Corneal topography is used to diagnose, monitor progression of various corneal pathologies, and aid in the preoperative evaluation for patients undergoing refractive surgery. Topography evaluation can be done using devices based on the following principles:

1. Placido Disc
2. Slit scanning
3. Scheimpflug imaging
4. Optical coherence tomography

The various principles and respective platforms are discussed below.

**Computer-assisted videokeratoscopy/placido disc based corneal topography**

Since the advent of elevation based topographer the placido based topographers have lost favor, but still the commonest topographers used in clinical practice are based on placido disk principles. The instrument consists of either a placido disk-type nose cone or a large placido disc consisting of dark and light rings of different number and sometimes even colours.

Before interpreting the data one must look at the output screen, warmer colours (reds, oranges) on the map represent steeper cornea with higher keratometric dioptric power, the cooler colours (violets and blues) represent flatter cornea with lower dioptric power and greens and yellows represent colours found in normal cornea. One can use an absolute scale or standardized scale for interpretation, having fixed dioptric increment for colour scales and can be used for comparing two maps, but is less sensitive.

Normalized maps have different colour scales assigned to each map. Advantage is that it is more sensitive and can even label normal cornea as keratoconic. Disadvantage is that the colours of different maps from even a same cornea cannot be compared directly as they may have different steps and the meanings of colours are lost.

Axial curvature map or sagittal curvature map is the most commonly used map. It is helpful in evaluating the overall shape of the cornea. The biggest advantage of this map is that the pattern diagnosis of a map can be done and a map can be classified into normal or abnormal (Figure 1).

Tangential curvature map or instantaneous map or meridional curvature maps are more sensitive in detecting local curvature change, hence can be useful in detecting early changes, which might have been missed by the axial map. It is more accurate than the axial map in corneal periphery.

One must keep in mind to rule out keratoconus or other ectatic disease before undertaking the patient for refractive surgery. For diagnosis of keratoconus, the Rabinowitz/
Mc Donnel diagnostic criteria consists of two topography derived indices, which are as follows; central K-value > 47.20 D and Inferior-Superior asymmetry (I-S value) > 1.4 D. Rabinowitz/Rasheed’s described KISA% to diagnose keratoconus. KISA% index is usually applied to the axial map. It uses four indices on the topography.

\[
\text{KISA\%} = \frac{[\text{K} \times (\text{I-S}) \times \text{(AST)} \times (\text{SRAX}) \times 100]}{300}
\]

K-value here is central keratomeral value in access of 47.2 D i.e., K-4 7.2. If value is less then or 47.2, it is replaced by 1. I-S or inferior-superior asymmetry, AST calculated from (Sim K1-SimK2, SRAX is calculated from 180-the angle between two steep axis above and below the horizontal meridian (smaller of the two angles). To amplify any abnormality, the value 1 was substituted in the equation whenever a calculated index has a value of less than 1.

Slit Scanning elevation based topography

OrbscanIIz is a three-dimensional slit-scanning topography system used for analysis of the corneal anterior and posterior surfaces as well as pachymetry. It uses a slit-scanning system to measure 18,000 data points and a Placido-based system to make necessary adjustments to produce topography data.

A typical Orbscan Output is a quad map (Figure 2)

1. **Anterior Float**: Elevation map of the anterior cornea, one must look for hot spots and irregularities on the anterior cornea.

2. **Posterior float**: It is important as Placido based systems cannot pick up early signs of ectasia, which starts from the posterior float. One must look for hot spots and see if it is coinciding with elevated anterior float.

3. **Thickness map**: Adequate thickness for LASIK depends on refractive error to be treated. For example a patient with -5 DS refractive error with thickness of 480 µm (No other warning signs) for LASIK. Assuming tissue ablation of 12-15µm per diopter, total tissue burn would be in the range of 60 to 75 µm. Considering flap of 120µm for manual keratome, one can expect a residual bed thickness (RBT) of 300 to 285µm. Refractive surgeons vary in their opinion on adequate RBT but we prefer to keep it >300 µm for our patients.

4. **Keratometric Map**: Gives the keratometric values for anterior cornea.

