Improving LASIK's and PRK's Outcomes on Irregular Corneas

How to succeed with topography-guided procedures.

BY A. JOHN KANELLOPOULOS, MD

Most ophthalmologists are familiar with computerized corneal topography maps and have been using them diagnostically in cataract and refractive surgery for nearly 2 decades. Because of the ease of assessing corneal data in this format (vs numbers, written axes, etc.), topographic maps have become a popular means in ophthalmology by which to illustrate corneal, lenticular, optic nerve, retinal, and other anatomical parameters. It is almost customary for current tomography devices such as the Orbscan (Bausch + Lomb) and Pentacam Comprehensive Eye Scanner (Oculus Optikgeräte) as well as anterior segment optical coherence tomography devices like the Visante (Carl Zeiss Meditec) and the RTVue (Optovue)[1] to provide corneal pachymetry maps in a similar color-coded fashion. Color light-emitting diode reflection topography (Cassini; i-Optics) promises even more central corneal accuracy and posterior corneal power calculations.[2] To evaluate corneal topography, clinicians must therefore understand the principles and parameters of its measurements (eg, anterior surface elevation, corneal curvature, corneal power, posterior elevation).

As a cornea surgeon for more than 20 years and after performing topography-guided excimer laser treatments for more than 10 years, I find topography to be even more essential for clinical assessments and the management of corneal, refractive, and even cataract surgery patients.

DETAILED KNOWLEDGE OF THE TECHNOLOGY

Placido disc topography is probably still the most widely used corneal imaging today. It uses the simple principle of reflection keratometry, in which a concentric ring pattern instrument illuminates the cornea while the patient fixates on the center. In the center of the Placido device, a small-aperture camera captures an image of the illuminated rings on the corneal surface (in essence, it is the tear film's mirror image). Clinicians have used these images for many years as a qualitative measurement of corneal curvature. For example, the circular mires appear to be compressed on the steep axis of corneal astigmatism or to bunch up at the apex of the cone in keratoconus. The problem is that this type of imaging requires an almost perfect tear film and a view of the entire corneal surface that is unobstructed (by eyebrow, lashes, nose).

METHODS AND RESULTS

To correct these irregularities from eccentric laser treatments, keratoconus, and post-LASIK ectasia, surgeons have turned to customized forms of ablation such as wavefront-guided and topography-guided treatment.[3-9] My colleagues and I have reported on our experiences with these modalities to treat highly irregular corneas.[10,11]

We have been working with the topography-guided WaveLight Allegretto WaveEye-Q (Alcon) for the past 11 years. The platform's proprietary software uses topographic data from the linked topographer (WaveLight Topolyzer and, recently, the Vario topolyzer to include centroid shift measurements and the ability to track iris and limbal landmarks for cyclorotation adjustment; both from Alcon). By default, the system permits us to consider up to eight topographies (of predetermined threshold accuracy), it can average the data and report consistency between the different takes, and it allows us to adjust many parameters such as desired postoperative corneal asphericity to include, or not, tilt correction and to adjust sphere, cylinder, axis, and treatment zone.

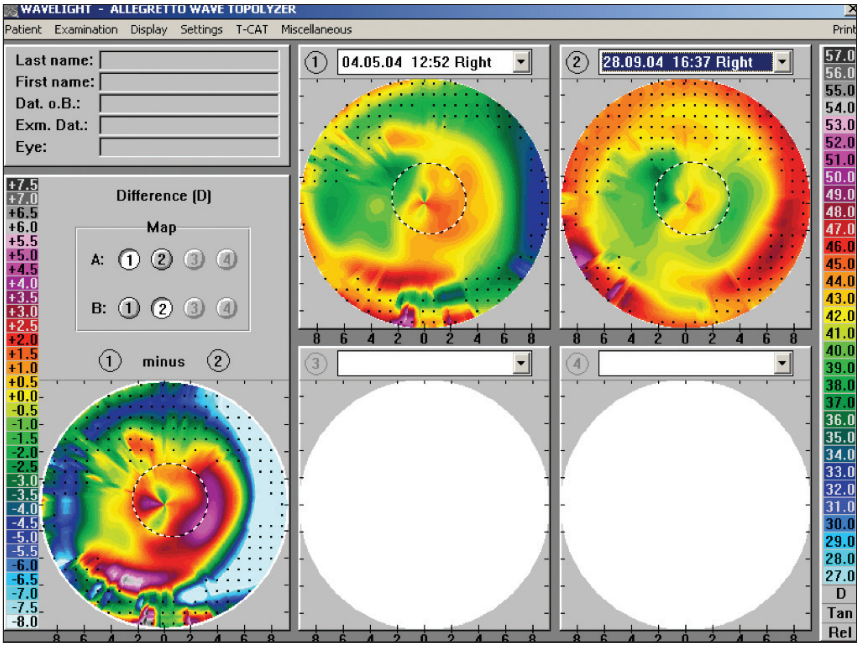

Figure 1. Pre- and post-LASIK topography (1 and 2, respectively) of an irregular cornea having topography-guided LASIK with the TCAT WaveLight platform. The corneal irregularity was caused by an old contact lens-related bacterial ulcer. The difference map (1 minus 2) demonstrates the highly irregular flattening achieved by the topography-guided treatment.

