Skillful Interpretation of Corneal Imaging

Systematic clinical interpretation can lead to improved refractive outcomes.

BY MAZEN M. SINJAB, MD, PhD

Skillful interpretation of corneal and anterior segment imaging is key to successful refractive surgery. Since the introduction of topography to ophthalmology, corneal and anterior segment imaging has been further advanced through technological developments including tomography, anterior segment optical coherence tomography (AS-OCT), and the newest devices measuring corneal biomechanics. Consequently, our understanding of refractive surgery has advanced and many new concepts have been introduced, resulting in the need for a systematic approach to the clinical interpretation of corneal imaging.

**TOPOGRAPHY VERSUS TOMOGRAPHY**

*Corneal tomography* is a relatively new term used to describe the maps and images generated by Scheimpflug-based imaging devices. *Corneal topography* is an older term, now applied to the maps produced by Placido-disc-based machines and consisting of anterior sagittal (axial) and anterior tangential (instantaneous) curvature maps. Corneal tomography includes not only these topographic maps, but also corneal pachymetry and other maps and profiles of both corneal surfaces.

Corneal tomography, the most important screening test for refractive surgery, can be used to detect abnormalities, diagnose and classify early cases of ectatic corneal diseases, diagnose postkeratorefractive ectasia, and help determine which refractive procedure is best for a given patient. Despite these capabilities, corneal tomography must be complemented by other investigations.

The four most important tomographic maps are the anterior sagittal curvature, anterior and posterior corneal elevation, and pachymetry maps. In each map, both shape and parameters should be studied, as described below.

**ANTERIOR SAGITTAL CURVATURE MAP**

*Shape.* The normal shape seen on this map is the symmetric bow tie (Figure 1). In this Figure, the two segments S and I are equal in size, and their axes are aligned.

Figure 1. A symmetric bow tie pattern is the normal pattern on the anterior sagittal curvature map. Segments S and I are equal, and their axes are aligned.

*Parameters.* Note the two opposing points on the anterior sagittal curvature map. (The symmetric bow tie may be seen in keratoconus when the K readings are abnormal.)

There are also abnormal shapes that the clinician should learn to recognize (Figure 2).

*Parameters.*
5-mm central circle on the steep axis in Figure 1. Normally, the inferior point has a higher value than the superior one, and the difference between the inferior and superior should be less than 1.50 D. The superior point may rarely have a higher value than the inferior one; in this case, the difference should be less than 2.50 D.

**ANTERIOR AND POSTERIOR ELEVATION MAPS**

**Shape.** The shape should be studied using the best-fit sphere (BFS) reference surface. The normal shape is the hourglass (Figure 3); abnormal shapes include irregular, tongue-like extensions and isolated islands (Figure 4).

**Parameters.** The parameters of anterior and posterior corneal elevation maps should be studied using the best-fit toric ellipsoid (BFTE) reference surface. There are two methods to study the values. The first is to look at the highest plus value within the central 5-mm zone; abnormal values are greater than 12 µm and greater than 15 µm on the anterior and posterior elevation maps, respectively. The second approach is to look at the values corresponding to the thinnest location (TL). Table 1 shows the normal values in myopic and hyperopic populations.

**PACHYMETRY MAP**

**Shape.** The normal pattern on a pachymetry map is concentric (Figure 5); abnormal patterns include horizontal displacement, dome-like, globus, and bell shapes (Figure 6).

**Parameters.** A thin cornea is defined as a cornea with less than 470 µm thickness at the TL with normal tomography, or a cornea with less than 500 µm thickness at the TL with abnormal tomography. Evaluate the difference in thickness between the TL and the pachymetric apex (ie, thickness at the center of the cornea); a difference greater than 10 µm is abnormal. Observe the y-coordinate of the TL; less than -0.5 mm, -0.5 to -1 mm, and greater than -1 mm are normal, suspect, and abnormal, respectively. Compare the thickness at the TL between the patient’s two eyes; the normal difference is less than 30 µm. Compare the thickness between the two opposing points on the steep meridian on the 5-mm central circle (Figure 5). The inferior point is usually thinner than the superior one, and the normal difference is less than 30 µm. Thickness at the TL is used in calculations for photorefractive surgery. There are different recommendations in regard to myopic, hyperopic, astigmatic, and wavefront- and topography-guided treatments.

**OTHER PARAMETERS**

**K readings.** The normal maximum keratometry (K) reading (K max) is less than 49.00 D. The normal difference between K max and the steep simulated K (sim K) is less than 1.00 D. The K max should be used in the calculation of photorefractive treatments of hyperopia. The rule
states that each 1.00 D correction adds 1.20 D to the K max. The final K max should not exceed 49.00 D; otherwise, negative spherical aberrations are induced. The flat sim K should be used in the calculation of photorefractive treatments of myopia. The rule states that every -1.00 D correction reduces the flat sim K by 0.75 to 0.80 D. The final flat sim K should not go below 34.00 D, or positive spherical aberration will be induced.

**Topographic astigmatism.** Topographic astigmatism is the difference between steep and flat sim K readings. Pure corneal astigmatism is calculated using the topographic astigmatism of the anterior and posterior surfaces. Topographic astigmatism should be compared with the manifest astigmatism. In case of disparity between these values, causes such as misalignment during capture, irregular astigmatism, tear film disturbance, corneal haze, and lenticular astigmatism (including subtle cataract) should be excluded.

