Corneal–Wavefront-Guided LASIK for Highly Irregular Corneas

Highly irregular corneas pose a unique challenge to the refractive surgeon. Typically, these patients are unable to obtain optimal vision and frequently experience better outcomes when expertly fitted with a semi-soft contact lens rather than spectacles.

When we think of highly irregular corneas, the following categories come to mind: post-keratoplasty patients, especially those with decentered grafts; post-radial keratotomy (post-RK) patients; patients with suboptimal eximer laser ablations (e.g., corneas with central islands and decentered ablations); corneas after incisional trauma, blast injuries, and war wounds; and scarred corneas with faces from healed ulcers and neubular grade stromal scarring from resolved interstitial keratitis.

At our LASIK center over the past 4 years, we have experienced some success in treating these cases with corneal wavefront-guided LASIK. We use the Schwind lEns excimer laser (200-Hz 0.9-mm Gaussian spot profile) and the Carraizo Pendular Mirokeratome (both manufactured by Schwind eye-tech-solutions, Kliensheim, Germany). The Keratton Scout Topographer (Optikon 2000 Industrie, Rome) is used to perform corneal topography.

The traditional axial map is a poor descriptor of corneal refraction because it does not account for spherical aberration and is not a good descriptor of shape; however, this technology adequately describes corneal asigmatism, including cylinders and bow-tie formations. The axial map distorts the size of the cornea, increasingly toward the periphery. For example, the red area of an axial map depicting keratoconus is actually much smaller than the exaggerated size shown. In examining post-LASIK and post-RK eyes, the high-curvature annular bendings and off-center islands cannot be seen. Due to its simplicity, however, the axial map is still considered the classic corneal topography map.

The tangential map is a more accurate descriptor of shape and corneal power compared with the axial map. The height or spherical offset map goes one step further and describes the height of one point on the cornea relative to another.

Once the tangential map is captured, repeatability of the measurements is checked. If five measurements—taken a few seconds apart and interspersed by blinking—are similar, one representative topography is retained and converted into the corneal wavefront by the Huygens Fresnel principle. This principle, which calculates path difference, proposes that light passing through corneal elevations and exiting the eye takes more time than light exiting the nonelevated area of the cornea. When all these points of light exiting the eye are connected, a wavefront can be described. In the absence of distortion on the corneal surface, all light would have exited the cornea at the same time and formed a plane wavefront. The difference between the calculated and ideal wavefront is known as the optical path difference (OPD).

In the time a light ray could travel 4 μm in air, it can travel approximately 3 μm in the cornea.[1] Hence, the rule of three: every 3 μm of distortion on the corneal surface causes 1 μm of optical path difference. This OPD is similar to the spherical offset (i.e., height difference between the cornea and an ideal reference sphere) found in most topographers.

The Keratron Scout creates a corneal wavefront map using true height data instead of keratometric data. With a Placido-type small cone and 28 rings, it allows the measurement of 85% to 90% of the corneal surface, which is necessary for hyperopic treatments and to enlarge treatment zones in
patients who previously underwent refractive surgery. Measurements of corneal height and distortion are accurate up to 1 μm.1,2 The software calculates the corneal wavefront and then converts the height data into Zernike polynomials. Therefore, refractive surgeons can compare the data with the wavefront derived from a standard aberrometer.

The Scout has a pupil edge tracker that superimposes the size and shape of the pupil onto the axial map. After the corneal wavefront is calculated, the data are imported into the laser (ORK Custom Ablation Manager [CAM]; Schwind eye-tech-solutions) to create an ablation pattern depicting the amount of corneal tissue to remove for a final prolate result. The ORK-CAM can control the diameter of the ablation to minimize glare, such as in the case of enhancements.

What is the need for corneal-topography--linked treatment when a plethora of Hartmann-Shack and Tschering-type aberrometers are already on the market? Corneal wavefront has a few advantages over standard aberrometry maps. First, the corneal wavefront is readily reproducible and repeatable, unlike aberrometry measurements that vary with ambient illumination, pupil size, and accommodation. Second, we can treat up to 9 mm of the cornea with corneal wavefront, which is useful for peripheral visual clarity. Third, when obtaining an aberrometric measurement in the eyes of our Indian patients—because the pupil opens 4 to 5 mm in the dark—we must use phenylephrine eye drops, which may alter accommodation. Fourth, the cornea is responsible for more than 80% of the aberrations in the eye, and therefore treating aberrations on the cornea makes sense.

The Carozzo Pendular microkeratome is an efficient and safe unit creating 90- to 160-μm flaps (depending on its head). It has a unique applanating head that warrants its use on distorted corneas. A ball-shaped cutting head protects the corneal center and applanates it before the blade engages the cornea. The head distributes pressure mainly to the center of the eye and protects the corneal center during the cut to avoid buttonholing. Unlike a traditional straight track or rotatory microkeratome, a more uniform flap thickness is generated at the periphery and center of the flap.