One must look for the Red Flags (Figure 3) on Orbscan (Roush criterion):

1. A thinnest point of < 470 µm on pachymetry
2. A difference of > 100 µm from the thinnest point to the values of the 7 mm Optic Zone implies a steep gradient of thinning from mid-periphery to the thinnest point.
3. The thinnest point on the cornea should correspond with the highest point of elevation of the posterior corneal surface. On posterior elevations map a posterior high point > 50 µm above best fit Sphere (BFS). BFS power greater than 55 D on the posterior profile.

4. Relative difference > 100 µm between the highest and lowest point on the posterior elevation map. Power map Keratometric mean power map > 46 D. Bow–Tie pattern or lazy C on the axial power map is suspect when the astigmatism shifts > 20 degree from a straight line.

5. A change within the central 3 mm optic zone of the cornea of more than 3 D from superior to inferior can be correlated to the presence of vertical coma (commonest aberration seen in keratoconus)
6. Composite integrated information which includes highest point on the posterior elevation coincides with the highest point on the anterior elevation, the thinnest point on pachymetry, and the point of steepest curvature on the power map.

In addition to that Efkarpis criteria say that ratio of the radii of the anterior BFS and posterior BFS of the cornea should be more than 1.21. Astigmatic discrepancy of > 1.5 D in the 3 mm zone and a discrepancy of > 2 D in the 5mm zone should be an alert sign.

**Scheimpflug imaging**

The Pentacam Standard (Figure 4) uses a rotating Scheimpflug camera (180 degrees) to provide a 3-dimensional scan of the anterior segment of the eye. A monochromatic slit-light source (diode-emitting bluelight at 475 nm) rotates around the optical axes of the eye. Within 2 seconds, 25 slit images of the anterior segment are captured. Each slit image possesses 500 true elevation points, and 25,000 points are obtained. For each slit image, mathematic software is used to detect edges, including the epithelium and endothelium of the cornea. Finally, a 3-dimensional mathematic image of the anterior segment is generated.

Scheimpflug derived corneal thickness maps identify the location and magnitude of the thinnest point on the cornea. In addition to measuring and locating the true thinnest point, a full thickness map allows one to look at the pachymetric progression or the rate of change in corneal thickness. It also gives information about posterior cornea, which is an earlier indicator of ectatic change or ectasia susceptibility and when combined with full pachymetric data serves as a more sensitive screening tool then anterior topography and ultrasound pachymetry combined.

Pentacam has a comprehensive refractive screening display [Belin/ Ambrosio Enhanced Ectasia Display III– (BAD III)], which combines nine different tomographic parameters in a unified screening tool. An abnormal final reading, which is colour coded, indicates suspicious cornea (Figure 5). It can also differentiate between keratoconus and pellucid marginal degeneration which may mimic the former.

An elevation of 12-15 µ on anterior surface and 18-22 µ on posterior surface should raise a suspicion of abnormal cornea (Figure 6).

This added information improves the ability of the refractive surgeon to screen patients for occult ectatic disease or to identify patients potentially at higher risk for post LASIK ectasia.

Sirius combines Scheimpflug camera and a small-angle Placido disk topographer with 22 rings. A full scanning acquires a series of 25 Scheimpflug images (meridians) and 1 Placido top-view image. The Placido image provides ring edges, and height, slope, and curvature data are obtained by the arc-step method with conic curves. Scheimpflug images showed the profiles of anterior cornea, posterior cornea, anterior lens, and iris. The data for the anterior surface are finally determined by merging the Placido image and the Scheimpflug images using a proprietary method. However,
other data of internal structures (posterior cornea, anterior lens, and iris) are obtained solely from the Scheimpflug images.

Systems with a single Scheimpflug channel use a mathematical equation to estimate compensation for an off-center measurement; however, the only way to properly compensate for an off-center measurement is with Dual-Scheimpflug technology.

