# Managing Highly Distorted Corneas

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The corneal surface is the principal refracting element of the eye; the air-to-tear film interface is responsible for the majority of refraction of light entering the eye.[1] Any change to this surface dramatically changes the refraction, which is what is accomplished in refractive surgery. Likewise, any irregularity in this surface dramatically affects the quality of vision. This may be the problem in eyes with decentered and/or small optical zone ablations; in these cases the cornea acts like a multifocal lens and causes uneven distribution of light. As a consequence, patients experience loss of BSCVA and contrast sensitivity and haloes and starbursts around objects. These symptoms are especially annoying during scotopic and/or mesopic conditions, when the pupil dilates and exposes more of the irregular cornea. [1,3,4,6,10-14]

## Methods and Results

We have previously presented and published our experience in utilizing wavefront[1] as well as topography-guided[2] excimer ablations in order to treat highly irregular corneas such as eccentric previous ablations, keratoconus and post LASIK ectasias. To correct these irregularities, surgeons have gone to "customized" forms of ablation, which include wavefront-guided ablations as well as techniques of topography-guided treatment.[3-9]

We have been working with the topography-guided platform by Wavelight (Erlangen, Germany) over the last four years. This proprietary software utilizes topographic data from the linked topography device (Topolyzer-Wavelight, Erlagen, Germany). It by default permits the consideration of eight topographies (of predetermined threshold accuracy), averages the data, and enables the surgeon to adjust desired postoperative cornea asphericity, to include, or not, tilt correction, and to adjust sphere, cylinder, axis, and treatment zone.

The mechanism of topography-guided ablation is the fitting of an ideal cornea shape (usually a sphere) under the present topography map with the ablation of tissue in between. The advantages of topography-guided treatments over wavefront-guided treatments include the following:

1. It can be used in highly irregular corneas that are beyond the limits of wavefront measuring devices.
2. It can be used in cases that have media opacity such as in eyes with corneal scars, since its measurements are based solely on the surface.
3. Since it is based on the corneal surface, it is theoretically possible to factor in the asphericity (Q value) and maintain the natural aspheric shape of the cornea.

Recent studies have demonstrated that there is a shift in the pupillary center between normal (photopic) and dark-adapted (mesopic, scotopic state). Therefore topography-guided treatments would hold greater accuracy on delivery to the cornea since they are captured with the photopic pupil, the same as in the treatment. The major disadvantage of topography-guided ablation is that ignores the rest of the refractive media since it concentrates mainly on the corneal contour. This may induce some refractive "surprises" previously encountered when utilizing this technique. One example of this would be in the treatment to widen the optical zone of previously myopic patients. The treatment would require the laser to flatten a broader area of the cornea and therefore ablate tissue peripherally; this ablation pattern will resemble a hyperopic treatment and thus will cause some amount of

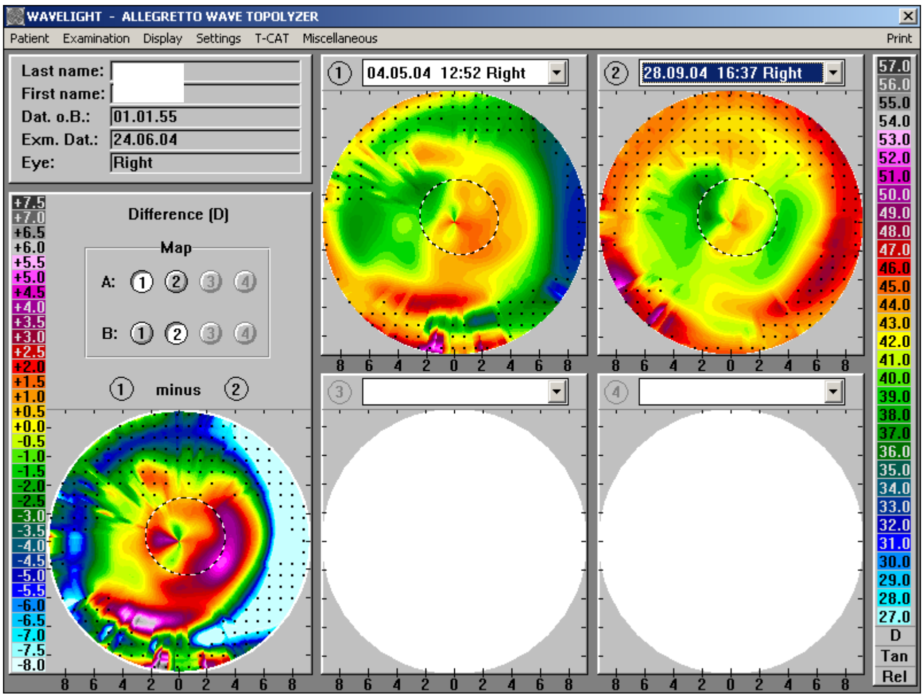


Figure 1. This is the pre– and post– LASIK topography (1 and 2, respectively) of an irregular cornea having topography-guided LASIK with the TCAT Wavelight platform. The cornea irregularity was caused by an old contact lens-related bacterial ulcer. The difference map ("1 minus 2") demonstrates the highly irregular flattening achived by the topography-guided treatment.

