

A Map to Diagnosing Corneal Disorders:

Employing the corneal topographer on diseased eyes

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One of the more sensitive instruments in practice today to describe corneal thinning disorders is the corneal topographer. This device provides us with an array of analysis options that can quickly and accurately diagnose conditions that warrant our attention or treatment. However, like many advanced instrument technologies in practice today, the wide range of options for interpretation can be overwhelming. As an example, which analysis display is best to diagnose the earliest signs of disease? How do we characterize one condition from another? What functions exist to monitor if changes are occurring over time? The corneal topographer can be a powerful tool in the hands of both the experienced and neophyte user when armed with basic fundamentals. This paper will discuss the various capabilities and functions as well as how we use this instrument to aid in contact lens fitting.

There are dozens of available corneal mapping systems which can be categorized as either reflection or projection units¹. Reflection systems are able to map the anterior surface of the cornea and can also provide non-invasive tear film break-up and stability tests as an added feature^{1,2}. More recently a number of reflective based instruments have been introduced which can measure well beyond the cornea and provide scleral shape and sagittal depth which is beneficial in large diameter lens fitting^{3,4}. However, all reflection systems measure the anterior surface only and therefore cannot describe the posterior cornea or thickness (Figure 1).

By comparison, projection based instruments can measure both the anterior and posterior corneal surface¹. This also allows for pachymetry measurement of the eye's thickness. Projection topography provides a more comprehensive picture of the cornea as a whole and is generally favored by surgical sites when considering LASIK candidacy (Figure 2).



Figure 1



Figure 2

When attempting to diagnose if a particular cornea is normal or abnormal, one of the simplest observations that can be made is to assess the range of power distributed across the corneal surface⁵. Using an “axial” interpretation, determine the flattest dioptic power the topographer can read on the selected cornea. Then conversely find the steepest reading on the surface. The dioptic difference between the two is the scale range of power (Figure 3). Normal corneas distribute less than 10 diopters of power from the flattest to steepest readings on the axial display. If the instrument doesn’t use the term “axial”, this analysis option is also described as “power” or “sagittal” displays by some units.

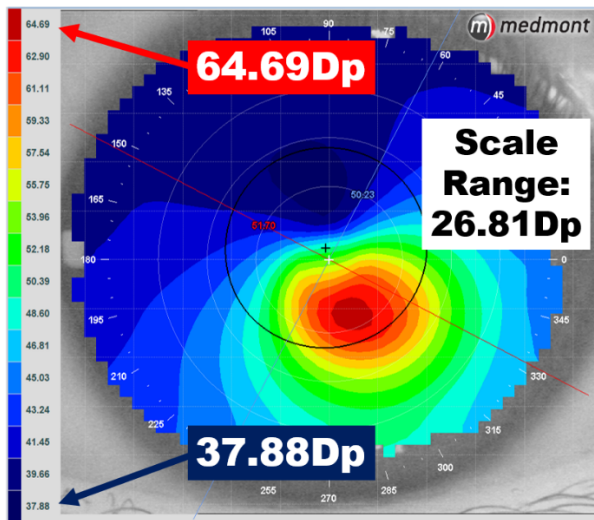


Figure 3

Another analysis option that has value is the “tangential” display which is known in some instruments as the “instantaneous” or “true curvature” map¹. This interpretation is more sensitive to finite surface changes in the eye which the axial display can miss due to the smoothing effects inherent in its formula. A tangential map can clearly define the size, shape and position of the anomaly or diseased tissue. This is helpful when characterizing one presentation of the condition over another. To help us simply and efficiently classify the various types, McMahon et al, studied irregular eyes and came up with the following findings⁶. Nipple cones were <3mm in diameter and are generally more central to the pupil

(Figure 4a). Oval keratoconus had diameters of 3.0-5.5mm in diameter and usually present inferior of the visual axis (Figure 4b). Cones >5.5mm were considered “globic” and involve much more of the corneal surface but present in a small percentage of cases (Figure 4c). Pellucid and Terriens marginal degeneration are other forms of thinning disorders that are rare and involve the tissue closer to the limbus than keratoconus typically would (Figure 4d).

