Keratoconus - Diagnosis and Evaluation of Visual Function

Keratoconus is abnormal thinning of the cornea. The weakened areas of the cornea bulge outward and the optical figure of the cornea deviates from the ideal shape. Keratoconus is associated with poor visual acuity that cannot be improved satisfactorily by normal spectacles or contacts.

COAS™ is ideal for the evaluation of keratoconus. Although COAS™ does not measure the thickness of the cornea, it does uncover the resulting optical defects of the eye and reveals keratoconus, even at early stages, that are unlikely to be identified by other instruments. In addition, the COAS™ software allows the doctor to view a simulation of the visual effects of the keratoconus which the patient experiences.

Figure 1 - Gradient map for a normal eye

Figure 2 - Gradient map for a keratonic eye

Diagnosis of Keratoconus

Keratoconus shows up most dramatically in the gradient map. This map is closely related to the vector field map used in mathematics. At each point on the cornea, there is a short line which indicates the direction the cornea bends each light ray. The length of the line shows the amount the ray bends when it enters the cornea. In a normal cornea, the light rays all bend in toward the center of the retina. A map indicating this would be dominated by the fact that rays further toward the edge of the pupil would have to bend more to reach the center of the retina. However, it is useful to have a map where the optimal amount of bending for each ray has been subtracted out. Then the deviation of each ray, in direction and magnitude from the optimal ray would be shown.

In this display, the region of the cornea that is perfect would be represented by a dot. A region that is wrinkled would be represented by a short line.

On a gradient map, a normal eye will show short vectors that point radially outward, signifying normal spherical aberration. The normal picture will also show a gradual increase in the length of the lines toward the edge of the pupil. In an eye with keratoconus, different regions of the pupil will show vectors that point in different directions.

The power map also provides a method of looking for keratoconus. It is important to realize that power is the amount of local curvature at some region of the cornea, without any indication of which direction the curvature is pointing. In normal eyes this is not a matter of concern because the direction the light bends does not change very much over small regions of the eye. With keratoconus, there can be two regions side by side with the same curvature, with the light pointing in different directions. Only the gradient map can reveal such patterns. (The phenomenon of light in adjacent regions pointing in totally different directions also occurs at the edge of Lasik ablation zones.)

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Keratoconus also shows up in the zonal wavefront map and the power map. Regions of localized corneal thinning will show up as local changes in the color of the map.

The COAS™ software displays a metric that is useful for identifying possible keratoconus. The RMS OPD HO (Root Mean Square Optical Path Difference High Order) appears on the main form.
Typical values are shown below for a 6mm diameter pupil.

RMS OPD HO	**Condition of eye**
0.1 to 0.3	Normal
0.3 to 0.5	High Normal
0.5 to 0.7	Irregular Astigmatism
over 0.7	Possible Keratoconus

The RMS values reported by the COAS™ software tend to be higher than other machines because of the small feature size that COAS™ is able to measure. Other wavefront sensors simply smooth over the small features and produce RMS values that are no larger for normal corneas than for keratoconus eyes.

The COAS™ software displays a prominent message when it encounters a wavefront that shows a level of higher-order aberrations that indicate possible keratoconus. In addition to the simple test described above, certain algorithms (patent pending) in COAS™ look for patterns of aberrations that may indicate keratoconus. In the event that this message displays, the ophthalmologist should examine the slope, wavefront, and power maps for further evidence of keratoconus, as well as pursue other classical diagnostic techniques.

Evaluation of the Effect of Keratoconus on Visual Function

The Visual Acuity Simulator built into the COAS™ software allows the doctor to see the effects of the eye's aberration on a patient's visual function. Normal eyes may show a fuzzy E when sphere and cylinder terms are uncorrected in the simulation, but the E becomes distinct when the low-order terms of sphere and cylinder are removed. However, with the keratonconus patient, the high order terms have a strong effect and the E remains fuzzy even after the sphere and cylinder terms are removed.

Advantages of COAS™

The thin regions of cornea can sometimes occur over a small area, particularly in early cases of keratoconus. **The COAS™ instrument is the only wavefront aberrometer on the market that measures the eye with small enough regions** Each sample on the eye covers a region 0.2mm by 0.2mm, for a total of 800 points over a 7.0mm pupil diameter. Other systems with fewer samples simply smooth over the defective regions.

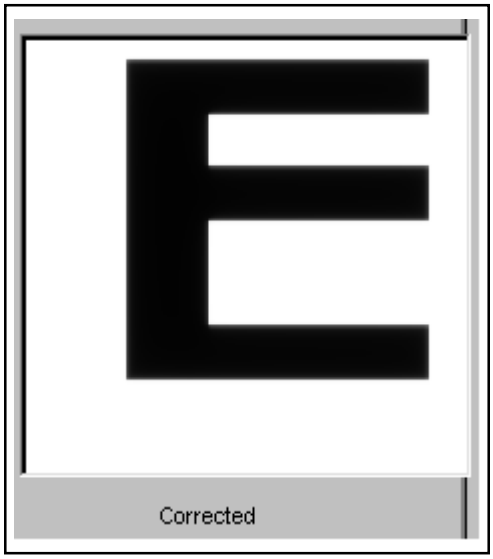

Figure 3 - Simulated E for normal eye (only higher order terms included)

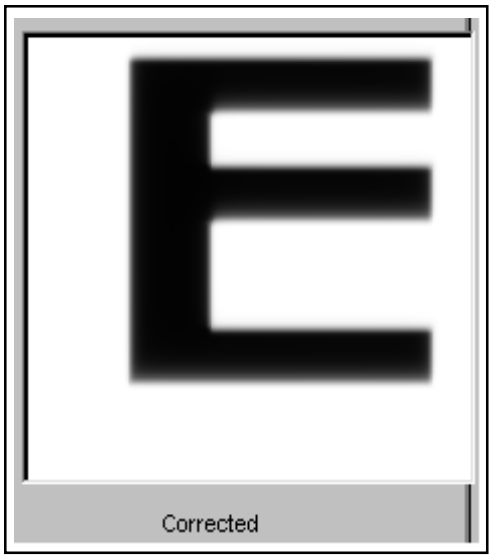

Figure 4 - Simulated E for eye with keratoconus (only higher order terms included)