

Keratoconus Detection Using Corneal Topography

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ABSTRACT

PURPOSE: To review the topographic patterns associated with keratoconus suspects and provide criteria for keratoconus screening.

METHODS: Case study using maps from the NIDEK OPD-Scan II and OPD Station to highlight patterns seen in keratoconic corneas.

RESULTS: Five criteria are listed for the detection of keratoconus: 1) apex of the cone is not centered at the 6-o'clock semi-meridian, 2) cone should appear round on the tangential map, 3) keratometry >45.00 diopters, 4) corneal thickness at the apex of the cone is approximately $30\ \mu\text{m}$ thinner than the corresponding distance above the pupil center, and 5) topographic patterns are not symmetric.

CONCLUSIONS: Standard corneal topography maps and simple clinical evaluation criteria are fundamental to detect keratoconus suspects and keratoconus. [*J Refract Surg.* 2009;25:S958-S962.] doi:10.3928/1081597X-20090915-11

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eratoconus is a progressive corneal disease characterized by central thinning and steepening of the corneal curvature. The progressive nature of this disease leads to increased myopia and irregular corneal astigmatism, which decrease visual acuity and visual quality.¹ Onset is often during the second decade of life onwards, typically when the patient is still socially and physically active. The reduced visual quality leads many patients with keratoconus to present at refractive surgery centers for alleviation of their symptoms via LASIK. Keratoconus and forme fruste keratoconus are contraindications for LASIK due to the high risk of postoperative ectasia. The incidence of keratectasia after LASIK is approximately 0.5%.² Early detection of forme fruste keratoconus and keratoconus is often performed by thorough topographic evaluation in conjunction with the clinical examination.

Improvement in the ability to detect and diagnose suspicious to advanced keratoconus will enable the exclusion of patients at risk for corneal ectasia after corneal refractive surgery. Earlier detection of forme fruste keratoconus may lead to earlier intervention. The specificity and sensitivity of the various automated keratoconus screening software are still not adequate for broad clinical use.^{3,4} Most of these automated detection programs cannot accurately classify suspicious topographies with an adequate degree of reliability.^{3,4} It is precisely these suspicious cases that cause clinicians the most difficulty. To date, a thorough clinical and topographic examination by the ophthalmologist is still requisite for keratoconus detection. This article presents the use of the OPD-Scan II (Optical Path Difference Scanning System II; NIDEK Co Ltd, Gamagori, Japan) combined with clinical features to screen for keratoconus.

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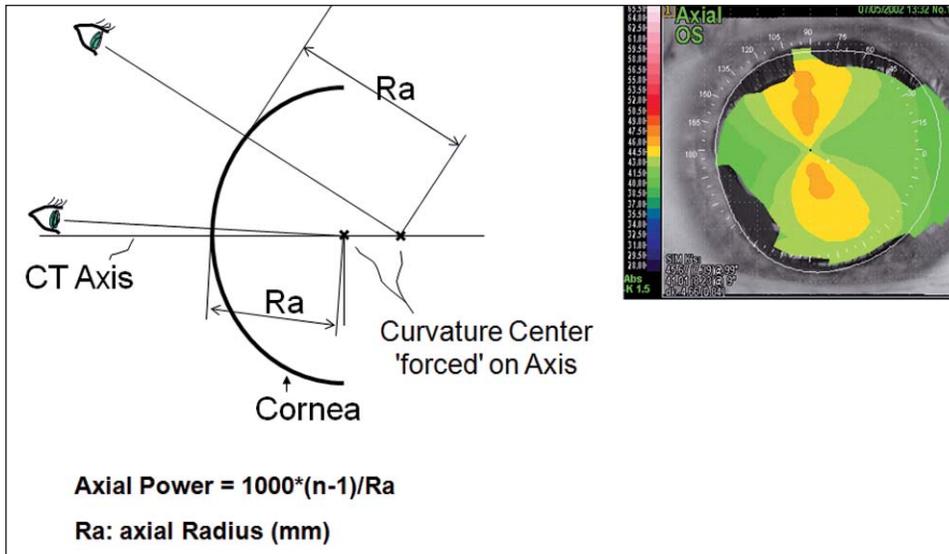


Figure 1. Schematic of axial topography including a sample topography of the left eye. Yellow denotes steeper curvature than green. CT axis = corneal topography axis

