Optimized Prolate Ablations With the NIDEK CXII Excimer Laser

Jack T. Holladay, MD, MSEE, FACS; Harkaran S. Bains

ABSTRACT

PURPOSE: To describe a novel excimer laser ablation algorithm, termed optimized prolate ablation (OPA), that uses both topography and ocular aberrometry and maintains or improves the natural corneal shape postoperatively.

METHODS: A descriptive article outlining the theory behind this OPA algorithm.

RESULTS: The theoretical changes to the ablation algorithm described in this article will produce a prolate cornea postoperatively.

CONCLUSIONS: OPA treated eyes will have equal or better visual quality than preoperatively because age-related changes from lenticular spherical aberration are measured and treated. [*J Refract Surg*. 2005;21(Suppl): S595-S597.

Excimer laser surgery, whether photorefractive keratectomy or LASIK, tends to induce aberrations that reduce scotopic vision, the most significant of which is spherical aberration. This reduction in vision has been attributed to the induction of oblate (or less prolate) shape of the cornea postoperatively. An oblate cornea is flat centrally and steep peripherally (Fig 1). The naturally occurring cornea is prolate with an asphericity quotient (Q) of approximately −0.25,[1,2] which results in approximately +25 µm of spherical aberration for a 6-mm pupil (Fig 2). In the virgin eye, coupling of the positive spherical aberration in the cornea and negative spherical aberration in the crystalline lens results in little or no ocular spherical aberration for the youthful eye. The absence of ocular spherical aberration leads to excellent visual quality as measured by contrast sensitivity, visual acuity, and modulation transfer function as determined by aberrometry. However, as one ages, the crystalline lens changes from −25 µm of spherical aberration, to 0 µm at age 40, and +25 µm of spherical aberration by age 60. The cornea spherical aberration remains constant throughout life, therefore the decrease in quality of vision as we age is due to the spherical aberration changes in the crystalline lens in individuals without corneal disease.

EXCIMER LASER: CALIBRATION AND TREATMENT

Excimer lasers are calibrated on a flat surface. The ablation energy is normal (perpendicular) to the calibrating surface. However, the cornea is dome-shaped, resulting in a loss of energy as the laser ablation is delivered obliquely to the paracentral and peripheral cornea. Excimer lasers that do not compensate for this loss of effective energy in the periphery cause a decrease in the effective optical zone as the amount

From Holladay Consulting Inc, Bellaire, Tex (Holladay); and NIDEK, Gamagori, Japan (Bains).

The authors are consultants for NIDEK, Gamagori, Japan.

Presented at the 10th NIDEK International Refractive Surgery Symposium; April 6, 2005; Dubai, UAE; and the NIDEK Asia-Pacific Refractive Surgery Symposium; June 2, 2005; Beijing, China.

Correspondence: Jack T. Holladay, MD, MSEE, FACS, Holladay Consulting Inc, PO Box 717, Bellaire, TX 77402-0717. Fax: 713.669.9153; E-mail: holladay@docholladay.com

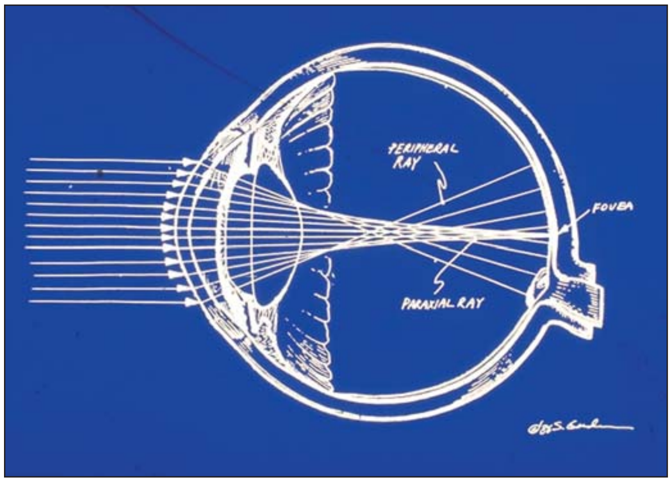

Figure 1. Schematic depicting light rays entering through an oblate cornea resulting in severe spherical aberration (peripheral rays bending too strongly) causing halos at night.

