Precise corneal power measurements are necessary for IOL calculation after refractive surgery. To obtain accurate corneal power measurements, ophthalmologists should measure the anterior and posterior surfaces of the cornea. Most traditional diagnostic methods measure only the anterior part of the cornea, while the Pentacam system (Oculus, Inc., Lynnwood, Wash.) ascertains corneal power from both anterior and posterior corneal surface measurements. Competing devices that measure the back surface of the cornea lack the Pentacam’s accuracy.

My colleagues and I have been using the Pentacam system in my clinic for more than 1 year. Prior to acquiring this new technology, I considered other devices for measuring the curvature of the back of the cornea, such as the Artemis 2 VHF Digital Ultrasound Eye Arc-Scanner (Ultralink LLC, St. Petersburg, Fla.) and the Orbscan topographer (Bausch & Lomb, Rochester, N.Y.), which I had helped to develop. The Artemis uses a high-frequency ultrasound to map the anterior or segment of the cornea, but I have found that it is not a cost-effective system. Although the Orbscan provides useful pachymetry data for corneal thickness, it cannot accurately compute the curvature of the back of the cornea.
When the Orbscan topographer captures an image, the slit lamp moves through space for 2.3 seconds. During this short time, significant eye movement may occur, resulting in variability of computation of the curvature of the back of the cornea. I advise clinicians to be cautious about using the Orbscan’s posterior float; three articles in the Journal of Cataract and Refractive Surgery have addressed the problems.1-3

Peripheral sampling inaccurate

A study that I presented at the 2005 American Society of Cataract and Refractive Surgery meeting in Washington, D.C. provides a method using the Pentacam to arrive at the proper K-reading for IOL calculations in patients who have undergone any refractive corneal surgery such as laser in situ keratomileusis (LASIK), photorefractive keratectomy (PRK), radial keratotomy (RK) and conductive keratoplasty (CK). Precise measurements of the front and back surface power are necessary and cannot be obtained by keratometry or topography. The reasons for this difficulty are two-fold. First, when a patient has undergone a refractive corneal procedure, the cornea no longer has the normal shape and is altered in a way that makes it aspheric, and the paracentral measurements no longer reflect the central power. Because topographers cannot measure the center 1-mm to 1.5-mm of the cornea, these central powers must be extrapolated from the paracentral measurements to the center, resulting in sizable errors.

For example, when a 7.5-D LASIK procedure is performed on a patient, a traditional device inaccurately measures the change to be 6.5 D instead of 7.5 D. That 1-D difference translates to a 15% error in measurement, which is an overestimation of the power of the cornea. Measuring the center part of the cornea based on peripheral sampling results in an unexpected refractive outcome after IOL power calculation.

Back radius assumption unreliable

The second reason relates to the inability of standard instruments to measure the back radius of the cornea. Assuming that the back radius is 82% of the front radius is unreliable after LASIK or PRK. For the patient who has had a 7.5-D LASIK procedure, standard instruments that assume the back radius of the curvature of the cornea is 82% of the front curvature would make a 0.75-D error in measurement. This error is 10% of the true measurement, 7.5 D. When taking into consideration the 1-D error (15%) resulting from peripheral sampling used to measure the center part of the cornea, the result is a total 1.75-D error (25%) of the total refractive change from refractive surgery in the IOL calculation.

Other methods flawed

Corneal measurements found using the historical and contact lens methods are also fraught with error. Using the historical method, clinicians take the change of the refraction following refractive surgery and subtract it from the keratometry readings. For example, if a patient’s cornea was 45 D before surgery, then the cornea should be 40 D after a –5-D LASIK procedure. The problem with the historical method, however, is that one cannot be certain that the refractive change was entirely due to the refractive surgery, because a patient’s cataract could have been growing during that time, as well. In the contact lens method, a rigid gas-permeable lens with a known base curve is placed on the eye. The patient is refracted and corneal power is estimated after refractive surgery. With the contact lens method, a 10% error still exists because it only determines the front surface power of the cornea. It also requires that the patient have good enough vision to have a reliable refraction.

In summary, the Pentacam system allows clinicians to accurately measure the power of the cornea in patients who have had prior refractive surgery, within ±0.5 D, which is at least four times better than previous studies with topographers and keratometers.

References
My colleagues and I had the pleasure of getting the first domestic Oculus Pentacam (Oculus, Inc., Lynnwood, Wash.) unit and have been using it at the TLC Laser Eye Centers in Albany, New York, for over 1 year. We have found the Pentacam, an elevation-based diagnostic imaging system, to be highly accurate in detecting keratoconus, because it provides the level of precision in measuring the corneal surface necessary to diagnose this condition. Most topographers rely on the outdated science of Placido disc technology and calculate corneal curvature based on derived slope data. Topography based on direct measurements of corneal elevation points more accurately maps the cornea than Placido-based topography. Although some other elevation-based diagnostic imaging systems are currently on the market, they do not have the accuracy of the Pentacam. The Pentacam has equaled and surpassed any device that I have used in the past.

