Slit Skiascopic-guided Ablation Using the Nidek Laser

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ABSTRACT

PURPOSE: To present the approach of using a scanning slit refractometer (the ARK 10000) in conjunction with a corneal topography system to guide customized corneal ablation. This diagnostic system is coupled with the Nidek EC-5000 system which combines scanning slit and a scanning small area ablation (1.0 mm) to perform a customized ablation.

METHODS: The ARK 10000 diagnostic system which contains a scanning slit refractometer is described. Information generated from the ARK 10000 wavefront sensor and corneal topography system can be coupled to the new Nidek EC-5000 excimer laser system, which combines the larger area of scanning slit ablation with the small area (1.0 mm) ablation.

RESULTS: The Nidek ARK 10000 diagnostic system captures wavefront information using a retinoscopic system which is converted into a refractive power map. This is different from other autorefraction systems in that it has four sensors at different diameters of the cornea and captures 1440 points in 0.4 seconds. This map is used in conjunction with corneal topography-captured simultaneously. This information is then combined to perform a customized ablation using the new Nidek EC-5000 system.

CONCLUSIONS: The ARK 10000 diagnostic system represents a different approach to customized ablation in that it combines a corneal topography system with a wavefront system and a larger treatment area of the traditional scanning slit ablation with a new small area ablation treatment for greater efficiency. [*J Refract Surg* 2000;16: S576-S580]

Customized corneal ablation can be designed using a variety of diagnostic techniques including Shack-Hartmann (Hartmann-Shack) wavefront sensing aberroscopic, the spatially resolved refractometer, and a variety of other diagnostic instruments.[1-4] Nidek Co., Ltd. (Gamagori, Japan) has developed a diagnostic instrument based on retinoscopic principles. This is a specialized autorefraction system coupled with a corneal topography system. The corneal topography system is used to confirm the centration of the skiascopic system and to correlate information on corneal shape changes before and after surgery. The resulting diagnostic information can then be used in conjunction with the new Nidek EC-5000 excimer laser which has a larger area scanning slit as well as small area ablation capabilities to perform customized ablation.

MATERIALS AND METHODS

The ARK 10000 measuring principle uses retinoscopic information obtained in the following fashion. (The principles of using this method have been described elsewhere.[5]) There is a projecting system and a receiving system. Both the projecting system and the receiving system rotate around an optical axis synchronously to measure the refraction at each one degree meridian. The target that the patient looks at is coaxial with the aperture of the ARK 10000. The center of the aperture is also the center of the photodetectors, which is the optical axis of the instrument. This is very close to the optical axis of the eye.

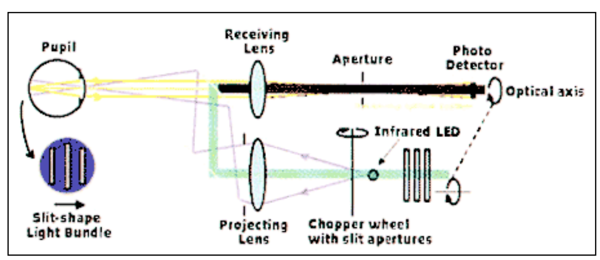

Figure 1. ARK 10000 projecting and receiving system. Infrared light is generated and passes through a chopper wheel, which creates slits of light that pass through a projecting lens and mirrors. The light slits then go into the eye and reflect off the retina through a receiving lens, an aperture, and onto photoreceptors. The projecting and receiving system rotate synchronously around an optical axis.

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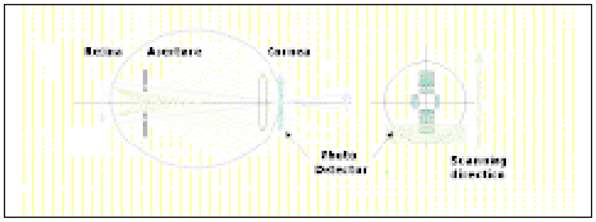

Figure 2. ARK 10000 photodectors. The LED (Fig 1) and photodetectors are conjugate with the cornea. There are four photodetector pairs (above and below the optical axis) that measure light at 2 to 5.5 mm in diameter at the corneal plane. There is also a pair of photodetectors located horizontally, which locates the center of the 4-photodetector pairs. This determines the center of the optical axis.

