Technology for Keratoconus Screening

BY ALLON BARSAM, MD, MRCOPHTH

Technological advances continue to yield safer, more precise and predictable outcomes in laser refractive surgery. Perhaps more important than the precision of the latest femtosecond and excimer laser systems is the surgeon's ability to screen patients and, in particular, exclude from treatment those with manifest or subclinical corneal ectasia. The incidence of keratoconus in the general population is estimated to be 1:2000.[1] Although not yet approved by the FDA, the development of corneal collagen cross-linking—the only treatment proven to halt the progression of keratoconus[2]—has also placed greater pressure on clinicians' ability to diagnose early keratoconus and to document and monitor its progression.

This installment of the "Peer Review" column focuses on articles related to the most recently available technology to help the clinician diagnose and monitor corneal ectasia. The three elevation-based topography machines in common use will be discussed, namely the Orbscan topographer (Bausch + Lomb), the Pentacam Comprehensive Eye Scanner (Oculus Optikgeräte GmbH), and the Galilei Dual Scheimpflug Analyzer (Ziemer Ophthalmic Systems AG). I will also outline the latest data with the Ocular Response Analyzer (Reichert, Inc.).

Until techniques such as slit scanning and Scheimpflug imaging appeared, the field of corneal imaging was restricted to the Placido disc-based analysis of the shape and optical quality of the cornea's anterior surface. New anterior segment imaging technologies can reconstruct the three-dimensional structure of the cornea from two-dimensional optical cross sections, which greatly enhances physicians' ability to investigate the properties of the cornea. Dynamic measures of corneal biomechanics are now possible with the Ocular Response Analyzer. These technologies are constantly under investigation to refine and define the relevant parameters of screening for keratoconus and monitoring its progression. Software upgrades often increase the precision of measurements. In the future, clinicians will likely be able to combine data from several imaging modalities, such as Placido disc, Schiempflug, and dynamic measurement of corneal biomechanics, to improve the sensitivity and specificity of screening even further.

It is a great honor to have been invited to join Mitchell Schultz as the section editor of the "Peer Review" column. I look forward to working with Cataract & Refractive Surgery Today's fantastic editorial team. I hope you enjoy my first edition of "Peer Review," and I encourage you to read the fascinating and innovative articles summarized herein.

—Allon Barsam, MD, MRCOphth, section editor

ORBSCAN II

The Orbscan II was the first elevation system with the capability to measure both the anterior and posterior corneal surfaces using a scanning-slit technique of optical cross-sectioning combined with Placido disc-based technology. Measuring both corneal surfaces potentially offered diagnostic advantages compared with Placido disc-based technology and allowed the computation of a pachymetric map (corneal thickness is the difference between the anterior and posterior surfaces). Numerous articles have outlined the limitations of this device, particularly its variable ability to locate the posterior corneal surface and underestimations of corneal thickness after refractive surgery.[3-5]

Faramarzi et al[6] prospectively enrolled patients undergoing PRK to correct myopia or myopic astigmatism and a postoperative follow-up of at least 5 months. The central corneal thickness (CCT) was measured in a single session using Scheimpflug imaging, scanning-slit topography, and ultrasound pachymetry. The CCT measurements in eyes that had PRK were thicker with Scheimpflug imaging than with ultrasound pachymetry or scanning-slit topography in the late postoperative period. With application of a correction factor, the Scheimpflug measurements were closer to the values obtained with ultrasound pachymetry and had better agreement than scanning-slit topography.

The last upgraded version of the device—the Orbscan IIz—can be integrated with the Zywave II wavefront aberrometer in the Zyoptix workstation (both from Bausch + Lomb). The Orbscan IIz provides accurate measurements of anterior surface elevation in a variety of test surfaces.[7,8]

