# Post Refractive Surgery High Order Aberrations

# Causes, Prophylaxis and Treatment

**Essay**

**Submitted for Partial Fulfillment of the Master Degree in Ophthalmology**

**By**


## Mohamed Samy Mohamed Samir

MB-BCH, Faculty of Medicine - Ain Shams University


**Supervisors**


## Prof. Dr. Tarek Maamoon

Professor of Ophthalmology

Faculty of Medicine-Ain shams University

## Dr. Emad Elsawy

Lecturer of Ophthalmology

Faculty of Medicine-Ain shams University



**Faculty of Medicine**

**Ain Shams University**

**2015**

# Contents

## List of Figures

# List of Tables

# *List of Abbreviations*

| | |
|---|---|
| HOAs | high order aberrations |
| RK | radial keratotomy |
| PRK | photorefractive keratectomy |
| LASIK | laser in situ keratomileusis |
| HCVA | high contrast visual acuity |
| LCVA | low contrast visual acuity |
| GVA | glare visual acuity |
| RMS | root mean square |
| BSCVA | best spectacle corrected visual acuity |
| FC | fractional clearance |
| OZ | optical zone |
| PD | pupillary diameter |
| IR | iris registration |
| UCVA | uncorrected visual acuity |
| LOAs | lower order aberrations |
| D | Diopter |
| SE | spherical equivalent |
| UDVA | uncorrected distance visual acuity |
| IOL | intraocular lens |
| BCVA | best corrected visual acuity |
| C-CAP | custom contoured ablation profile |
| T-CAT | topography custom ablation treatment |
| HDE | humanitarian-use device exemption |
| HUD | Humanitarian-use device |
| SCI | steep central island |

# *CHAPTER ONE*

# Introduction

## Causes and Sources of Vision Blurring In The Human Eye:

The human eye can be described as a compound lens system consisting of 3 main components: the cornea, the pupil, and the crystalline lens. The cornea (or better, the first corneal surface; that is, the cornea including the tear film) is the first optics of the eye and the dominating structure in the optical power of the eye (mean approximately 70%). Accordingly, it is the main contributor to aberrations in the eye. The anterior cornea has a prolate profile; that is, the central region is steeper than the periphery. This shape helps reduce the amount of spherical aberration in the whole eye. However, corneal shapes vary significantly between individuals and give rise to astigmatism and higher order asymmetrical aberrations.

The second component, the pupil, regulates the aperture of the eye's image system, influencing the amount of light that reaches the retina. As in any optical system, the size of the pupil has important consequences for image formation. A smaller pupil increases the depth of focus and minimizes the effects of higher-order aberrations (HOAs) by reducing the size of the blur circle onto the retina, although down to approximately 2.3 mm diameter, then diffraction begins to increase the blur circle and the effect of diffraction ***(Holladay et al,1991).***To the contrary, the magnitude of aberrations increases with pupil dilation ***(Thibos et al, 2002),***leading to a decrease in visual performance and optical quality of the retinal image.

The human eye is affected by aberrations that degrade the retinal image and ultimately limit spatial vision ***(Artal et al, 2001).*** The lower order aberrations, defocus and astigmatism, are corrected routinely with spectacles, contact lenses, intraocular lenses, and refractive surgery. The higher order aberrations, beyond defocus and astigmatism, have been known to exist in the eye for more than 150 years ***(Helmholtz and von, 1881)***.

The neural visual system is adapted to the eye's particular aberrations, so that edges appear sharp despite the modest blur in the normal retinal image. Moreover, the neural visual system adapts to prismatic distortions, contrast or blur ***(Webster et al, 2002).*** Adaptation to blurred images can also improve letter acuity ***(Williams et al, 1998)***.

In normal population the dominant aberrations are the ordinary second-order spherocylindrical focus errors. Higher order aberrations are a relatively small component, comprising about 10% of the eye's total aberrations ***(Lawless and Hodge,2005).***

HOAs increase with age and mirror symmetry exists between the right and the left eyes ***(Charman,2005).***

Several studies have reported a compensation of the aberration of the cornea by the aberration of the crystalline lens. The spherical aberration of the cornea is usually positive whereas the young crystalline lens exhibits a negative spherical aberration. Besides, there is strong evidence of compensation for aberrations between the cornea and intraocular optics in cases of astigmatism (horizontal/vertical) and horizontal coma. The balance of corneal and internal aberrations is a typical example of creating two coupling optical systems ***(Marco and Giuseppe,2010).***