Our procedure for all distorted corneas is the same. We perform an accurate refraction and corneal topography, checking corneal thickness at different points with a pachymeter. We pay close attention to thin ectatic zones of scarring at graft-host interfaces as well as areas of healed scarring. Frequently, in the case of corneal grafts, there will be a mismatch between the host and donor graft edge with over-riding and localized ectasia. With the exception of grafts, we perform a one-step procedure for all distorted corneas, involving creation of the corneal wavefront from the topography and a flap cut. Using a 110-μm--head microkeratome, the final cut is between 100 and 120 μm thick.

Care must be taken while reflecting the flap in post-RK patients. In these eyes, the pie-shaped segments, usually held together by tenuous scar tissue, frequently separate when repositioning the flap. Once the ablation is complete according to the software generated by the software, a bandage contact lens is placed on the eye for 48 hours. Ofoxacin and dexamethasone combination eye drops are continued four times daily for 1 week. Lubricating eye drops are continued three times daily for 3 months.

Corneal wavefront-linked treatments are invaluable in postkeratoplasty eyes, and the need for penetrating keratoplasty (PK) is steadily increasing. The World Health Organization (WHO) estimates that more than 100,000 keratoplasties are carried out annually.11 Considering there are an estimated 10 million cases of corneal blindness worldwide, the number of keratoplasties is still woefully inadequate.

Once keratoplasty is successfully carried out (and assuming that the cornea maintains its clarity), significant visual morbidity depends on the residual refraction and cylinder. Perlman11 showed that the inability to construct a perfectly similar recipient bed for the donor graft, both in shape and regularity, is the main factor responsible for inducing high astigmatism.

Truly symmetrical, regular astigmatism is a rare condition after PK, and irregular astigmatism cannot be corrected with existing technology. Studies have shown11 that 8% to 20% of eyes have significant irregular astigmatism that cannot be managed with glasses or contact lenses following PK.

In a series of 44 eyes post-PK, Pradera11 reported a mean astigmatism of 5.11 ±2.68 D and a spherical equivalent of ±3.47 D. Such anisometropia leads to loss of stereopsis and eventually foveal suppression. In our opinion, a minimum of 6 months after suture removal is mandatory before performing LASIK. In the literature,12 investigators recommend waiting approximately 3 to 6 months after suture removal to perform LASIK. Arenas et al11 recommend waiting 1 to 7 years after suture removal. We have no established time interval between the initial PK and LASIK procedure. We have treated these patients from a minimum of 6 months after suture removal to up to 5 years after suture removal.

We should remember that with the suction ring on the eye, the intracocular pressure may rise as high as 60 mm Hg. The graft-host junction must be evaluated, verifying that it can take such elevated pressure for nearly 30 seconds if necessary.

There are two ways of performing LASIK in postkeratoplasty eyes. The first method is to create the flap and wait 1 week before applying laser ablation. By performing the cut and letting the corneal tissues realign, the cylinder will frequently decrease—by as much as 30% in some cases—with this method. After making the flap cut with the microkeratome, the stress existing between graft and host cornea, which lead
Figure 1. A 38-year-old male underwent PRK 2 months prior to visiting us. On topography with the Keratron Scout, 4.50 diopters of cylinder with a para-central island was detected. It was decided to perform a corneal wavefront-guided LASIK enhancement.

Figure 2. On corneal wavefront analysis, more than 5 μm of root mean square wavefront aberration is noticed. Anything over 2 μm of root mean square aberration is deemed significant enough to treat with corneal wavefront guidance.

Figure 3. Ten days after the enhancement, corneal wavefront analysis shows reduction in root mean square to 2 μm.

To astigmatism, are released. In some cases, the cylinder may decrease. In fact, the greater the flap thickness, the more corneal lamellae intersected—particularly in the periphery where they maintain corneal structure and stability.10

We have recently begun to perform LASIK as the primary procedure, avoiding the 1-week wait between flap creation and treatment. Jaycock et al11 showed that the peripheral corneal lamellae support the corneal structure. Therefore, a thinner flap or LASEK is preferable to a regular 130- to 160-μm flap. When using a thin flap (80–90 μm), fewer corneal lamellae are transected. In our experience, cylinder has not regressed after 3 months. Additionally, the correction remains stable. One case is depicted in Figures 1 through 3. Many of the cases we have performed present with extreme refraction of up to 12.00 D cylinder and 9.00 D hypermetropia. The maximum permissible correction is performed as per the corneal thickness. The patient is prescribed spectacles to compensate for any residual correction.

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