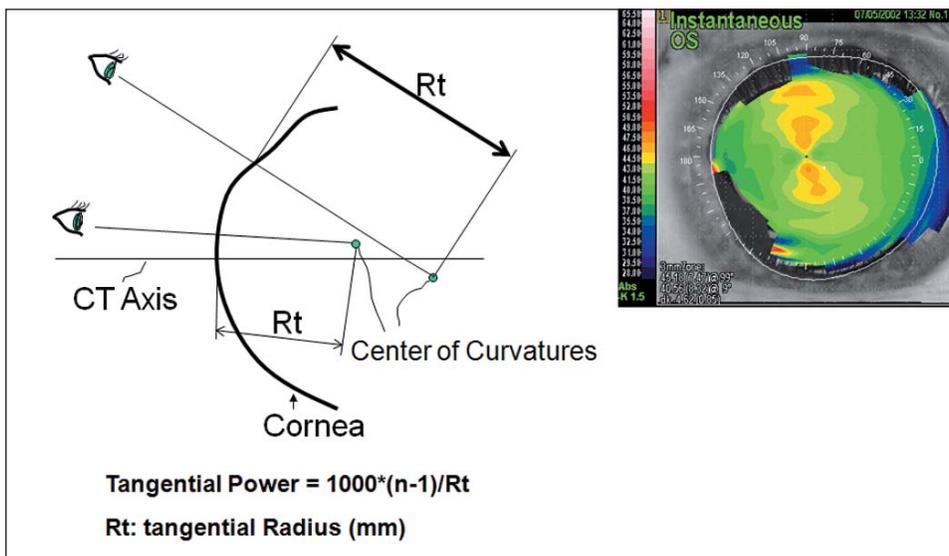


Figure 2. Schematic of instantaneous topography including sample topography of the left eye (same as Figure 1). Yellow denotes steeper curvature than green. CT axis = corneal topography axis

SCREENING FOR KERATOCONUS

A number of topography maps are available on the OPD-Scan II. The most commonly used are the axial map, instantaneous map, and refractive map. Axial corneal topography measures all curvatures relative to the corneal topography axis (vertex normal). All radii are measured relative to this axis. Due to the common reference axis, small surface irregularities may not be visible (Fig 1). The instantaneous map, or local radius of curvature map, has no reference axis and only determines the local radius of curvature (instantaneous radius of curvature) at each point. It shows much more detail in the actual geometry of the cornea (Fig 2). The refractive map is similar to the axial map, but uses Snell's law with ray tracing to determine the power at each point on the cornea rather than the keratometric approximation (Gaussian optics) used for axial maps. The refractive

map plots the refractive power of the corneal surface at each point. For example, if the cornea was spherical (of course it is not, it is a prolate ellipsoid) with a radius of 7.50 mm, the corneal power would be 45.00 diopters (D) at all points using the keratometric index of refraction (1.3375). The map would look uniform in power at all points. If, however, Snell's law was used, the actual dioptric power would be found to increase when moving towards the periphery (spherical aberration). With the refractive power map, the increase in power would be apparent. The refractive map is especially useful when trying to correlate topographic power changes over the pupil with refractive changes in the eye.

CASE EXAMPLE

A case example of keratoconus is presented to highlight the criteria used for keratoconus detection that