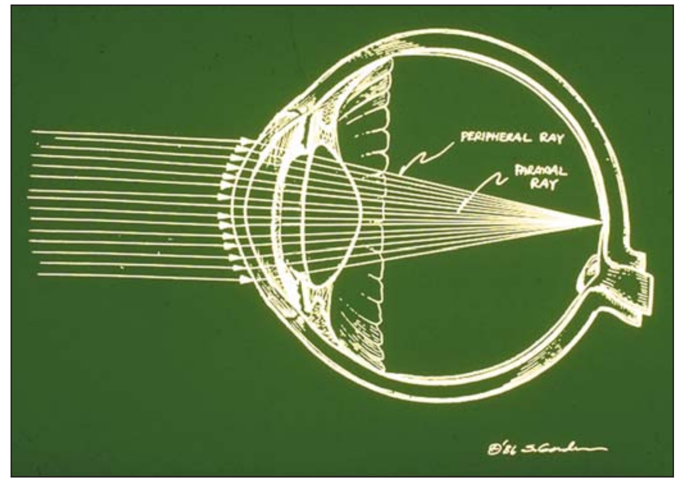

Figure 2. Schematic depicting light rays entering through a prolate cornea with no ocular spherical aberration.

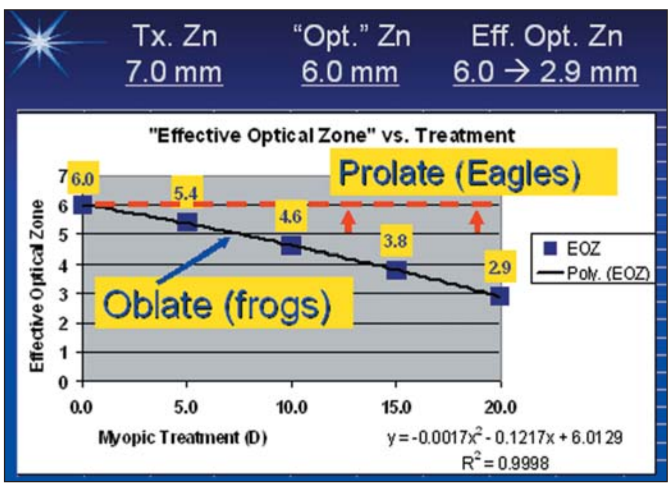

Figure 3. Effective optical zone as a function of myopic treatment for excimer lasers without any energy compensation to increase the effective energy as the laser moves from the center.

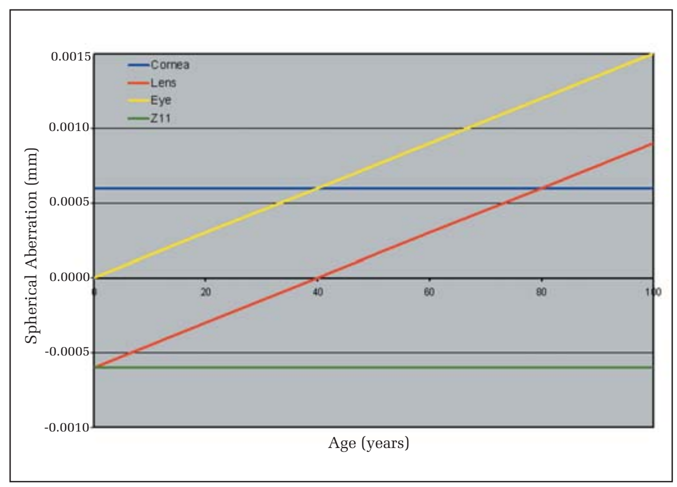

Figure 4. Change in corneal, lenticular, and whole eye spherical aberration with age. The cornea and lens spherical aberration are equal and opposite at birth and the eye changes with the changes in the crystalline in the absence of corneal pathology.

of refractive treatment increases, resulting in more induced spherical aberration (Fig 3). Postoperatively with these lasers, the effective optical zone is not as large as the programmed optical zone and the cornea is rendered oblate (~10% smaller optical zone @ −5.0 diopters [D] of treatment and 25% smaller @ −10.0 D). To overcome this loss of effective energy in the periphery, laser manufacturers will have to deliver progressively more energy as the laser treatment moves from the center. By introducing newer ablation algorithms that compensate for this energy loss, the cornea can maintain its preoperative shape or even become slightly more prolate to account for the age-related changes in crystalline lens.