Topography-guided ablation involves fitting an ideal corneal shape (a sphere) in relation to the present topographic map documented as elevation data, achieved with ablation of tissue over the "peaks" and also ablation of tissue aside of the troughs. The advantages of this approach over wavefront-guided treatment are as follows:

• Topography-guided ablations may be performed on highly irregular corneas that are beyond the limits of wavefront measuring devices.

• It is customary that, with this platform (the WaveLight Platform from Alcon), there is a high consistency of topographic sensitivity and specificity—most exams are essentially the same—enhancing the surgeon's sense of safety. In contrast, it is common for wavefront documentation to have some or even great variability, which is understandable when one considers for a moment that the eye's wavefront measurement is dynamic and not static.

• Placido-based topographic-guided ablations can be performed even on eyes that have media opacity, such as those with corneal scars, because the measurements are based on the surface—the tear film actually.

Because topographic measurements are based on the corneal surface, it is theoretically possible to factor in the cornea's asphericity (Q value) and to maintain its naturally aspheric shape. Recent studies have demonstrated a shift in the pupillary center between the normal (photopic) and the dark-adapted (mesopic, scotopic) state of the pupil (centroid shift). It stands to reason, then, that topography-guided treatments will be more accurate than wavefront-guided treatments, because measurements for the former are captured while the pupil is photopic, as it will be during treatment.

DISCUSSION

The only essential disadvantage of current topography-guided ablations—the ones described herein based on Placido-disc imaging but also the ones based on Scheimpflug imaging—is that they cannot include data from the rest of the refractive media, because they concentrate on the corneal contour. A spherical refractive surprise could be the result. For example, treatment to widen the optical zone of previously myopic patients would require the laser to flatten a broader area of the cornea and therefore remove tissue in a peripheral ring. This ablation pattern would