Corneal refractive surgery, such as radial keratotomy (RK), photorefractive keratectomy (PRK), and laser in situ keratomileusis (LASIK), is designed to modify the curvature of the central cornea, reducing it for the correction of myopia. In general, these surgeries produce a non-physiologic, oblate-shaped cornea with a flat central area and increasing power toward the periphery. This might influence the optical quality of the cornea, as well as the quality of the retinal image ***(Applegate et al, 1996).*** Previous studies have indicated that higher order aberrations of the cornea increase after radial keratotomy and PRK ***(Schwiegerling and Snyder, 2000).*** Studies using aberroscopy demonstrated that PRK also increases ocular aberrations of higher order ***(Seiler et al, 2000).***

Most reports of results after PRK and LASIK include measurements of only one quality of vision; high-contrast visual acuity (HCVA), both uncorrected and best spectacle corrected. In fact, the efficacy and safety of the procedureare determined by this parameter. But other qualities of vision, such as low contrast visual acuity (LCVA), glare visual acuity (GVA), and scotopic visual acuity are equally important and are rarely reported after refractive surgery ***(Ghaith et al, 1998).***

Till now, when we discuss refractive errors we discuss only spherical and cylindrical correction. But in today's world we have to think of a third parameter that is the aberrations present in the eye which can be anywhere in the optical media. ***(agrawal et al,2010)***

With rapid strides made in wave-front sensing technology and customized ablation, a paradigm shift has occurred in our perception of ‘vision’. We now realize that vision is not merely the ability to read the high contrast Snellen’s chart,but a composite dynamic specialized function, which varies according to the surroundings, lighting and contrast ***(Radhakrish, 2011).***

Based on the recent development of wavefront technology and functional vision tests, some researchers have recognized the relationship between increased wavefront aberration and degradation in visual quality ***(Yoon and Williams, 2002).***

Clinical studies also show that laser refractive surgery increases HOAs, mainly spherical and coma ***(Miller et al, 2002).***

Several recent studies focused on the correction of wavefront aberrations. After correcting of HOAs, the optical quality and visual quality were improved to varying levels ***(Guirao et al, 2002).***

## What Is Aberrometry?

Aberrometry is another means to measure optical aberrations or refractive errors. It measures the shape of a wavefront of light that has passed through the eye’s optics. Wavefront technology brings our understanding of the eye’s refractive characteristics to a new level.

Optical aberrations or refractive errors include myopia, hyperopia, astigmatism and higher order aberrations. The sphere and cylinder are termed lower order aberrations and can easily be corrected by glasses. Other optical aberrations, for instance coma, spherical aberration, trefoil etc., which

are not corrected by traditional spherocylinder lenses are called higher order aberrations. Correction of such opticalaberrations improves the optical transfer function and increases the contrast and spatial detail of retinal image. Wavefront guided customized refractive surgery is aimedat correcting higher order aberrations in addition to lower order aberrations ***(Radhakrishnan, 2011).***

The quality of an optical system can be specified in three different ways- point spread function, line spread function and wavefront aberration. The third way of specifying optical quality is by measuring the underlying optical aberrations rather than the secondary effect of these aberrations on the image quality. This is a more fundamental approach to the description of optical imperfections in the eye from which secondary measures can be derived ***(Thibos et al, 2002).***

## Wavefront:

If we have an eye with perfect optical system focused for distance, light from a point source on the retina will form a perfect parallel beam as it leaves the eye. A wavefront is a virtual surface perpendicular to these rays of light ***(Panagopoulou and Pallikaris, 2001).***

### ***Wavefront Error/Aberration***

Wavefront error is the error between actual wavefront and ideal wavefront typically defined within the area delimited by pupil. A variety of wavefront-sensing or aberrometry devices are available to measure it, which are employed to guide laser ablation during customized refractive surgery ***(Mrochen et al, 2000).***

### *Methods of Wavefront Analysis*

The three main technologies used for analyzing wavefronts are Hartmann-Shack aberrometry, Tscherning aberrometry and Laser Ray tracing.

In Hartmann-Shack, the most common type of aberrometer a collimated HeNe laser beam is projected on the retina. The light reflected from the retina is imaged onto a lenselet array and sampled with a charged coupled device chip. An aberrated wavefront passing through this lenselet would produce varying shifts of these spots over their subapertures. The shift gradient of thesespot positions is analyzed which gives an accurate account of wavefront error.

There are two common algorithms for wavefront analyzis: Zernicke polynomials (mathematical functions are used to describe complex shapes) and Fourier analysis (sine waves are used to reconstruct the wavefront).

The normalized *Zernicke polynomials*, which represents total wavefront error as a series of terms that describe surface shape components with respect to angular and radially arranged basis functions of different frequencies and orders has been popular as the standard method to depict wavefront error ***(Thibos et al,2002).***