Optimized Prolate Ablation (OPA) versus Conventional Ablation For the Treatment of Myopia

A Thesis submitted
By

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Abstract

Purpose

To evaluate the safety, efficacy and predictability of the Optimized Prolate Ablation (OPA) profile of the NIDEK Advanced Vision Excimer laser platform (NAVEX) for myopia treatment, report the ocular higher order aberrations and to compare the visual quality with the Conventional algorithm of the same platform.

Setting

German Egyptian Eyecare center, Private practice, Cairo, Egypt.

Design

Prospective randomized clinical trial.

Methods

Patients were randomized to have bilateral Laser in Situ keratotomileusis (LASIK) either with the OPA algorithm and or with the conventional algorithm. Visual acuity, manifest refraction, ocular Root Mean Square higher-order aberrations (RMS HOAs), corneal asphericity (Q value), spherical aberation (SA), coma and modulation transfer function (MTF) in the 2 groups were compared preoperatively and 3 months postoperatively.

Results

The study enrolled 94 myopic eyes of 47 patients: 56 eyes in the prolate ablation group and 38 eyes in the conventional group. The mean manifest refraction spherical equivalent at 3 months was 0.00 diopter (D) ± 0.18 (SD) in the prolate ablation group and -0.11D ± 0.48 (SD) in the conventional group. Predictability (±0.50 D from intended refraction) at 3 months was 93% and 89%, respectively. 55 eyes (98.2%) in the prolate ablation group and 36 (94.7%) in the conventional group had an uncorrected distance visual acuity of 20/20 or better. 3 eyes in the prolate ablation group and 4 eyes in the conventional group lost 1 line of corrected distance visual acuity. At 3 months the prolate ablation group had statistically significant lower values of Root mean square (RMS), Coma and Q value and a higher value of Strehl ratio than the conventional group. SA value was also lower in the prolate ablation group, 0.0066±0.122 versus 0.0829±0.299 in the conventional group, however the difference between the 2 groups was not statistically significant. In the prolate ablation group the SA showed no statistically significant difference from “0” which is the preset target in this group. The MTF was higher in the prolate ablation group, than in the conventional ablation group.

Conclusion

The prolate ablation algorithm gave similar predictable visual outcomes. However it induced fewer ocular HOAs, and conserved more preoperative corneal asphericity and contrast sensitivity than the conventional algorithm.

Financial Disclosure

No author has a financial or proprietary interest in any material or method mentioned.

keywords

Asphericity, Higher order aberration, Root mean square, Modulation transfer function, Munnerlyn, Zernike polynomials

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List of Abbreviations

OPA	Optimized Prolate Ablation
NAVEX	NIDEK Advanced Vision Excimer laser platform
HOA	high- order aberrations
SA	Spherical aberration
Nd:YAG	neodymium: yttrium-aluminum-garnet
OPD	Optical path difference
D	Diopter
PSF	Point spread function
RMS	Root mean square
PDIST	Pupillary distance from corneal light reflex
OPDCAT	OPD-guided custom aspherical transition zones
OATz	Optimized aspherical transition zone
CATz	customized aspherical transition zones
µm	Micron
mm	millimeter
Hz	Hertz
DS	Diopter sphere
DC	Diopter cylinder

OZ	Optical zone
TZ	Transitional zone
CCT	Central corneal thickness
UDVA	Uncorrected distance visual acuity
MRSE	Manifest refraction spherical equivalent
CDVA	Corrected distance visual acuity
BSCVA	Best spectacle corrected visual acuity

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Introduction

Corneal refractive surgery is based on the change in corneal curvature to compensate for refractive errors of the eye. After many mechanical approaches, such as radial keratotomy, keratomileusis, and astigmatic keratotomies, ablative procedures using the excimer laser have become the most successful technique. It was mainly the submicron precision and the high repeatability of the ablation of the cornea accompanied by minimal side effects that guaranteed this success. [1]

More than 20 years have passed since the first excimer laser treatment for the correction of a refractive error was performed. The procedure was done in a myopic patient. Today, although demographic data show there are more hyperopes than myopes, most treatments are myopic or myopic-astigmatic corrections. The classic laser algorithms are based on Munnerlyn's formula for calculating a laser profile and removong a convex–concave tissue lenticules with spherocylindrical surfaces.[2]

Although these algorithms proved to be effective to compensate for refractive error, the quality of vision deteriorated, especially under mesopic and low-contrast conditions secondary to induced high-order aberrations.[3,4,5,6]

Visual symptoms as generated by an increase in high-order aberrations are closely related to the type of induced aberration after refractive surgical procedures. Spherical aberration is usually reported as a peripheral halo, particularly when viewing lights at night time. Coma induces disturbances referred to as double vision with multiple fading images and a bright light is referred to as a comet. Secondary astigmatism induces ghost and double images which are particularly difficult to deal with.[7]

So while conventional treatment is a Munnerlyn based spherocylindrical ablation, Optimized Prolate Ablation (OPA) is a topography and wavefront guided ablation treating corneal high-order aberrations except spherical aberrations, entire eye spherical aberrations and entire eye low-order aberrations (sphere and cylinder).[8]

Aim Of Work

The aim of this thesis is to evaluate the safety, efficacy and predictability of the **Optimized Prolate Ablation (OPA)** profile of the NIDEK Advanced Vision Excimer laser platform (NAVEX) for myopia treatment, report the ocular higher order aberrations and to compare the visual quality with **Conventional (Spherical)** Munnerlyn based LASIK of the same platform.