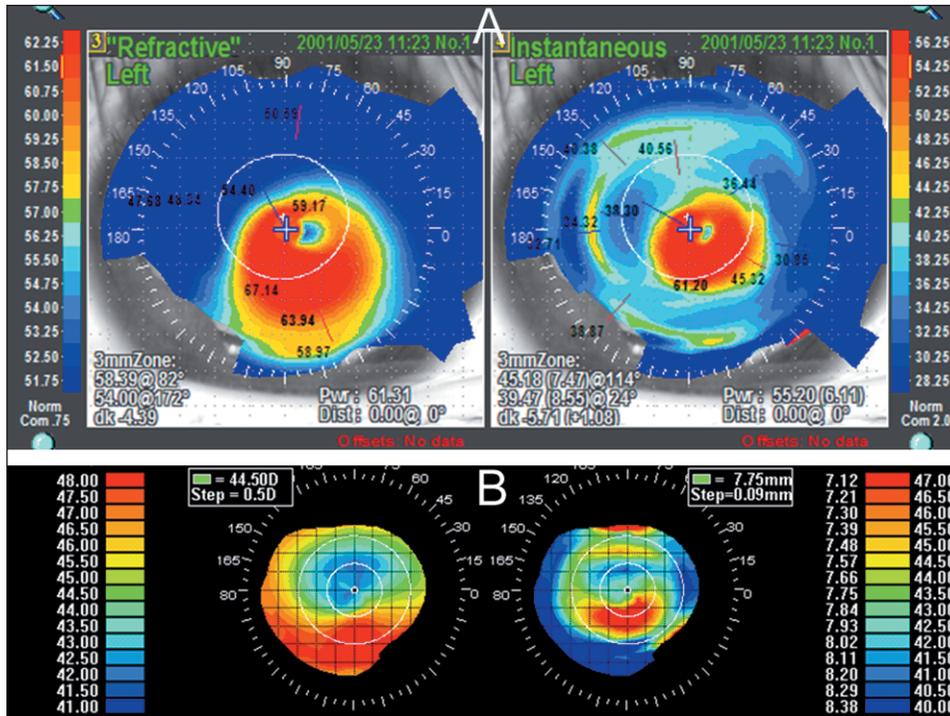


Figure 3. Refractive (left images) and instantaneous corneal (right images) topographies of **A)** a patient with keratoconus and **B)** a patient with contact lens warpage.

includes evaluation of corneal topography. The following criteria are used to screen for keratoconus:

1. Use the instantaneous map to determine the apex of the cone. The apex of a keratoconic eye is usually not centered at the 6-o'clock semi-meridian, but on either side. Contact lens warpage is almost always centered at 6 o'clock.
2. The cone should appear round on the tangential map, whereas with contact lens warpage, it looks like a smile (arcuate in shape).
3. The keratometry values usually are >45.00 D in keratoconus and flatter with contact lens warpage.
4. Measure the corneal thickness at the apex of the cone and at the corresponding distance above (opposite) the pupil center. In keratoconus, the apex will be approximately 30 μm (or more) thinner than the corresponding distance above the pupil, whereas in normal corneas with contact lens warpage, the lower cornea is rarely greater than 20 μm thinner.
5. The topographic patterns are rarely symmetric in keratoconus and almost always symmetric for contact lens warpage.

Sample topographies are presented in Figure 3. The eye with keratoconus shows a cone that is not centered at 6 o'clock whereas the eye with contact lens warpage has an arc-shaped pattern (“smile”) centered at 6 o'clock (see Fig 3).

Complementary clinical information is provided by the refractive wavefront maps and the modulation transfer function (MTF) from the OPD-Scan II (Fig 4).

Although keratoconus and contact lens warpage both cause a reduction in the optical performance of the eye, the OPD map in diopters (rather than microns) provides much better information to the clinician than standard wavefront maps. A side-by-side comparison of the refractive wavefront map plotted in diopters (OPD map) and the traditional wavefront maps plotted in microns (wavefront higher order [HO]) shows little clinical information is garnered by evaluating the wavefront higher order maps (see Fig 4). The OPD map plots the change in refractive power across the pupil directly due to the cornea (approximately 22.00 D in this case) (see Fig 4). The refractive gradient across the pupil due to the higher order aberrations is plotted in the OPD HO map. This map shows a pattern similar to the OPD map, indicating a major portion of the refractive error is due to the corneal distortion induced by the keratoconus (see Fig 4). The internal OPD map shows hyperopic and myopic areas bisecting the pupil indicative of the corneal distortion extending into the cornea below the front corneal surface (see Fig 4). The MTF graph plots the quality of the image across a range of spatial frequencies. In this case, the MTF indicates that correcting lower order aberrations alone will not have a significant effect on increasing visual performance across the range of spatial frequencies for daily living (see Fig 4).

The range of clinical variability seen in practice means ambiguous cases will always arise. For example, a 30-year-old man presents with a suspicious topogra-