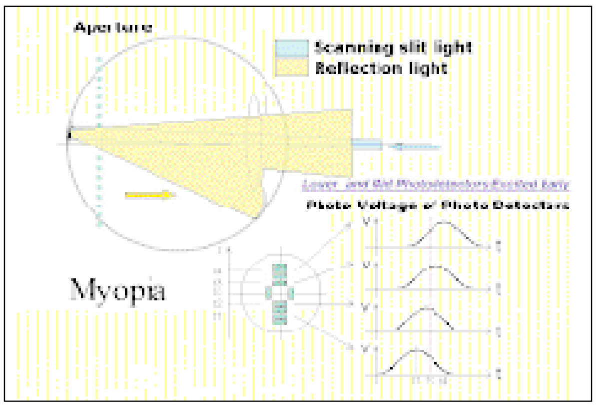

Figure 4. ARK 10000 in myopia. The lower and mid photodetectors are excited early.

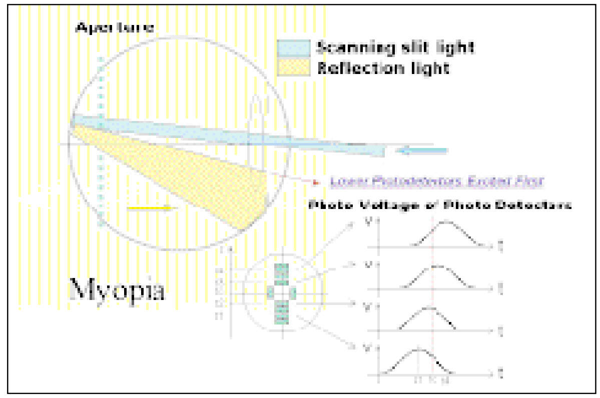

Figure 3. ARK 10000 scanning light slit in myopia. The slit light goes in (blue) and reflects off the retina (yellow) and stimulates the lower photodetectors first.

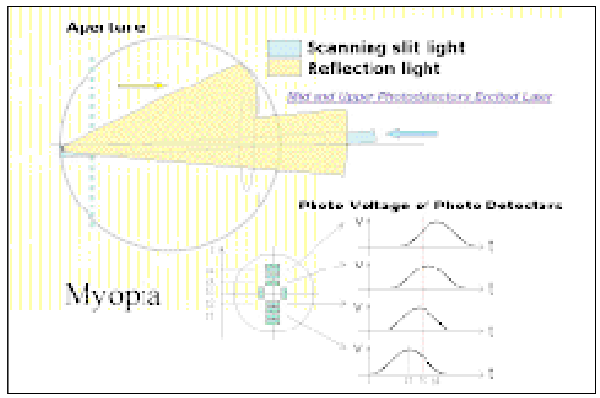

Figure 5. ARK 10000 in myopia. The mid and upper photodetectors are excited later.

The projecting system consists of an infrared LED that emits light which goes through a chopper wheel and then a projecting lens and several mirrors (Fig 1). The chopper wheel with its slit apertures is located between the light source (LED) and the projecting lens. It rotates constantly at high speed to scan the retina. The chopper wheel has slit apertures which create slit shape light bundles. The projecting system rotates 180° in 0.4 seconds across both hemimeridians so that 360 meridians are covered. The slit light rays go into the retina and are reflected back out the eye and through a receiving lens, an aperture stop, and finally a group of photodetectors that receive the light signal. The LED and photodetectors are conjugate with the cornea. The aperture stop is conjugate with the retina when the eye is emmetropic. In myopia, the aperture stop is in front of the retina; in hyperopia the aperture stop is behind the retina.

There are four photodetectors above and four photodetectors below the optical axis. There are also two photodetectors, one on each side, that detect the center of the photodetector pairs. This center point determines the optical axis of the eye with this system (Fig 2), when the optical axis of this device and the examined eye are aligned correctly. The photodetectors measure light at the corneal plane, at diameters of 2.0 mm, 3.2 mm, 4.4 mm, and 5.5 mm.

Figures 3 through 11 demonstrate the system in myopia, emmetropia, and hyperopia.

In the myopic condition the aperture stop is located in front of the retina. The incoming slit-shaped light bundle bounces off the retina and the reflecting slit moves in an opposite direction compared to the incoming slit. This causes the lower photodetector cells to be stimulated earlier than the upper photodetectors, indicating myopia (Figs 3 to 6).

In the emmetropic eye the aperture stop is located directly on the retina. Under these conditions the incoming slit-shaped light bundle goes into the retina and comes out synchronously so that all of the photodetectors are excited simultaneously (Fig 7).

