation data) seems fairly normal, although a post hoc calculation of the I-S value showed it to be slightly above the bar for suspicion of keratoconus (1.43 D). Close inspection of the pachymetry map, however, reveals a large deviation of the thinnest point on the cornea from the instrument optical axis and significant asymmetry between the inferior and superior thicknesses. Not enough data have been collected to validate these pachymetric findings as a definitive abnormality that is possibly associated with keratoconus. Such findings should, however, prompt the clinician to look more closely at corneal topography.

CORNEAL OPTICAL ANALYSIS TO VALIDATE SURGICAL APPROACHES

One of the most underutilized features of a corneal topographer may be the software that provides clinical information on the quality of vision. Possibly the first clinically useful index for this parameter was the surface regularity index,[8] which was correlated clinically to potential Snellen visual acuity using variations in corneal curvature within the entrance pupil. The development of methods by which to measure the optical aberrations of the eye allows ophthalmologists to dissect out specific optical aberrations from corneal shape such as cylinder, coma, and spherical aberration. As a result, the radially symmetric aberrations can now be compensated for in the design of IOLs. Equally important, physicians can use this approach to evaluate the optical quality of refinements to keratorefractive surgical techniques aimed at reducing aberrations from the peripheral areas of treatment.[9]

WHERE WE ARE TODAY

Corneal curvature, shape, thickness, diagnostics, and optical properties are now available from a variety of corneal topography instruments. Corneal topography continues to be a very sensitive detector of possible keratoconus. Screening software can be an excellent adjunct with which to identify the abnormal cornea. Corneal tomographers provide essential global pachymetry to flag patients who may be at risk for ectasia when reflection topography is difficult to interpret. Finally, aberration analysis of corneal topography provides a method by which to refine keratorefractive surgical procedures, relegating halos, monocular diplopia, and other visual symptoms to baggage left behind. ■

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