CORRESPONDENCE

Overestimation of the spherical aberration after laser refractive surgery

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For wavefront sensing in the human eye, Zernike polynomials are widely used to reconstruct a continuous function over the entrance pupil, as wavefront inclination is obtained for discrete pupil positions. Although smooth wavefronts (such as those in intact and healthy eyes) can usually be reconstructed with acceptable accuracy using Zernike polynomials of up to the 4th- or 5th-order, this is not necessarily true when the wavefront exhibits abrupt inclination changes. In this case, accurate fitting imposes the use of a larger number of polynomials.

Recently, a plethora of reports have highlighted the induced aberrations after laser refractive procedures. The common finding of these reports is a postoperative increase of higher-order aberrations, particularly spherical aberration. Numerous factors such as the oblique incidence of radiation at the periphery, epithelial-stromal healing, and biomechanical response have been proposed to explain this finding.[1,2]

It is generally accepted that the impact of all these factors is more pronounced at the border of the optical zone, thus effectively decreasing the diameter of the central (relatively) uniform part of the cornea, suitable for clear image formation. This shortfall of the functional optical zone in respect to the programmed ablation zone has been identified as a source of night-vision problems when the pupil diameter is wider than the central uniform part of the cornea.[3]

Another implication of this peripheral undercorrected annulus in the pupil, frequently neglected by investigators, is the possible overestimation of the postoperative spherical aberration. In a case in which the wavefront is sampled in a pupil diameter wide enough to include part of the peripheral undercorrected zone (eg, if the measurement is made to the diameter of the programmed optical zone), Zernike polynomial expansion will result in high values of the Z_4^0 coefficient that may be misleading if they are interpreted as spherical aberration.

In the following paradigm (Figure 1), the wavefront aberration is calculated directly from the corneal geometry after laser ablation for the correction of myopia. The postoperative corneal profile is modeled as a combination of 2 coaxial prolate ellipsoids (central, treated; peripheral, untreated) having equal conic constants (−0.26) but different base curvatures resulting in a 6.0 difference in dioptric power, the central being less refractive than the peripheral. An annulus of 0.5 mm between the ellipsoids is modeled using a 3rd-order spline polynomial to simulate the transition zone. Wavefront aberration is calculated as the optical path difference in a fan of rays initially parallel to the axis of the ellipsoids propagated through the paraxial focus of the inner ellipsoid, when an index of refraction of 1.337 is assumed to be bound by the surface described above.

The resulting wavefront aberration is characterized by a relatively flat central part and an abrupt retardation at the periphery due to the transition zone. A set of Zernike polynomials up to the 8th order was used to reconstruct this wavefront. Figure 1 shows the increasing accuracy of the fit as higher-order terms are added to the reconstructed wavefront.

It is noteworthy that the coefficient of Z_4^0 has the same value in all cases. However, when higher-order terms are used, the effect of Z_4^0 within the optical zone is balanced by the Z_6^0 and Z_8^0 terms as they add up to reconstruct the flat part of the wavefront. When only up to the 4th-order terms are used, the reconstructed wavefront exhibits marked spherical-like aberration in the central zone and underestimated steepness of the transition zone. This

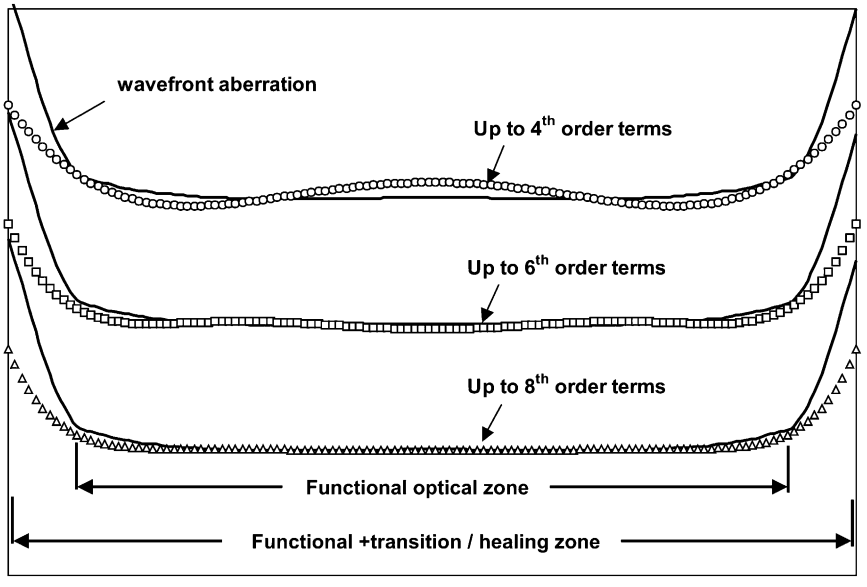

Figure 1. Wavefront is evaluated for a 6.0 mm optical zone. The functional optical zone is 5.5 mm, for which the corneal shape is assumed to be an ideal aspheric surface. A transition zone annulus between 5.5 mm and 6.0 mm is analyzed along with the (ideal) central part. The edge of the transition zone corresponds to the untreated cornea, 6.0 diopters more myopic than the central cornea. Note the resulting distorted central part of the reconstructed wavefront when polynomials up to only the 4th order are used.