In hyperopia, the aperture stop is located behind

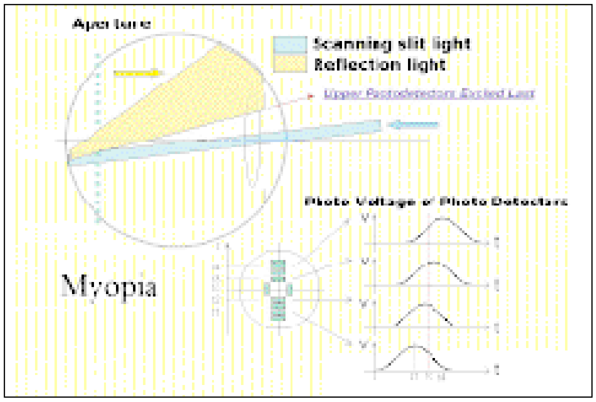

Figure 6. ARK 10000 in myopia. The upper photodetectors are excited last.

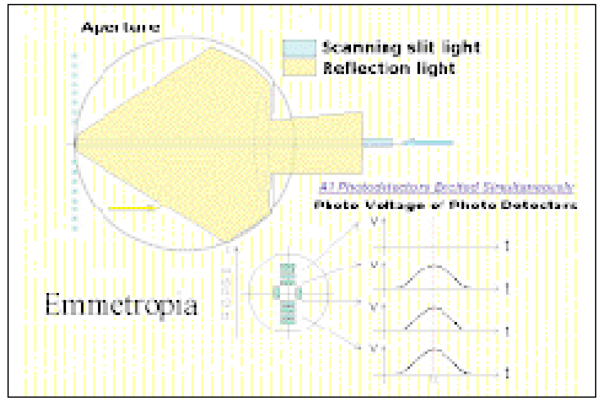

Figure 7. ARK 10000 scanning light slit in emmetropia. All photodetectors are excited simultaneously.

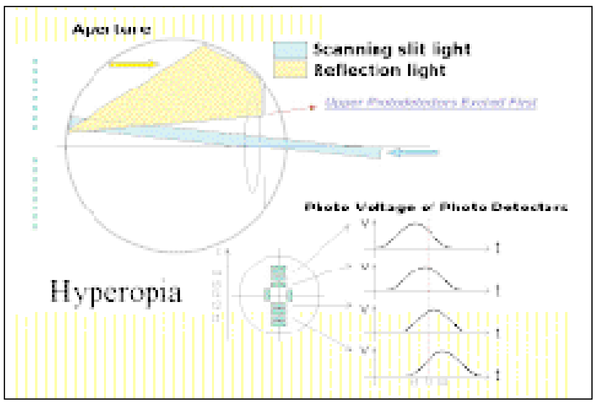

Figure 8. ARK 10000 scanning light slit in hyperopia. The slit light excites the upper photodetectors first.

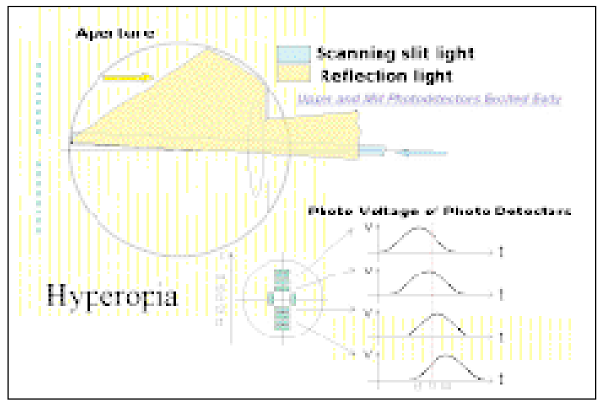

Figure 9. ARK 10000 in hyperopia. The slit light excites the upper and mid photodetectors early.

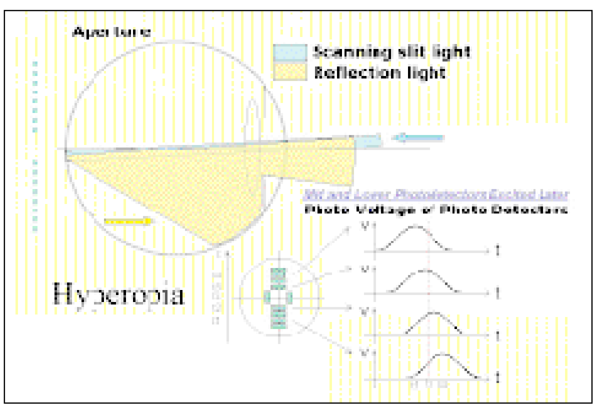

Figure 10. ARK 10000 in hyperopia. The slit light excites the mid and lower photodetectors later.