The goal of laser refractive correction should be to 1) create a prolate cornea over the scotopic pupil and 2) correct the refractive error and ocular spherical aberration for the entire eye. In most cases, this will require maintaining the preoperative Q-value or making it slightly more negative depending on the ocular aberrometry. The Q-value must be customized to the ocular aberrometry and topography of each patient.

CORNEA AND CRYSTALLINE OPTICAL COUPLING

The optical properties of the crystalline lens and therefore the eye are not static but change as we age. As previously mentioned, the cornea has constant positive spherical aberration throughout life (unless corneal pathology is present such as dry eye, dystrophies, etc). However, the spherical aberration in the crystalline lens changes from negative to positive as one ages, causing an overall increase in the positive spherical aberration of the eye (Fig 4). Consequently, the corneal laser treatment must be customized to each individual. Although younger patients generally will not require a more negative Q-value in their cornea as will older patients, significant variability exists in the population as with any biological variable, so aberrometry and topography must be performed and used to determine the correct treatment for each individual. As the magnitude of positive spherical aberration increases in the eye, the presence of glare and halos at night also increases. In fact, the use of spherical intraocular lenses induces significant spherical aberration and is the reason that aspheric intraocular lenses will dominate the market in the next few years. Likewise, the delivery of ablation profiles onto the cornea that do not compensate for the crystalline lens spherical aberrations may yield adequate visual acuity but will continue to produce symptoms of halos at night and reduced mesopic contrast sensitivity.[3,4]

TOPOGRAPHY/ABERROMETRY-GUIDED ABLATIONS

Ablations based on refractive wavefront aberrometry alone, without detailed knowledge of the patient's current corneal topography will never attain the best visual results and is the reason wavefront-guided ablations have lost much of their luster. Ocular aberrometry and topography are both essential ingredients for optimal results. Ablation algorithms may also anticipate the increase in spherical aberration expected in the crystalline lens with age; based on this, the cornea can be made slightly more prolate than currently necessary to yield improved visual quality for several years in the future, rather than a decay in visual quality that begins the day after surgery. The NIDEK Optimized Prolate Ablation (OPA) system (NIDEK, Gamagori, Japan) implements all of these ingredients with the OPD-Scan (combined ocular aberrometer and topographer) and the NIDEK Scanning Slit Excimer Laser. This treatment strategy developed by Jack Holladay, MD, and the NIDEK engineering team, uses the OPD-Scan to measure the spherical aberration of the eye and uses the corneal topography to calculate the appropriate prolate shape over the entire scotopic pupil and an optimized blend to minimize abrupt changes in curvature in the periphery.

In summary, the new NIDEK OPA system will improve the visual quality and contrast sensitivity as well as reduce complaints of dysphotopsia after laser refractive surgery for many years after the patient's treatment. Clinical trials using the OPA software are currently in progress internationally. Widespread availability of this system is scheduled for the first quarter of 2006.

REFERENCES

1. Holladay JT, Janes JA. Topographic changes in corneal asphericity and effective optical zone size following LASIK. *J Cataract Refract Surg*. 2002;28:942-947.
2. Holladay JT. Corneal topography using the Holladay Diagnostic Summary. *J Cataract Refract Surg*. 1997;23:209-221.
3. Holladay JT, Dudeja DR, Chang J. Functional vision and corneal changes after laser in situ keratomileusis determined by contrast sensitivity, glare testing, and corneal topography. *J Cataract Refract Surg*. 1999;25:663-669.
4. Hersh PS, Shah SI, Holladay JT. Corneal asphericity following excimer laser photorefractive keratectomy. Summit PRK Topography Study Group. *Ophthalmic Surg Lasers*. 1996;27:S421-S428.