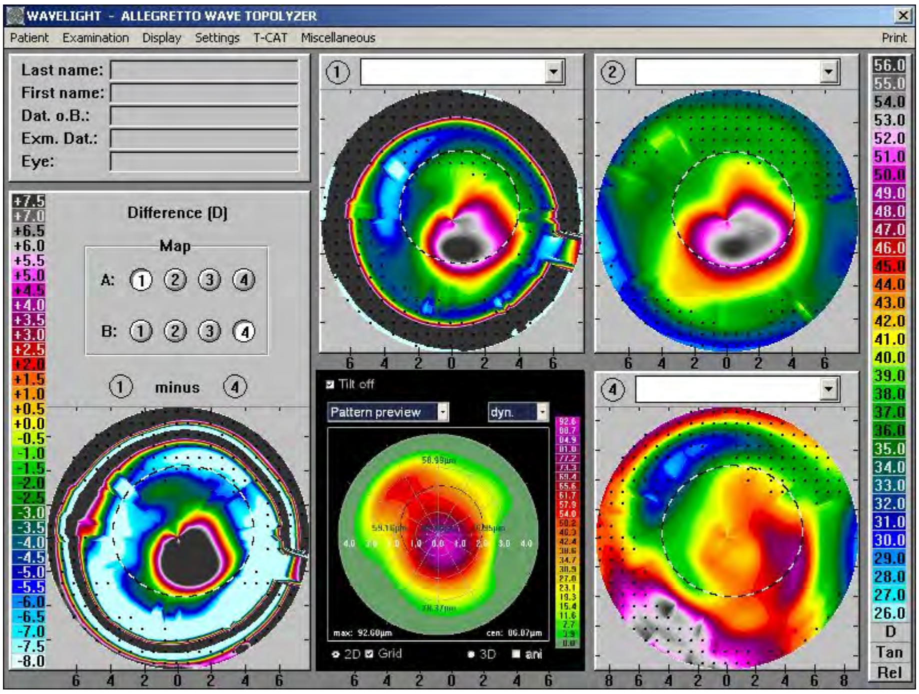


Figure 2. This display of topographies depicts the following: (1) The cornea topography of this case when first seen by the authors with central cornea ectasia and midperiphery flattening as an effect of the Intacs that were present. At this point BSCVA was 20/200. (2) The cornea topography here is two months after the removal of Intacs and one month after UVA collagen crosslinking. The central steepening is still present and the effect of the Intacs removal is appreciated compared to the previous image, mostly at the midperiphery, that appears steeper now. At this point BSCVA was 20/200. (3) The lower row image in the center is an estimated cornea topographic ablation pattern as a laser treatment plan of the topography-guided procedure that took place in the case. It is notable that this ablation pattern is highly irregular with a "deeper" ablation plan just inferiory and right to the center, that matches through the central cornea irregularity in the previous topographies. (4) The cornea topography here is six months after topography-guided PRK. The central cornea appears more regular and much flatter. At this point BSCVA and UCVA is 20/20. (5) The lower row image on the left is a comparison map. This map depicts the difference of subtracting the cornea topography 4 (final result) from the cornea topography 1 (original state of this complication when encountered by us). The difference resembles impressively the topography-guided ablation pattern (next image to the right), demonstrating effectively the specificity of this treatment in reducing the pathogenic cornea irregularity, which we theorize contributed to the drastic improvement of BSCVA.

myopic shift. Some of these patients may later require an enchancement procedure with a "standard" treatment to correct for the remaining spherical refractive error. We made adjustments to the refractive targets (ie, putting in a myopic postop target) to our later cases to compensate for this shift in refraction.

The Q value was targeted to the ideal endpoint of –0.46 in all cases, which is believed to be an ideal cornea 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, in which the postoperative cornea shape is determined only by the difference between the preoperative shape and the ablation profile. However, other factors may be responsible for explaining the discrepancy between the clinical findings and the theoretical predictions in cornea 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, while flap-induced changes, together with indirect biomechanical shifts of the cornea, are present in LASIK 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 cornea surface regularity.

We have previously reported utilizing topography-guided treatments in keratectasias. [13-15] Both post-LASIK ectasias and keratoconus have been successfully treated with a topo-guided PRK following stabilization with collagen crosslinking (CCL). The first scale of this treatment was employed in order to stabilize the cornea ectasia, as reported in previous laboratory and clinical studies. The use of the riboflavin solution over the de-epithelialized cornea was employed in order to, first, protect the crystalline lens and possibly the retina from UVA radiance and, secondly, to enchance UVA absorption in the anterior stroma and facilitate the crosslinking process as described previously.[10,11] We employed the subsequent topo-guided PRK procedure in order to visually rehabilitate the irregular corneas. The visual rehabilitation had been very rewarding in a relatively moderate postop follow-up of one year. Representative corneal topographies are shown in Figure 2.One can appreciate the difference map between pre– and post-UVA CCL (2C) as well as the difference map between pre– and post-topography guided treatments (2F) and, finally, the actual ablation profile that was used for the treatment (Figure 2D: "treatment plan"). It is quite interesting to appreciate the qualitative changes on the cornea surface. Both in the treatment plan D as well as the difference map F there is strong evidence of "deeper" ablation over the steep cone area. Another important factor is the attempt in 1D and actual effect in 2F of a mid-peripheral "steepening" effect of the diametrically opposite cornea to the cone center. This is achieved by flattening the outer of the mid-cornea that is planned to be "steepened."

Therefore, normalization of the cornea is achieved by both flattening the cone apex and steepening its diametrical opposite, preserving significant tissue thickness reduction that a similar wavefront-guided treatment would require.

We employed topography-guided PRK on the crosslinked cornea in that case in order to obtain better visual rehabilitation. This customized approach can in my opinion address the extreme corneal irregularity that these cases may have and enchance visual rehabilitation, leads us to believe that this combined approach may have a wider application in the near future.

## Conclusions

All this work has complemented our customized approach to refractive surgery and addresses the most irregular corneas that a regular or wavefront-guided ablation cannot treat.

The limitation of refractive outcome in regard to sphere can be refined by incorporating axial length measurements in the topography images. More studies and continuous treatments algorithm evolution may enchance our treatment armamentarium as refractive surgeons.

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