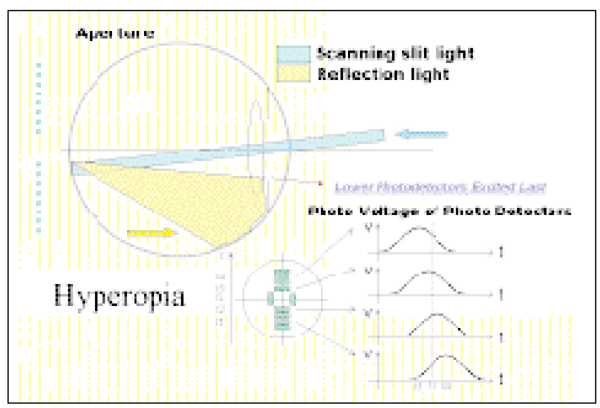

Figure 11. ARK 10000 in hyperopia. The slit light excites the lower photodetectors last.

the retina. The scanning slit light is reflected off of the retina and the reflecting slit moves in the same direction as the incoming slit light. Thus the upper photodetectors are stimulated earlier than the lower photodetectors by the returning light (Figs 8 to 11).

The time difference generated at any point on the cornea is based on the distance between the retina and the aperture. The time difference between the center and each photodetector in the four pairs of photodetectors is converted into the refractive power.

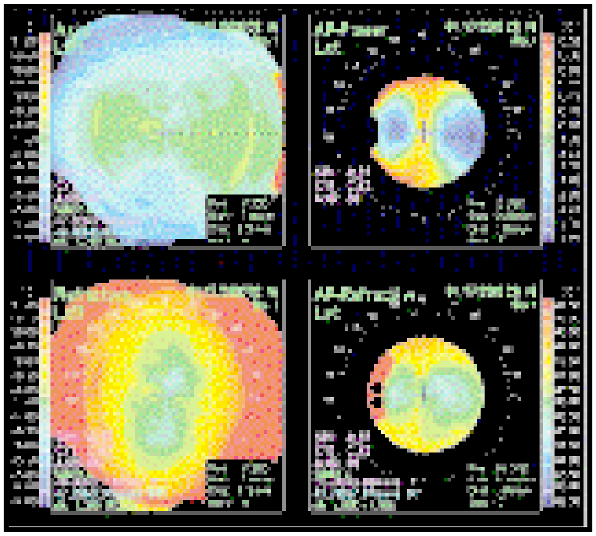

Figure 12. Corneal topography with ARK 10000 for myopic astigmatism. **Upper left)** Axial topography map. **Lower left)** Refractive power map based on the axial topography. **Upper right)** Slit light autorefraction system also generates a refractive power map. **Lower right)** Refractive power map from the topography and autorefraction are combined into a combined refractive power map.

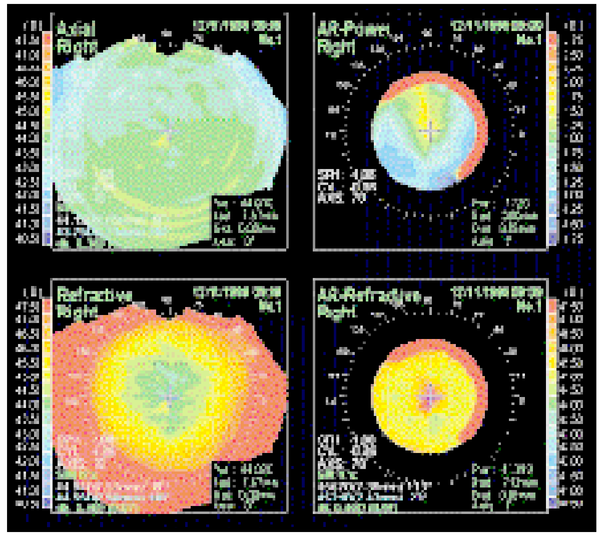

Figure 13. Same display sequence as Figure 12 in a patient who was treated with a -4.25 D spherical PRK.

The placido rings are used to measure corneal topography and integrate this data into the assessment. The placido corneal topography image is used to confirm the centration of the skiascopic system and to evaluate corneal curvature changes before and after surgery

RESULTS

Figure 12 shows output data for the ARK 10000 for a patient with mild myopia and slight cylinder. The data output includes an axial topography map (upper left). This axial topography map then can be converted to a refractive power map (lower left). In addition, the slit light bundle autorefraction system generates a refractive power map, shown in the upper right. The refractive power map from the topography and the autorefraction can be combined as well as shown in the lower right portion of Figure 12 (a normal myope with moderate astigmatism). Figure 13 shows the same series of maps on an eye after photorefractive keratectomy (PRK) that had -4.25 diopters (D) of myopia preoperatively.