Review of literature

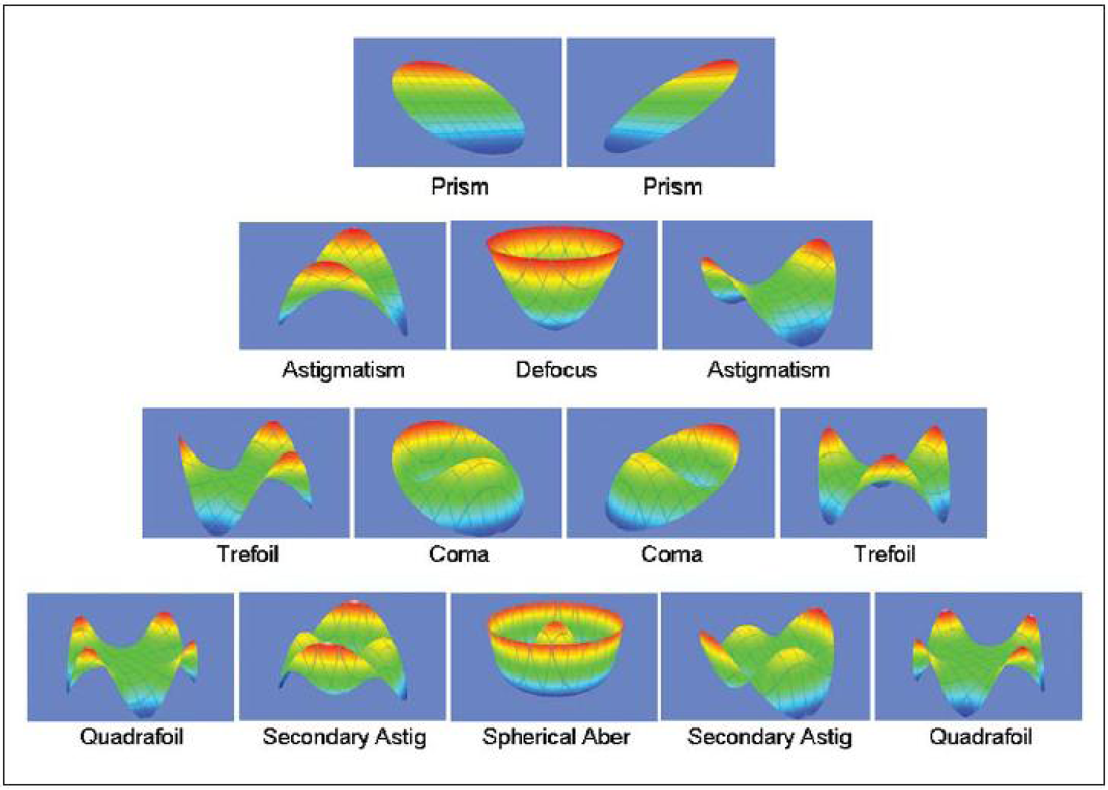
Aberrations:

The term aberration derives from the Latin word ab-erratio, which means going off-track or deviating. Aberration is defined as the difference that exists between the ideal image that we would expect to see when luminous rays are refracted in the perfect optical system (Snell's law) and what is actually achieved. These differences are characteristic of each optical system and vary from simple defocus to highly aberrated wavefronts.[9]

Aberrations can be described quantitatively using Zernike polynomials, named after Frits Zernike, a Dutch mathematician and astronomer who won the Nobel Prize for his invention of phase contrast microscopy. These mathematical models are adequate for describing the wavefront measurements of the eye, because they are defined based on a circular form. The shape of the wavefront is described in the x and y coordinates; the third dimension, height, is described in the z-axis. The final figure is obtained from the sum of the Zernike polynomials describing all types of deformation.[9]

Aberrations can be divided into two groups: chromatic and monochromatic. Chromatic aberrations are caused by the difference in distribution of incident polychromatic radiation throughout a medium and depend on the wavelength of the light that penetrates the eye. They are influenced by variations in the refractive index of a material in relation to the wavelength of the light that travels through it. This type of aberration cannot be corrected, because it depends on the composition of the ocular structures and not their shape. Monochromatic aberrations are related to a specific wavelength and include spherical refractive error (defocus), cylindrical refractive errors (astigmatism), and high-order aberrations (HOA) such as spherical aberrations and coma.[9]

Based on Zernike's polynomials, aberrations are described numerically and ranked accordingly. First to fourth-order polynomials are shown graphically in **Fig. 1**.



(Figure1) Zernike pyramid showing lower and high order aberrations [9]

Low-order aberrations:

Low-order aberrations include the following:

- ***Order-zero (no order).*** These aberrations are characterized by axial symmetry and a flat wavefront.

- ***First-order.*** These linear aberrations correspond to tilting around a horizontal (x) or vertical (y) axis. They describe the tilt or prismatic error of the eye.

- ***Second-order.*** Spherical defocus and astigmatism describe the spherical error and astigmatic component and its orientation or axis. These components are similar to measurements found with basic refraction.

High-order aberrations:

High-order aberrations are as follows:

- ***Third-order aberrations*** correspond to horizontal and vertical coma and triangular astigmatism with the base along the x- or y-axis (trefoil).

- ***Fourth-order aberrations*** include spherical aberration (SA), tetrafoil, and secondary astigmatism.

- ***Fifth-tenth order aberrations*** are important only when the pupil is greatly dilated.