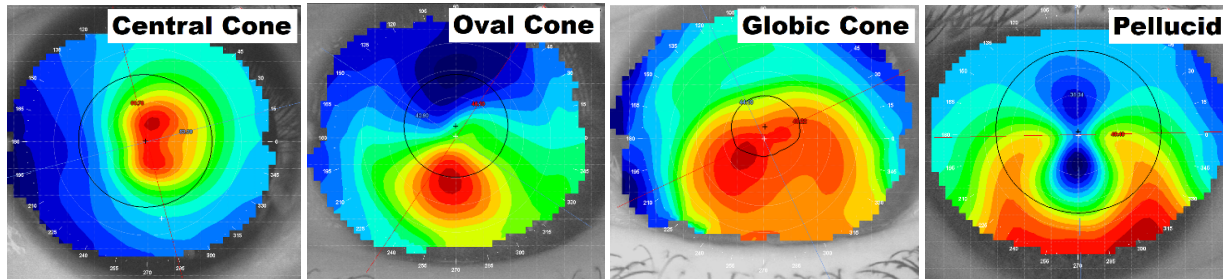


Figure 4a

4b

4c

4d

We can use the axial and tangential map to classify when the condition is moderate or severe. But neither interpretation can provide a definitive diagnosis when the case is mild or in the early onset of the disease. For this reason, disease detection indices have been developed by researchers and instrument designers alike. These values eliminate the need for experience in the subjective appearance of the topography contours but rather analyze the corneal shape mathematically.

The first and possibly most relied upon by refractive surgeons in assessing the possible signs of disease is the “I-S value”⁷. The “I” is an abbreviation for the “inferior” while the “S” an abbreviation for superior (Figure 5). The I-S value compares the average power of the inferior cornea against the average of the superior. If one hemisphere is significantly different from the other, this is usually a strong indicator of an abnormal and possibly diseased eye. Considering approximately 90% of the corneal thinning disorders present in the inferior hemisphere, its logical to have the inferior cornea much steeper than the superior. I-S values greater than 1.50Dp are indicative of a diseased or abnormal eye.

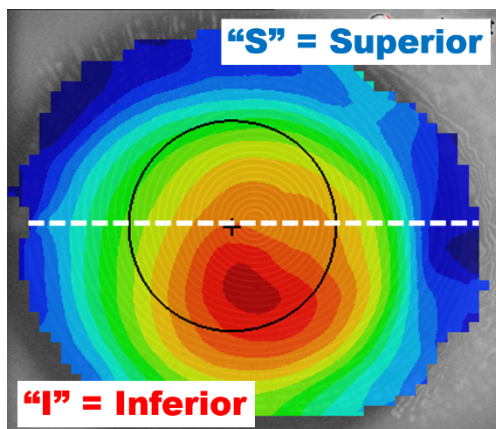


Figure 5

Another commonly employed disease detection indices is the “surface asymmetry index” (SAI)⁷. This interpretation compares the principle oblique meridians for symmetry (Figure 6). As an example, the curvature from the apex along axis 45 degrees is compared to the opposing curvature from the center along axis 225°. Then the same hemi-chord comparison is done between axis 135° and 315°. A

completely symmetric eye would have an SAI value of zero. However, if the oblique meridians are significantly different from each other, this would indicate an asymmetric surface. SAI values greater than 1.0 are indicative of a diseased or irregular eye.

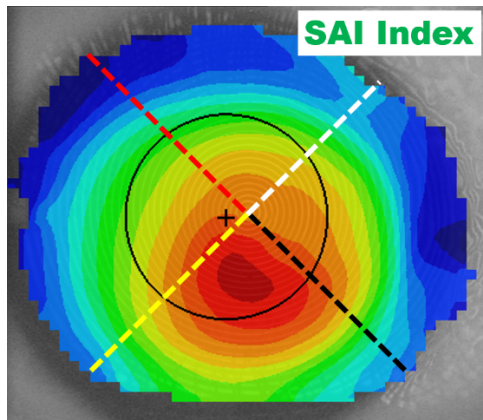


Figure 6

The last typically employed diseased detection indices is the “surface regularity index” (SRI)⁷. This center weighted analysis determines the relative smoothness of the cornea. High power distributions within the pupil could be indicative of an irregular cornea. A healthy normal eye would have a very smooth central cornea allowing for high quality visual acuity. A diseased eye with radical surface power changes within the pupil is more likely to degrade vision. SRI values greater than 0.80 are considered abnormal and suspect of a diseased eye.

