Conventional versus wavefront guided vision correction by LASER

Essay
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Dedication

Introduction

The classical optical errors of the human eye - myopia, hyperopia, and astigmatism - are known to reduce the visual performance of the patient eye and can be corrected by means of glasses, contact lenses, or corneal laser surgery. ***(Mrochen, 2004)***[1]

Laser in situ keratomileusis (LASIK) is currently the refractive surgery of choice for most patients with low to moderate refractive errors. LASIK has gained this acceptance because of minimal discomfort and rapid visual recovery with good long-term results and stability of refractive effect**. *(leaming, 2004)***

However, modern laser systems used in corneal laser surgery possess the potential to correct the optics of an individual eye for such higher order imaging errors. ***(Mrochen, 2004)***[1]

Lower order aberrations such as defocus and astigmatism and high order aberrations (HOA) appear to contribute to significant night vision problems such as haloes, glare and decreased contrast sensitivity. Significant changes in central corneal curvature are potentially at risk for visual aberrations, especially if the degree of correction is high**. *(Tran, 2005)***[2]

Conventional versus wavefront-guided treatment whether the surgeon does LASIK or surface ablation, the "Where?" in laser refractive surgery is decided. With the advent of wavefront aberrometry and lasers capable of translating these data into ablation profiles, we now have a choice in "How?" the laser surgery will be done. Conventional ablations make use of data obtained during manifest and cycloplegic refractions. The ablation profile will contain a spherical component and an astigmatic component when applicable. Although the profiles incorporate additional nomogram adjustments and additional components for blending the transition zone between the treated and untreated stroma, they essentially treat what glasses have been treating for hundreds of years. ***(Sakimoto, 2006)***[3]

Wavefront-guided treatments allow optical properties beyond spherical and cylindrical defocus to be corrected. Wavefront aberrometers capture data that describe the optical aberrations of a patient's eye as an optical system. These measurements take into account factors beyond corneal irregularities. Aberrations from other sources, however, can be corrected at the corneal plane by the excimer laser guided by the wavefront data. Preoperative analysis of higher-order aberrations (those beyond defocus corrected by glasses) can be done preoperatively and quantified. Whether the degree of higher-order wavefront aberrations should be the determinant for a particular eye to receive wavefront- Guided ablation is still unclear. ***(Sakimoto, 2006)*** [3]

Refractive surgery itself produces higher-order aberrations, and it can be argued that even in the patient with a perfect preoperative wavefront, wavefront-guided treatment should be done to prevent the inevitable increase of aberrations caused by the procedure. Since wavefront-guided treatments correct more components, it is not surprising that for a given eye the wavefront-guided treatment will ablate deeper into the stroma. The increased depth of these ablations might hinder their use in higher myopia or patients with thin corneas (patients who might have a great deal of higher-order aberrations). ***(Sakimoto, 2006)***[3]

The effectiveness of custom treatments to correct aberrations after previous surgery is also not well established. In theory, affected patients might benefit most from a wavefront-guided enhancement. In practice, however, whether the algorithms used to translate the aberrometry data into ablation profiles have been optimised for enhancements, particularly when the aberrations are caused by previous, often complicated refractive surgery, is unclear. ***(Sakimoto, 2006)***[3]

Aim of the work

The aim of this essay is to review the literature concerning conventional versus wavefront guided LASER eye surgery , identifying advantages in customized ablation.

Contents

Aberrations

The perfect eye would image every point in the scene to a corresponding small point on the retina . In other words , no blurring would occur for any point in the scene . (Mac Rae et al , 2001)

To accomplish this perfect imaging , the eye must capture the wavefronts emanating from a given point and perfectly focus them on the retina . The wavefronts are perfectly spherical and emanate outwards or diverge from their arbitrary point till they encounter the perfect eye which converts these diverging spherical waves into converging spherical waves which is the only wavefront shape that will be focused to a perfect point . The deviation of the converging wavefronts from perfect sphere is called aberrations . (Mac Rae et al , 2001)

Two categories of aberrations commonly are used to describe vision errors, including:

Lower-order aberrations consist primarily of nearsightedness and farsightedness (defocus), as well as astigmatism. They make up about 85 percent of all aberrations in an eye.