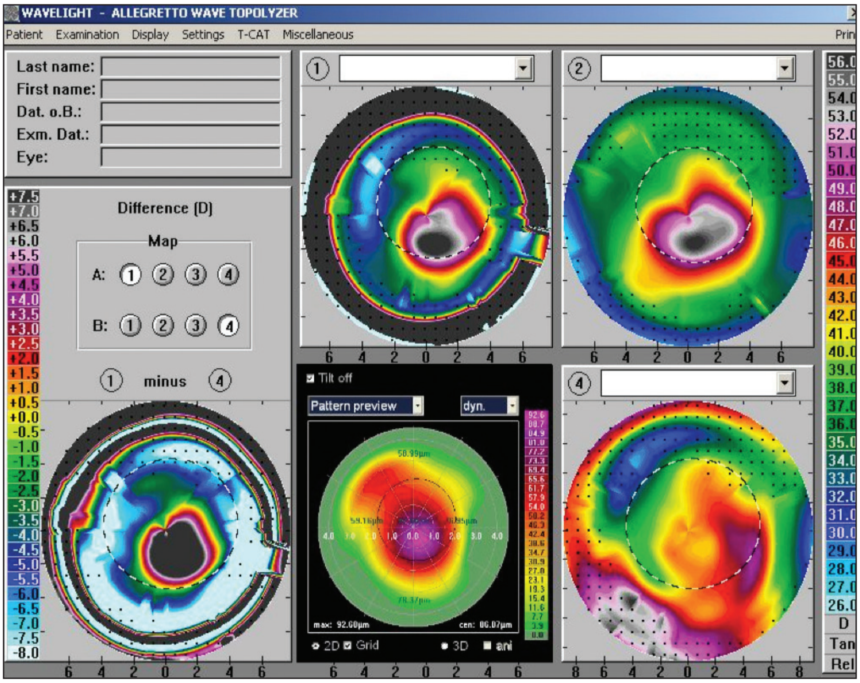

Figure 2. The corneal topography of this case, when first seen by the author, with central corneal ectasia and midperipheral flattening as an effect of the Intacs (Addition Technology) that were present (1). At this point, the patient's BCVA was 20/200. The corneal topography here is 2 months after the removal of Intacs and 1 month after ultraviolet A corneal collagen cross-linking (CXL) (2). The central steepening is still present, and the effect of the Intacs' removal is appreciable compared to the previous image, mostly at the midperiphery that appears steeper now. At this point, the patient's BCVA was 20/200. The lower-row image in the center is an estimated corneal topographic ablation pattern as a laser treatment plan of the topography-guided procedure that took place in the case (3). It is notable that this ablation pattern is highly irregular with a "deeper" ablation plan just inferior to and right of the myopic shift. Some of these patients may later require an enchancement procedure with a standard treatment to correct the remaining spherical refractive error. The author made adjustments to the refractive targets (ie, putting in a myopic postoperative target) to later cases to compensate for this shift in refraction.

resemble a hyperopic treatment and thus would cause some amount of inadvertent central refractive steepening, therefore inducing myopia. The corneal topography in Figure 1 is from 6 months after topography-guided PRK. The central cornea appears more regular and much flatter. At this point, the patient's best-corrected distance visual acuity and UCVA are 20/20. The image in the lower row on the left is a comparison map. This map depicts the difference of subtracting the corneal topography final result from the corneal topography from the patient's original state when encountered by us. The difference resembles the topography-guided ablation pattern (next image to the right), effectively demonstrating the specificity of this treatment in reducing the pathogenic corneal irregularity, which we theorize contributed to the drastic improvement in corrected distance visual acuity.

The Q value was targeted to the ideal endpoint of -0.5 in all cases, which is believed to be an ideal corneal asphericity for an average human eye using a Navarro eye model. A common flaw in the theoretical calculation of the ablation profile is its basis on a static shape-subtraction model; the postoperative corneal shape is determined only by the difference between the preoperative shape and the ablation profile. Other factors may be responsible for explaining the discrepancy between the clinical findings, however, and the theoretical predictions in corneal asphericity (ie, biological effects of healing and the variations of the applied fluence at the cornea). Epithelial hyperplasia is a more predominant factor after PRK, and flap-induced changes, together with indirect biomechanical shifts of the cornea, are present in LASIK-treated eyes. This could explain the refractive inaccuracy, as well as the asphericity adjustments' imprecision, of the topography-guided treatments, despite a notable improvement in the regularity of the corneal surface. We have nevertheless tried to overcome this limitation by using a phototherapeutic keratectomy mode to remove the epithelium (50 µm, 6.5-mm optical zone), using in this manner the epithelium as a "masking" agent to its possible remodeling that has taken place in order to "smooth" the corneal irregularities.

OUR EXPERIENCE

We have reported on our use of topography-guided treatments for keratectasias.[12-16] We have successfully treated both post-LASIK ectasias and keratoconus with a topography-guided PRK after CXL and have introduced the simultaneous combination of topography-

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guided normalization and high-fluence CXL as a single treatment for keratoconus and corneal ectasias, with multiple large numbers and long-term data presented and reported. The topography-guided PRK plus CXL treatment has become more known as the "Athens Protocol" and has found worldwide acceptance in everyday practice already.

CXL was performed first and topography-guided normalization later (2002-2005). The first stage of this treatment stabilized the corneal ectasia, as reported in previous laboratory and clinical studies. Riboflavin solution is instilled over the de-epithelialized cornea to protect the crystalline lens and possibly the retina from ultraviolet A radiance to enhance its absorption in the anterior stroma and to facilitate the CXL process, as described previously.[17-19]

Next, we performed topography-guided PRK to visually rehabilitate the irregular corneas. We observed improvement in a relatively short postoperative period of 1 year. Representative corneal topographies are shown in Figure 2.

Our subsequent experience was to combine the two treatments into the Athens Protocol with topography-guided partial PRK first and high-fluence CXL immediately after as a combined simultaneous procedure.

It appears that normalization of the cornea is achieved by both flattening the cone's apex and steepening the diametrically opposite (usually superonasal) paracentral corneal area, thereby preserving significant tissue thickness reduction that a similar wavefront-guided treatment would require. Wavefront-guided treatment usually reduces the corneal peaks to match the flatter area, whereas topography-guided treatment will flatten the peaks more moderately and "steepen" the flatter areas by performing a hyperopic-type ablation peripheral to them.

CONCLUSION

In my opinion, supported time and again by our 10-year clinical experience with the WaveLight platform and extensively presented and published, a topography-based customized approach can address even extreme corneal irregularity. Some of these patients may have significant quality-of-vision issues, and thus, treatment enhances their visual rehabilitation and visual quality. The ideal scenario would include topography-guided sphericity improvement combined with a more predictable nomogram for the spherical refractive error achieved. ■

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