As a simple way of remembering how each of these indicators diagnose an irregular eye, the higher the value, the more abnormal the surface. The scale range, I-S, SAI and SRI would indicate a symmetrical or normal eye is closer to zero values while a more irregular or diseased eye would be a higher value.

The position and size of the steepest curvature or apex can also provide insight in diagnosing a diseased eye⁶. For example, a normal, healthy eye should exhibit an axial or tangential topography with the steepest curvature near the center and a gradual rate of flattening towards the periphery (Figure 7a). By comparison, a keratoconic patient generally has an apex inferior of center with a higher rate of curvature change within a smaller surface area of the topography (Figure 7b). In central or nipple keratoconus, the apex might present central to the pupil but regardless of the position of the apex, its common in diseased and irregular eyes to see radical power changes within tighter distances compared with normal, healthy eyes.

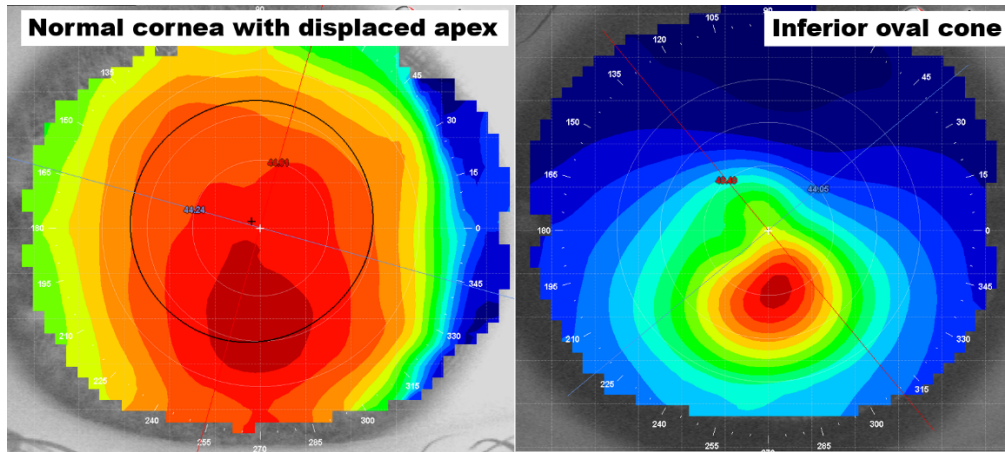


Figure 7a

Figure 7b

Another interpretation that topography software allows is the elevation display. This map overlays a best fitting spherical surface on the anterior surface and defines where the tissue is above the surface (red) and where it is below in height (blue), measured in microns⁸. This can be a helpful analysis to appreciate how high the elevation changes are in the eye surface. Projection topographers have the added benefit of being able to image the posterior surface as well as the anterior (Figure 8). Studies have suggested that the posterior elevation analysis can be more accurate in diagnosing the earliest signs of thinning disorders where at times the anterior surface may be absent of irregularity^{9,10}.