Galilei uses a monochromatic slit-light source (diode emitting blue light at 470 nm) which combines dual Scheimpflug cameras and a Placido disc to measure both anterior and posterior corneal surfaces. It requires 1 or 2 seconds to make a whole scan, which obtains more than 122 000 points. During the rotating scan, the Placido and Scheimpflug data of the corneal information are simultaneously obtained. The anterior corneal measurements are made by a proprietary method of merging the 2 types of data. Two Scheimpflug slit images are made by the dual camera from opposite sides of the illuminated slit, and the data are averaged. Meanwhile, the dual camera simultaneously tracks decentration due to eye movements. In addition to refractive indices (Figure 7), it utilizes the concept of Best Fit toricasphere (BFTA) that conforms regularly to the cornea than a BFS. True corneal power is also given, which is calculated using ray tracing.

It also gives Keratoconus prediction index (KPI), which is based on anterior surface measurements. It predicts percentage probability of keratoconus. KPI 0-10% is normal, 10-20% is borderline to suspicious, 20-30% suspicious to keratoconus >30% is highly suggestive of keratoconus or pellucid marginal degeneration.

Detection of subclinical keratoconus is of prime importance in modern refractive surgery, the posterior asphericity asymmetry index (AAI) on Galilei is a quantitative indicator of the posterior surface asymmetry which was first described by Arce in 2010. AAI is calculated by absolute summation of maximum elevation and maximum depression in the 6 mm zone on BFTA map. Smadja et al concluded the AAI with a cutoff value of 21.5 µm and the corneal volume at 30.8 mm³, as the two most discriminant variables among the parameters incorporated in the analysis for differentiating between normal corneas and those with forme fruste keratoconus (Figure 8).

**Optical Coherence Tomography (OCT)**

The use of OCT technology to obtain a precise pachymetric map of the cornea was first described by Li et al., in 2006.

We use RTvue-100 which is a Fourier domain OCT featuring 5 mm of depth resolution in tissue and high-magnification imaging of the cornea within 0.04 seconds. It adopts a super-luminescence diode as a low coherence light source, which emits light with a 50-nm band width centered at 830 nm. A corneal-anterior module long lens adapter with low magnification is added to the RTvue to image the anterior segment. The corneal pachymetry protocol acquires 8 evenly spaced 6-mm radial lines oriented 22.5 degrees from one another, consisting of 1024 A-scans per line in 0.31 seconds.

The OCT is a noncontact imaging modality that provides a high resolution cross-sectional analysis of the corneal thickness. A quantitative system of assessment has been in which five OCT pachymetry (Figure 9) characteristics were identified which showed high specificity and sensitivity.

1. Minimum-median. (Cut off value: 62.6 µm).
2. The I-S: The average thickness of the inferior (I) octant minus that of the superior (S) octant (cut off value: 31.3 µm).
3. The IT-SN: The average thickness of the IT octant minus that of the SN octant (cut off value: 48.2 µm).
4. Minimum (cutoff value 491.6 µm).

5. Vertical location of the minimum. Locations superior to the corneal vertex had positive values and locations inferior to the vertex had negative values (cut off value: 716 µm).

Epithelial thickness profile (Figure 10) maps using Fourier domain OCT have been shown to be useful in detecting subtle epithelial changes, which have been to be a sign of early keratoconus. Apical epithelial thinning over the apex of the cone in early ectasia can mask topographic changes on anterior corneal surface.

Future Trends

Good topography (Pachymetry) and meticulous surgery doesn’t guarantee that patient will not develop post LASIK ectasia. Unfortunately, we still lack clear cut guidelines to label patients on topography as at risk or normal. Corneal biomechanics, which is measure of elasticity and strength of cornea, coupled with careful analysis of topography can be a better screening tool for screening patients undergoing LASIK. We have come across a number of patients who have seemingly normal topography but poor biomechanics (Figure 11). We believe these patients are potential candidates, who can develop ectasia after LASIK surgery and hence, LASIK should not be done on these patients.

Summary

Topography is an excellent tool to screen out potentially borderlines cases in refractive practice. Placido disc based devices are very useful tool; however they do not show any changes on the posterior surface of the cornea. Newer, diagnostic devices like elevation based topographers and OCT can help us to visualize the posterior surface of cornea and can also give an accurate idea about the pachymetry of entire cornea. These newer modalities can help us diagnose ectatic disease in preclinical stage, thus allowing an early treatment.

References

4. Rousch C. Orbscan II Manual (Salt Lake City, Utah: Orbscan)