Advanced mechanism separates Pentacam from competition
The Pentacam system measures anterior and posterior elevation and curvature as well as global cornea thickness. The system allows clinicians to reconstruct all of the dimensions of the anterior chamber and yields a cross-section of a natural lens, as well as transmissibility. What separates the Pentacam from other instruments currently claiming similar features is its accuracy. Part of the system’s precision is due to its mechanism. Compared to other systems, a greater density of the points used by the Pentacam, when obtaining measurements, is located in the central cornea. The Pentacam’s Scheimpflug camera rotates around the center of the cornea where the density of points is higher than those in the periphery. In our office, we have found the Pentacam to be highly reproducible and accurate, unlike other currently available elevation-based diagnostic imaging units. The system has greatly assisted our clinical practice by allowing us to accurately diagnose confusing topographies and helps greatly in assessing post-LASIK evaluation of the posterior corneal surface.

Pentacam’s elevation-based map clears keratoconus confusion
Many clinicians diagnose keratoconus based on inferior corneal steepening on the curvature map, which is inaccurate and unreliable. Curvature is not an innate property of an object, but is related to how the object is oriented. Patients with normal corneas that appear to be slightly off-axis can be improperly diagnosed as having keratoconus if only a curvature map is used. Many of the eyes considered to be keratoconic merely have decentered apexes. The distinction between the two is clearly evident on an elevation-based map, such as that with the Pentacam.

Additionally, a small number of patients who have normal anterior surfaces, both in elevation and curvature, also have abnormal posterior elevation and pachymetry maps that suggest risk for any type of surgical intervention on the cornea. Using a Placido system, the patients’ corneas would look completely normal. The Pentacam system, however, shows posterior elevation with significant steepening, often off-axis. In these patients, pachymetry maps show that the area of minimal thickness is not at the apex but is usually decentered slightly inferiorly.

Accurate detection of keratoconus is important because the condition is a direct contraindication for refractive surgery. One reason for this is that patients with keratoconus often have abnormal collagen in addition to thin corneas. Thin corneas do not have adequate tissue for ablative laser
refractive procedures. However, patients with keratoconus who have adequate tissue are still not good candidates for refractive surgery because their abnormal collagen may not behave the same and lead to variable refractive results.

**Posterior elevation pushes Pentacam past other methods**

We have seen a number of cases in my office where the only corneal abnormality is posterior elevation. A number of patients who have presented with posterior elevations three standard deviations out of the normal range have normal anterior curvature and anterior elevation measurements. Posterior elevation data allow clinicians to identify patients at risk and remove them as candidates for refractive surgery. The Pentacam system’s posterior elevation data are reproducible, and this accuracy separates it from other systems. Other scanning systems, such as the Orbscan topographer (Bausch & Lomb, Rochester, N.Y.), provide flawed posterior elevation measurements. Their postoperative corneal thickness readings are consequently inaccurate because thickness is determined from anterior and posterior elevation measurements. The Pentacam system appears less susceptible to these types of errors.

**Selecting appropriate patients for refractive surgery**

Clinicians must be familiar with both the device they are using and with normal corneal values. Using the standard anterior elevation map, which is a spherical subtraction map, I consider apical protrusions greater than 14 µm to be abnormal, between 10 µm and 14 µm to be suspicious and below 10 µm to be within the normal range. For posterior elevation, there is greater variation in the normal range. An apical protrusion greater than 20 µm is abnormal, while 14 µm to 20 µm is suspicious. These numbers are significantly lower than the corresponding Orbscan elevation numbers. Orbscan operators typically see posterior elevations up to 50 µm in normal corneas. Fifty microns of posterior elevation off the best fit sphere is not normal (if it was accurate) and reflects the difficulty Orbscan has in generating accurate posterior data.

Additionally, clinicians may want to avoid performing LASIK on patients whose pachymetry reading on the Pentacam is 495 µm or less. In my practice, I routinely avoid performing any type of ablative procedure on patients with pachymetry readings less than 475 µm. Clinicians also must note where the area of maximum thinness is located. If the area of maximum thinness is inferior to the geometric center, then the patient may have keratoconus. Regarding curvature, clinicians should be concerned with simulated K-values or maximal curvature of the central zone measuring more than 48.5 D, but I rely more on elevation data and pachymetry data than on curvature values.

The Oculus Pentacam has affected my ability to accurately detect keratoconus in patients. The system’s precision and reproducibility, far surpassing that of traditional methods, allow me to appropriately select and eliminate candidates for refractive surgery.