Higher-order aberrations comprise many varieties of aberrations , such as coma, trefoil and spherical aberration, but many more of them are identified only by mathematical expressions (Zernike polynomials) . They make up about 15 percent of the total number of aberrations in an eye . Order refers to the complexity of the shape of the wavefront emerging through the pupil the more complex the shape, the higher the order of aberration . (V.Thomson)

Lower order aberrations is used in wavefront technology to describe 2nd-order Zernike polynomials. It is basically the same as conventional spherical and cylindrical refractive error, which are the types of optical aberrations which are generally fully correctible with corrective lenses. (V.Thomson)

Higher-order aberrations can produce vision errors such as difficulty seeing at night, glare, halos, blurring, starburst patterns and diplopia .

Types of higher order aberrations

- Spherical aberrations :

For spherical aberrations , the converging wavefront looks spherical near the centre of the pupil but changes its curvature towards edge of pupil . (MacRae et al , 2001)

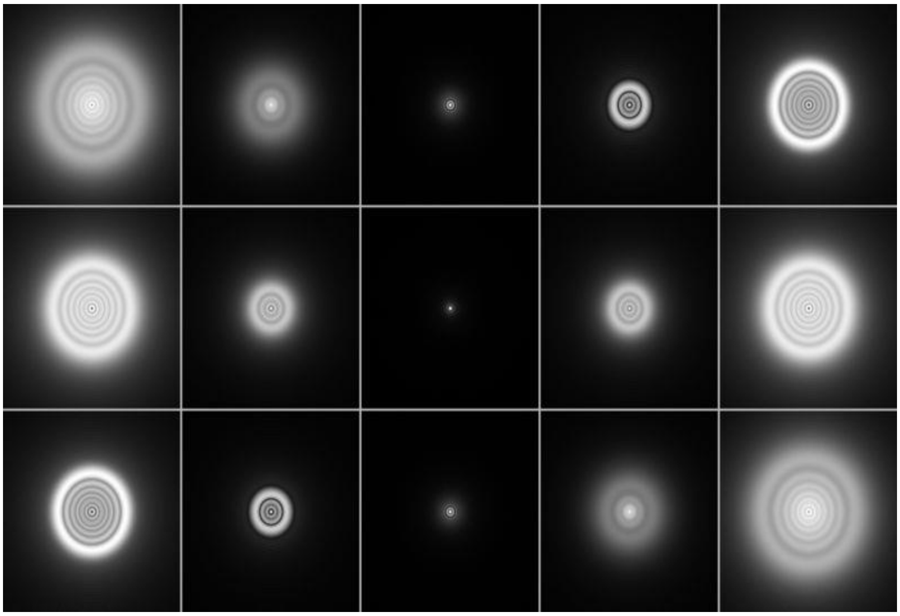

Fig 4 - spherical aberrations ;

This aberration gives a continuum of foci and results in point images with haloes.

- Coma aberrations:

The wavefront is asymmetric about perfectly spherical wavefront , producing a comet-shaped pattern on the emmetropic plane. (MacRae et al , 2001)

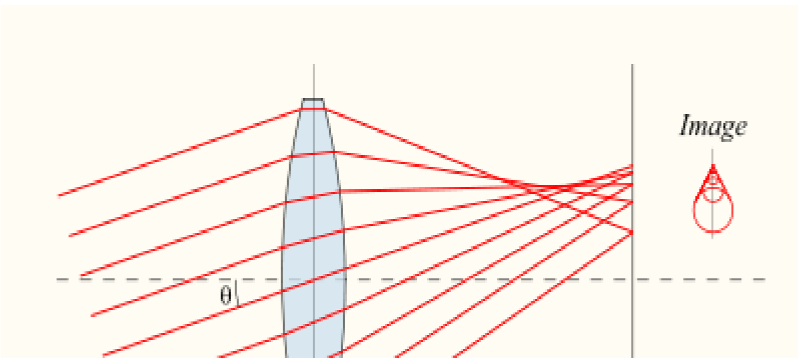

Fig 5 - coma aberration :
Asymmetric wavefront with a comet –shaped or V-shaped pattern.