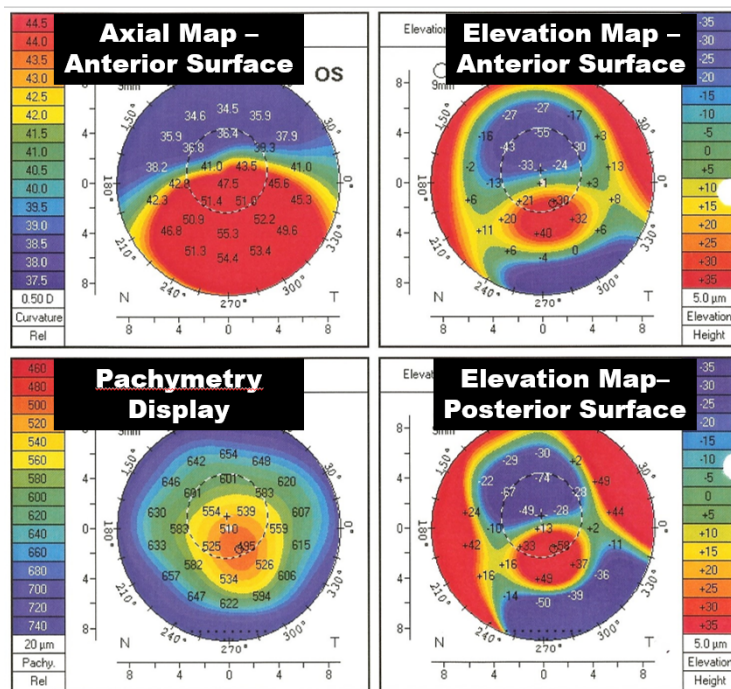


Figure 8

Characterizing the difference between keratoconus, Pellucid (PMD) and Terriens marginal degeneration (TMD) can be difficult at times. To properly define the presentations, the topographer can make it relatively clear. For instance, keratoconus appears on the axial or tangential map as a round or oval acute area of steep curvature (red) generally within the central or para-central cornea¹¹ (Figure 4b). By

comparison, PMD or TMD would present with red curvature far more peripheral and nearer to limbus¹². Additionally, PMD takes on a “kiss doves” or “butterfly wing” appearance on the axial map (Figure 4d) while TMD presents as various forms. Both however, are usually associated with lower flat K (Kf) readings than keratoconus. In PMD as an example, the Kf value is usually ≤ 40 diopters where in keratoconus patients, their Kf value is usually ≥ 45 diopters.

When monitoring diseased patients, the “subtractive” or “difference” maps can be very helpful in defining the smallest changes over time. Typically, this analysis function is used in orthokeratology cases to assess the corneal changes produced following overnight wear. However, the subtractive map can be employed in a diseased eye to determine if the condition is stable or advancing. When comparing two visits, a subtractive map showing all green would indicate no changes over time (Figure 9a). However, red areas on the subtractive map indicate steepening between the visits and blue defining flattening (Figure 9b). If there is steepening over the cone, this is likely advancing of the disease but can also be caused by contact lens molding. Conversely, we can often see more blue over the cone following corneal cross linking on the subtractive map.

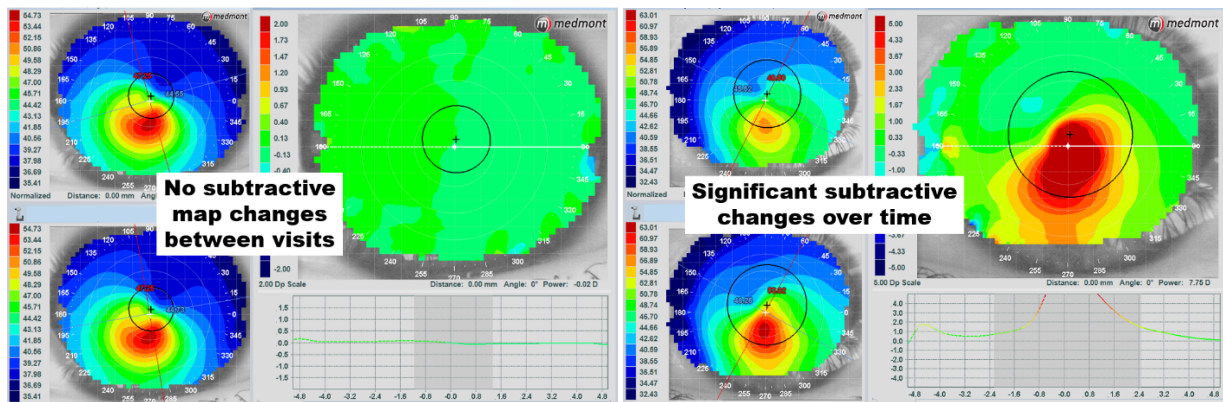


Figure 9a

Figure 9b

Ultimately if we are diagnosing corneal thinning disorders in our patients, there is a high likelihood we will be fitting specialty contact lenses to improve the patient’s visual quality of life. Clearly these instruments can aid in diagnosing irregular eyes but can they help us to choose the right contact lens path for a patient?