If lenticular astigmatism is present without cataract and disparity is present, the strategy for correcting astigmatism can be chosen based on one of nine probabilities (Table 2), each of which has its own rules to avoid overcorrection or converting the orientation of the topographic astigmatism. For example, if the manifest astigmatism is -3.00 X 180º and the topographic astigmatism is -2.00 X 180º, correcting the full manifest astigmatism will induce -1.00 X 90º, which the patient may not tolerate despite zero manifest refraction. In such a case, one of the recommendations is to correct -2.00 X 180º and adjust the sphere to achieve the same spherical equivalent (eg, 0.00 -3.00 X 180º corrected to -0.50 -2.00 X 180º).

**Pupil coordinates.** The horizontal (x) coordinate of the pupil center reflects angle kappa. The normal value of the latter is less than 100 µm (<5º). With machines that do not measure angle kappa, the x-coordinate of the pupil can be used; the normal value is less than 200 µm. Angle kappa is important for the decentration technique used in hyperopic and highly astigmatic photorefractive correction. A large angle kappa can also explain the skew seen in some curvature and elevation patterns.

**Anterior chamber parameters.** Anterior chamber depth (ACD), anterior chamber volume (ACV), and anterior chamber angle (ACA) are important parameters for the detection of glaucoma and for phakic IOL implantation. An ACD of less than 2.1 mm, an ACV of less than 100.0 mm³, or an ACA of less than 24º may indicate a risk of angle-closure glaucoma. If a phakic IOL is indicated, the ACD should be greater than 3 mm and the ACA should be greater than 30º.

**TAKE-HOME MESSAGE**

- Skillful interpretation of corneal and anterior segment imaging is key to successful refractive surgery.
- Corneal topography and tomography play important roles in preoperative evaluation and planning and in guiding suture removal after corneal grafting and cataract surgery.
- AS-OCT is a useful tool in differential diagnosis of some LASIK complications and in follow-up after CXL.
OTHER CLINICAL APPLICATIONS

Classification of ectatic corneal disorders. Generally, in ectatic corneas the cone can be nipple-, oval-, or globus-shaped, depending on the shape and size on the tangential curvature map (Figure 7). The cone can be localized using the elevation maps with the BFS reference surface. The location may be central, eccentric, or peripheral (Figure 8).

Ectatic corneal disorders can be classified into five major entities: keratoconus, forme fruste keratoconus, pellucid marginal degeneration (PMD), pellucid-like keratoconus (PLK), and keratoglobus. These entities can be differentiated by their tomographic features on the curvature, elevation, and pachymetry maps. For example, the claw pattern (Figure 9) can be seen in both PMD and PLK, but the bell shape (Figure 6) is seen only in PMD.

Forme fruste keratoconus has been defined in a number of ways. In a patient with a normal cornea in one eye and keratoconus in the other, the normal cornea can be considered forme fruste keratoconus. If both eyes are normal but the patient has a first- or second-degree relative with keratoconus, that patient may be considered to have forme fruste keratoconus. In other words, forme fruste keratoconus is neither early nor subclinical keratoconus; it is the potential to develop ectasia after keratorefractive surgery. Another definition of forme fruste keratoconus is a cornea with abnormal tomography that is not distinct enough to be classified clearly as one of the ectatic disorders.

Guided suture removal. After corneal surgeries, astigmatism can be controlled by using tomography images to guide suture removal (Figure 9). In a cornea with a graft, a steep axis indicates tight sutures on opposite sides on the same meridian; however, a peripheral banana-like shape indicates loose sutures with a gap. It is recommended to resuture the loose area before proceeding with the removal of tight sutures.

Cataract surgery. It is wise to study corneal tomography before performing cataract surgery. Corneal irregularity, rather than the cataract itself, may be a cause behind the patient’s decreased vision. Additionally, corneal irregularity affects treatment decisions regarding multifocal or toric IOL implantation or astigmatic keratotomy.

DIAGNOSIS

AS-OCT can be used to diagnose corneal lesions such as sub-Bowman calcification, Salzmann nodular degeneration,

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CXL = corneal collagen crosslinking; ICRS = intrastromal corneal ring segment; WTR = with the rule; ATR = against the rule; TA = topographic astigmatism; MA = manifest astigmatism
posterior corneal abnormality, and keratoglobus (Figure 10). It may be helpful in the differential diagnosis of LASIK flap complications such as diffuse lamellar keratitis, central toxic keratopathy, pressure-induced stromal keratopathy, and epithelial ingrowth. AS-OCT is also essential in the diagnosis of double anterior chamber after lamellar keratoplasty. New OCT software includes indices for the detection of subclinical keratoconus, but the most interesting feature is the novel epithelial pachymetry mapping.

TREATMENT

AS-OCT is essential for phototherapeutic keratectomy, as the depth of the scar to be treated and its thickness should be measured before proceeding with the procedure. It can also be used in follow-up after corneal collagen crosslinking to detect the demarcation line. Additionally, AS-OCT can measure ACD and ACA and, therefore, can be used in planning phakic IOL implantation and in the diagnosis of glaucoma.

CONCLUSION

Skillful interpretation of corneal imaging is essential to refractive surgeons for making informed decisions, obtaining optimal results, and avoiding complications.

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