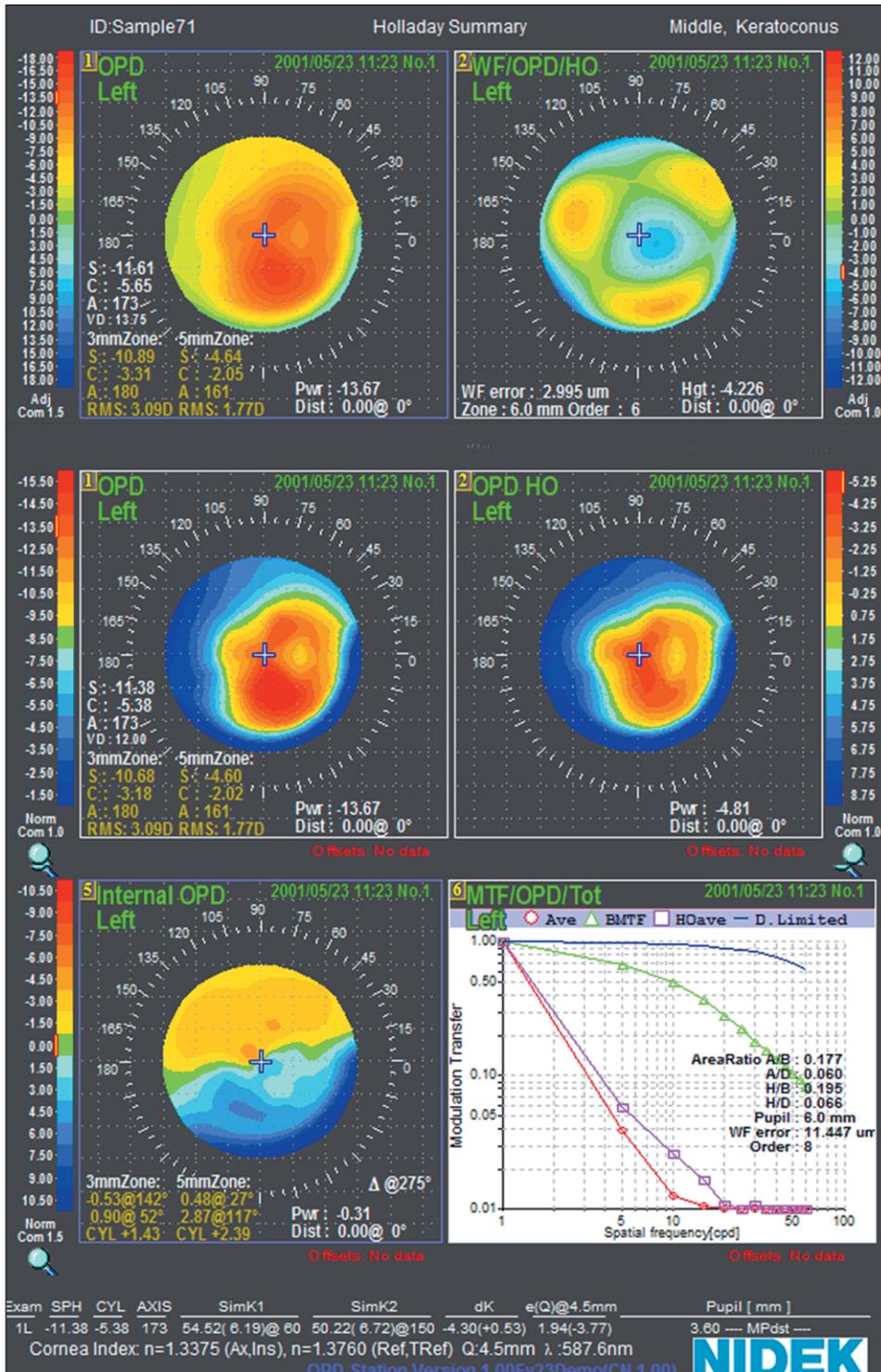


Figure 4. Wavefront measurement of an eye with keratoconus. OPD, OPD higher order (HO), and internal OPD maps are refractive wavefront maps plotted in diopters. The wavefront HO map is a wavefront map plotted in microns. MTF = modulation transfer function

phy and a “hot spot” centered at the 4-o’clock meridian. A repeat corneal topography is recommended to ensure accurate measurement followed by corneal pachymetry to determine whether a 30- μ m difference exists as outlined in the criteria above. Subsequently, it is determined whether refractive change has occurred over the

past 5 years (approximately) consistent with increasing against-the-rule astigmatism. If corneal thickness is thinner and against-the-rule astigmatism has increased, this is considered indicative of keratoconus. Follow-up at 6-month intervals is warranted in such cases to determine the progression of this disease.

Corneal topography combined with clinical evaluation is required for the definitive diagnosis or exclusion of keratoconus. Evaluation of corneal curvature maps in addition to refractive wavefront maps and the five outlined criteria help determine the severity of the disease and its effects on visual performance.

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