There are many custom soft lenses for keratoconus today but when can they provide the patient with 20/happy vision? The axial map can be beneficial to understand the power of the anterior surface. If the distributed power within the pupil show a range >10 diopters, this could create too much aberration for a custom soft lens to mask. Additionally, the symmetry within the pupil can be a telling sign. The more extreme the power distribution, the less likely a conventional or custom soft lens is going to be able mask the asymmetry.

Another quandary we face is when should we fit a particular eye with a corneal GP or scleral? Zheng et al attempted to answer this question by analyzing the elevation map¹³. In this study, they determined the highest point of elevation in microns (red area) and the lowest point of depression (blue area) on each eye. The difference in height between the two was considered the elevation differential (Figure 10). In this study, they found that patients with ≤ 350 microns of elevation change could achieve a

successful corneal GP fit 88% of the time. Conversely, when the elevation differential was >350 microns, a scleral lens was required to fit the high asymmetry of the eye in order to achieve success.

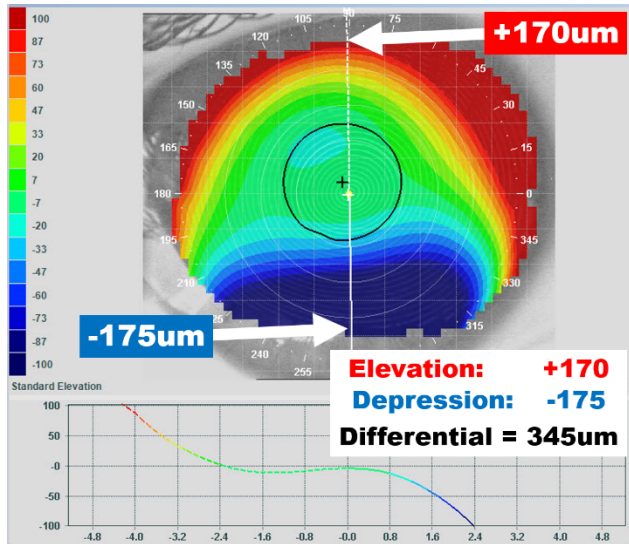


Figure 10

Corneal topographers not only steer us in the right direction in terms of which modality to use, they also come with contact lens fitting modules. These programs allow simulated fluorescein modeling of specific lens designs to accurately determine the initial trial or custom parameters best suited to the eye (Figure 11). Sindt et al showed that corneal topography fitting software can predict the fluorescein pattern 74% of the time regardless of the map quality¹⁴. However, with good quality images, this fitting accuracy could be improved to 95%. These modules can help reduce chair time and lab costs by improving the efficiency of the trial process and accuracy of the initial custom parameters.

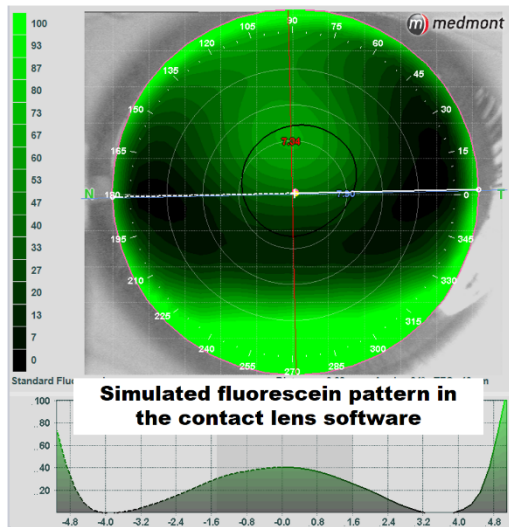


Figure 11

Diagnosing corneal thinning disorders cannot be limited to the application of just one instrument. The slit lamp, pachymetry and visual cues are critical tools along with corneal topography in making an accurate and definitive diagnosis. But corneal topography can be sensitive to the earliest presentation of the disease and can provide us with the ability to categorize the type of condition and severity of the

disorder. Understanding its functions will greatly aid practitioners both in the characterization but also in the choosing a contact lens path best suited for the patient.

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