PENTACAM COMPREHENSIVE EYE SCANNER

Scheimpflug photography can achieve a wide depth of focus, which provides images that include information from the anterior corneal surface through to the posterior crystalline capsule. The Pentacam Comprehensive Eye Scanner combines a rotating Scheimpflug camera with a static camera to acquire multiple photographs of the anterior segment. The Scheimpflug camera rotates with a monochromatic slit light source around the optical axis to obtain the slit images. This rotating system performs a corneal scan from 0° to 180°, and each of the photographs is an image of the cornea at a specific angle. The static camera is placed opposite the center of the pupil to detect the pupil's contours and control fixation and captures and corrects the eye's movements. The photographs are used in the reconstruction of the anterior and posterior corneal topographies from height data. The Pentacam can also provide analyses of corneal pachymetry, corneal wavefront aberrations, densitometry, and the complete anterior chamber. Three Pentacam models are available: basic, classic, and high resolution (HR). The versions differ mostly in their software features, but the HR model also provides upgraded hardware.[7]

Ambrosio et al[9] analyzed 113 eyes randomly selected from 113 normal patients and 44 eyes of 44 patients with keratoconus. The investigators studied all eyes with the Pentacam HR by acquiring thickness measurements. They evaluated relational thickness by looking at ratios of CCT, thinnest point, and pachymetric progression indices. Ambrosio and colleagues found that relational thickness was better than single-point pachymetric parameters for distinguishing normal corneas from those with keratoconus.

GALILEI DUAL SCHEIMPFLUG ANALYZER

The Galilei Dual Scheimpflug Analyzer integrates a Placido disc and a dual rotating Scheimpflug system for corneal topography and three-dimensional analysis of the anterior segment. Like the other two devices, the Galilei covers the cornea, anterior chamber, and lens of the eye. During the rotating scan, Placido disc and Scheimpflug images are simultaneously acquired to obtain the information on the curvature and elevation of the cornea, respectively. The dual camera configuration captures two Scheimpflug slit images from opposite sides of the slit

> "Scheimpflug photography can achieve a wide depth of focus, which provides images that include information from the anterior corneal surface through the posterior crystalline capsule."

beam and simultaneously tracks decentration due to the eye's movements. The height data obtained from two corresponding slit images are averaged to improve the measurements of corneal elevation and thickness.

Menassa et al[10] compared CCT and keratometry readings using the Galilei Dual Scheimpflug Analyzer, the Orbscan II anterior segment analysis system, and the Sonogage ultrasound pachymeter (Sonogage, Inc.). This prospective single-center study included 85 eyes of 45 healthy volunteers who were randomly examined with the Orbscan II or the Galilei followed by Sonogage ultrasound pachymetry.

The mean CCT was 551.7 ±36.6 µm (standard deviation) with the Galilei, 554.8 ±45.1 µm with the Orbscan II, and 558.5 ±38.4 µm with the Sonogage. The CCT readings of the Galilei and Orbscan II did not differ significantly. The mean keratometry readings with the Galilei and Orbscan II were similar, although both the steep (Ks) and flat (Kf) axes tended to be flatter with the Galilei system. The investigators concluded that keratometry and pachymetry readings with the Galilei and Orbscan II systems showed strong concordance and high reproducibility, which would allow the examinations to be delegated to nonmedical personnel.[10]

OCULAR RESPONSE ANALYZER

The Ocular Response Analyzer was introduced on the ophthalmic market in 2005 as the first device able to perform in vivo biomechanical measurements of the eye.[11] The unit assesses the apical kinetics of the cornea in an inward and an outward movement using a patented air-puff tonometer. Initially designed for follow-up of IOP after refractive corneal surgery, the analyzer is now used for other clinical purposes, mainly in the fields of glaucoma and keratoconus screening.

Touboul et al[12] compared eyes with mild keratoconus (study group, n = 103 eyes) with preoperative eyes that later had LASIK (control group, n = 97 eyes). Corneas with a CCT within 500 to 600 µm were targeted. The biomechanical measurements were acquired, and 12 parameters were analyzed after extraction from the signal data. The mean corneal hysteresis was 9.2 mm Hg in the study group

and 10.1 mm Hg in the control group, and the mean corneal resistance factor was 8.9 mm Hg in the study group and 10.6 mm Hg in the control group. The authors reported that, at present, the Ocular Response Analyzer is not able to produce a specific signature for keratoconus. They stated that it can still be considered a useful index for keratoconus screening, however, or more widely for abnormal corneal biomechanical behavior.[12]

CONCLUSION

The constant evolution of imaging techniques available for screening keratoconus now allows refractive surgeons to carry out excimer laser-based treatments on normal patients with a greater safety margin and greater precision and accuracy. ■

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