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smoothing effect is inherent to the low order of the polynomials and is not dependent on the calculation method.

In clinical practice, the transition zone is known to cause visual disturbances at low-illumination conditions, especially when localized light sources are present. The severity of these symptoms is dependent on the actual pupil diameter and its relation to the functional optical zone of the cornea and on the amount of dioptric difference between the central (treated) and peripheral (untreated) cornea. However, these visual effects result from aberrations originating from the actual corneal geometry, which cannot be adequately approximated by low-order (eg, up to the 4th order) Zernike polynomials. We strongly believe that in postoperative eyes, especially after correction of high refractive errors, the optical system should be divided into 2 parts: the central part, including the uniform part of the cornea, that can be measured using commercial instruments and approximated with Zernike polynomials and the peripheral part, involving the transition zone and the untreated cornea, which is not suitable for sharp image formation. Conventional optical analysis of postoperative eyes should be restricted to pupil diameters including the central part only.

It is therefore suggested that the transition zone should not interfere with the sampled pupil if a limited set of Zernike polynomials are used to approximate the wavefront. Furthermore, the statistical evaluation of isolated Zernike coefficients (eg, C_4^0) may lead to erroneous conclusions because they exhibit high intrasubject variability[4] and because their true impact may be balanced by other higher-order coefficients, possibly neglected at wavefront reconstruction.

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Vigamox: How good is its self-preservation?

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Vigamox (moxifloxacin 0.5%) is the first commercially available ophthalmic antibiotic solution free of benzalkonium chloride (BAK). Although Vigamox has been approved by the U.S. Food and Drug Administration as a preservative-free ophthalmic antibiotic solution, there is concern among some physicians as to whether the solution can be contaminated by patient use.

Advantages of having preservatives such as BAK include increased corneal penetration and stabilization of the active drug.[1] Benzalkonium chloride has also been shown to be active against some bacteria (gram positive more than gram negative), viruses, fungi, yeast, and protozoa, serving as additional protection from contamination. One study has shown possible synergistic antimicrobial effects in combinations with BAK (Eser I, et al. IOVS 2004; 45 ARVO E-abstract 4921). The main drawback of having a preservative is the potential theoretical damaging effect to the ocular surface. This could be especially irritating to patients with ocular surface diseases such as sicca syndrome, inflammatory disorders, medicamentosa or those with preexisting corneal problems.

A previous study looking at the self-preserving capability of Vigamox found only 1 positive culture of coagulase-negative *Staphylococcus* from the thread of a Vigamox bottle.[2] This study included patients having different anterior segment procedures such as cataract and refractive surgery using Vigamox for different time periods ranging from 1 to 23 days. The objective of our study was to test the efficacy of the self-preservative capability of Vigamox after the bottle had been manipulated by a patient after cataract surgery for prophylaxis for 7 days in a typical 4 times per day dosing.

Vigamox bottles from 40 consecutive patients who had cataract surgery from November 2003 to January 2004 were collected 1 week after surgery (after patient use with 4 times daily dosing). For sterility control, 5 sealed bottles of Vigamox from the same batch were cultured without patient use. No other topical ophthalmic antibiotics solutions were used for comparison in this study.

Cultures were obtained for each bottle by using a split-plate technique testing the first 2 drops, discarding the next 10 drops, and culturing the following 2 drops. These plates were incubated at 37°C for 72 hours.

Of the 40 distributed bottles, 38 were returned by patients. Four bottles did not have enough solution to undergo full testing. No growth was detected on any of the culture plates. This showed a 0% bacterial recovery rate with a 95% exact confidence interval for the true proportion of 0% to 10.3%.

Our study focused on the self-preserving capability of Vigamox after a typical 7-day course of 4 times daily use for prophylaxis after routine cataract surgery. We failed to detect any bacterial growth. Our study showed promise in the effectiveness of the self-preserving property of Vigamox as an antibiotic despite handling of the bottle by patients for up to 7 days after routine cataract surgery. One potential downside to our study is the small number of bottles tested. It would take a much larger sample size to more definitely suggest Vigamox cannot be contaminated because contamination of an ophthalmic antibiotic solution is a rare phenomenon. Another limitation of our study is that other non-BAK preserved topical antibiotics such as some aminoglycosides were not tested. Inclusion of such medications would allow a more objective and controlled testing environment. More studies are needed to draw a more definitive conclusion. However, from our small study, the results suggest that contamination of Vigamox, a nonpreserved topical ophthalmic antibiotic, is unlikely even after manipulation of the bottle by the patient after a 7-day course of 4 times daily use for prophylaxis after cataract surgery.

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