DISCUSSION

Scanning Slit Diagnostic Approach—ARK 10000

Key points to the scanning slit ARK 10000 system are:

1) It measures the time difference between the center of the cornea and each of the photodetectors.

2) The time difference is proportional to the refractive power.

3) The refractive power range is wide (0 to ±20 D sphere, 0 to ±12.00 D cylinder).

4) This retinoscopic autorefractive system does not assume the eye is symmetric. (Previous autorefractors assumed the eye's symmetry.)

5) The number of diameters measured for each half of the cornea can be increased.

The addition of another photodetector at the 6.5 mm diameter is also being considered. It will also be interesting to integrate corneal topography data with autorefraction data and see how these two systems interact preoperatively and postoperatively. The corneal topography data can provide feedback on how the cornea has been reshaped after the laser treatment and can also be helpful in eyes that have a corneal or lenticular opacity which may interfere with data acquisition using the autorefractor.

Nidek EC-5000 Scanning Slit and Small Area Ablation

The system can be combined with the Nidek EC-5000 excimer laser in a unique fashion. The Nidek EC-5000 has a scanning slit delivery system that can treat over 7.5 mm of the cornea in myopia and up to 10 mm of the cornea in hyperopia. It uses 10 to 40 Hertz. The larger area ablation can be combined with a new small area (1.0 mm) ablation over a 10 mm diameter of the cornea. This combination of the scanning slit system with the segmental small

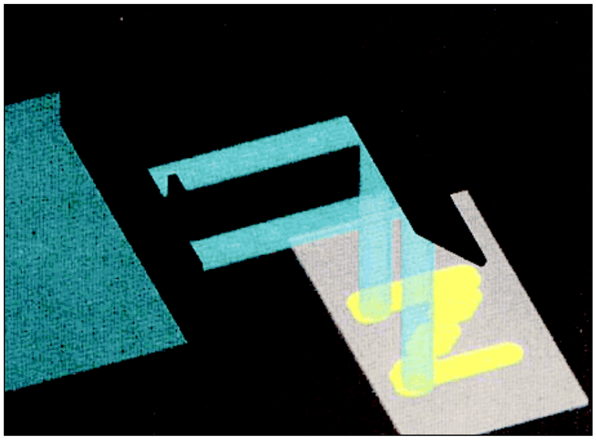

Figure 14. Nidek EC-5000 segmental small area ablation. Six apertures deliver small area ablation (1.0 mm) over a 10.0-mm diameter area. Several apertures can be opened simultaneously for greater efficiency, as shown.

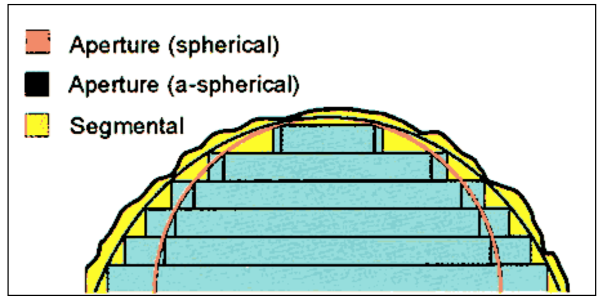

Figure 15. Nidek EC-5000 combines the variable aperture of the current scanning slit system with the segmental small area (1.0 mm) ablation. It can treat with spherical (red outline, upper left) and newer aspheric (green, upper right) ablation using the current scanning slit system. The aspheric program is used to reduce spherical aberration. The segmental small area ablation (gold area removed) removed a customized treatment area of more subtle irregularities detected by the ARK 10000.

area ablation (1.0 mm) allows for more efficient treatment and shorter treatment times.

The segmental spot ablation uses a 1.0 mm small area ablation that can be used at the end of the traditional sphere and cylinder treatment using the scanning slit treatment, which has been used to treat patients in the past. The segmental small area ablation treatment can be used to treat subtle irregularities for a customized ablation based on the ARK 10000 diagnostic system.

Figure 14 shows the segmental small area ablation. There are six apertures that can deliver more than one small area ablation treatment at a time for greater efficiency. Figure 15 demonstrates the combination of the scanning slit in the segmental ablation program. Shown in this figure is the regular spherical treatment, aspheric treatment, and segmental small area ablation program. The segmental small area ablation (1.0 mm) can treat subtle aberrations detected by the ARK 10000.

The Nidek customized ablation system utilizes retinoscopic principles in the ARK 10000 system to give wavefront data. This information is combined with corneal topography for preoperative and postoperative evaluation. The new Nidek EC-5000 laser delivery system combines the traditional scanning slit with a newer segmental small area (1.0 mm) of ablation to maximize laser efficiency. Such combination strategies may be more common in the future.

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