Here in this case , rays at one edge of the pupil cross the finish line first ; rays at the opposite edge of the pupil cross the finish line last . the effect is that the image of each object point resembles a comet with a tail . coma is common in patients with decentered corneal grafts . (K . Miller , 2003)

- Chromatic aberrations:

The eye also suffers from chromatic aberrations or aberration that depends upon the color or wavelength of light coming into the eye . In terms of foveal vision , the dominant chromatic aberration is longitudinal or axial . this aberration is equivalent to spherical refractive error depends on the color or wavelength of light. In general , when a subject views a point of white light , blue light focuses in front of retina , green light at retina , red light focuses behind the retina. The spectral sensitivity of the eye helps to reduce the effects of chromatic aberrations by making the visual system more sensitive to the green light focused on the retina and less sensitive to blue or red light focused away from the retina. (Mac Rae et al , 2001)

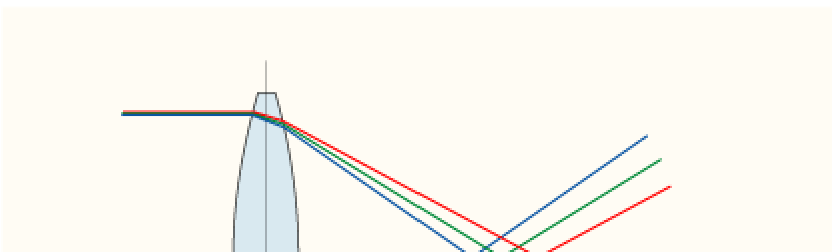

Fig 6 - chromatic aberrations :
blue light focuses in front of retina , green light at retina , red light focuses behind the retina .

The cause of chromatic aberrations is dispersion in the cornea , aqueous , crystalline lens and vitreous . Refractive surgery techniques can't correct chromatic aberrations , since this error is inherent to the properties of ocular materials and not to shape of ocular components . (MacRae et al , 2001)

- Zernike polynomials

The wavefront error map only provides qualitative information about the wavefront . the shapes of the wavefront takes on many forms and it is difficult for the clinician to evaluate the effects of the shape on vision . in order to analyze the wavefront quantitavely , it needs to be broken down into terms which are clinically meaningful. Conventional refraction breaks the wavefront down into basic terms ; sphere , cylinder , cylinder axis.

A more sophisticated analysis is required to understand the subtle aberrations . Zernike polynomials are equations which are used to fit the wavefront data in 3 dimensions . these polynomials have unique qualities , the principle one being that they decompose the shape of the wavefront into terms which describe optical aberrations such as spherical aberration , coma (Dave .2004)

Wavefront can be derivate into Zernike polynomials sphere (1st order Zernike polynomial), cylinder and axis of cylinder (2nd order Zernike polynomial), coma (3rd order Zernike polynomial), spherical aberration (4th order Zernike polynomial) and higher order aberrations can be separated (Fig 7) . (R. Martiz 2004)

The shape of a wavefront passing through a theoretically perfect eye with no aberrations is a flat plane known, for reference, as piston (see chart). The measure of difference between the actual wavefront shape and the ideal flat shape represents the amount of aberration in the wavefront. (V.Thomson)

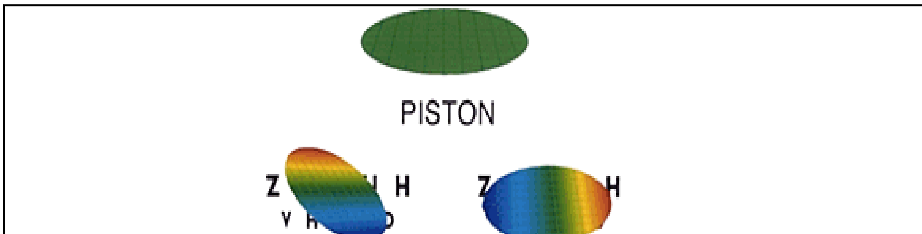

Fig 7 - common aberrations:

This chart reveals more common shapes of

Zernike terms are defined using a double index of notation as proposed by optical society of America . this nomenclature groups each term according to the radial order (n) and angular frequency (m)

, thus each term is written in the form of Z^m_n . the radial order (n) groups Zernike modes in term ñ (rho) , whereas the angular frequency (m) groups the modes in term of è (theta).the coefficient , C ; in each term varies according to the number of modes in the Zernike polynomial . C defines the level of a particular mode of aberration in microns and can have a positive or negative value . (Dave 2004)