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Original article

Comparison between Changes of Higher Order Abberations Following Zyoptix HD Ablation and Proscan Ablation

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Abstract

Background: The eye, like any other optical system, suffers from a number of specific optical aberrations. The optical quality of the eye is limited by optical aberrations, diffraction and scatter. Aim of the Work: To compare between the effect of different types of LASIK (proscan ablation and Zyoptix HD ablation) in correction of higher order abberations. **Patients and Methods:** This comparative prospective study was conducted on 50 eyes of 27 Egyptian patients divided into two groups, Group A: Twenty five eyes of 14 patients (11 patients both eyes and 3 patients one eye) underwent conventional LASIK (Proscan) using mechanical microkeratome. The mechanical microkeratome (Moria) was used to create the flap (superior hinge). The selected plate thickness was 110 µm. And Group B: Twenty five eyes of 13 patients (12 patients both eyes and 1 patient one eye) underwent custom LASIK (Zyoptix HD) using mechanical microkeratome. The mechanical microkeratome (Moria) was used to create the flap (superior hinge).The selected plate thickness was 110 µm. **Results:** The results found in our study indicate that conventional LASIK surgery was associated with higher values of high order aberrations after surgery than custom LASIK. Compared to the preoperative status, we found that wavefront guided LASIK (Zyoptix HD) was effective in reduction of HOA than conventional LASIK with no statistically significant difference in HOA 1 week post operative compared to 1 month and 6 months post operative in both custom or conventional LASIK. Conclusion: Zyoptix custom HD treatment is superior to Proscan conventional treatment in the correction of low and high order eye aberrations.

1. Introduction:

The eye, like any other optical system, suffers from a number of specific optical aberrations. The optical quality of the eye is limited by optical aberrations, diffraction and scatter. Correction of spherocylindrical refractive errors has been possible for nearly two centuries following Airy's development of methods to measure and correct ocular astigmatism. It has only recently become possible to measure the aberrations of the eye and with the advent of refractive surgery it might be possible to correct certain types of irregular astigmatism. [1]

Low Order Aberrations:

Includes Myopia (positive defocus), hyperopia (negative defocus), and regular astigmatism), which are correctable with glasses. Other lower-order aberrations are non-visually significant aberrations known as first order aberrations, such as prisms and zero-order aberrations (piston). Low order aberrations account for approximately 90% of the overall wave aberration in the eye. [2]

High order Aberrations:

Higher-order aberrations (HOAs) are small optical irregularities or imperfections of the eye which cannot be corrected by simple sphere and cylinder corrections. Many authors believe that HOAs are the reason many patients complain of halo, glare and decreased contrast sensitivity after successful corneal refractive surgery. In the normal eye, 90% of total aberrations are caused by the cornea. [3]

There are numerous higher-order aberrations, of which only spherical aberration, coma and trefoil are of clinical interest. Spherical aberration is the cause of night myopia and is commonly increased after myopic LASIK and surface ablation. It results in halos around point images. [4]

Coma is an aberration which causes rays from an off-axis point of light in the object plane to create a trailing "comet-like" blur directed away from the optic axis.[5]

Many techniques for measuring the eye’s aberrations have been described, the most common technique is Shack-Hartmann aberrometry. Other methods include Tscherning systems, ray tracing and Skiascopy methods.[6]

Laser-assisted in situ keratomileusis (LASIK) is becoming widely accepted as an effective method for the correction of myopia and astigmatism. However, the induction of higher-order aberrations (HOAs), which lead to deterioration in visual performance and subsequent patient dissatisfaction, cannot be ignored for the prevalence of this surgical approach. Since this surgical technique requires more laser ablation in high myopic eyes, the cornea becomes more oblate, resulting in more surgically induced HOAs especially spherical aberrations.[7]

LASIK procedure requires the surgeon to create a corneal flap. After that, an excimer laser will be used to reshape the corneal surface, in which way refractive errors can be corrected. The corneal flap is traditionally created by a mechanical microkeratome. However, Femtosecond Lasers have been developed to manage this task. This new technology has been reported to have more advantages over conventional microkeratome.[8]

2. Patients and Methods:

This comparative prospective study was conducted on 50 eyes of 27 Egyptian patients divided into two groups:

Group A:

Twenty five eyes of 14 patients (11 patients both eyes and 3 patients one eye) underwent conventional LASIK (Proscan) using mechanical microkeratome. The mechanical microkeratome (Moria) was used to create the flap (superior hinge). The selected plate thickness was 110 µm.

Group B:

Twenty five eyes of 13 patients (12 patients both eyes and 1 patient one eye) underwent custom LASIK (Zyoptix HD) using mechanical microkeratome. The mechanical microkeratome (Moria) was used to create the flap (superior hinge). The selected plate thickness was 110 µm.

Patient selection:

- **Inclusion criteria**

1- Eyes with myopia fit for LASIK or hypermetropia fit for LASIK or astigmatism fit for LASIK.
2- Eyes with central corneal thickness (CCT) of 500 microns or more.

- **Exclusion criteria**

1- Eyes at risk for developing post-refractive corneal ectasia, such as keratoconus, keratoconus suspect.
2- Previous refractive surgery.
3- Corneal dystrophy, corneal guttae or opacities.
4- Glaucoma.
5- Diabetes.

Pre-Operative Examination:

Complete ocular examination was done using the following:

- Autoreferaction
- Visual Acuity Measurement:

  - Uncorrected visual acuity (UCVA) and best corrected visual acuity (BCVA) decimal values.
  - Duochrome test.
- Slit-Lamp Examination:
  - Patients were subjected to proper slit lamp examination.
- Corneal topography using ORBASCAN and PENTACAM:
  - Patients who were spherical soft contact lens wearers must have discontinued the wear for at least 7 days prior to the preoperative evaluation.
- Wavefront analysis: using ZYWave (Hartmann-Shack Aberrometer) to measure root mean square (RMS). Wavefront aberrations were calculated relative to the pupil.

Operative steps:

- Laser calibration.
- Topical anesthesia.
- Alignment mark (gentian violet or methylene blue).
- Pneumatic suction ring (while applying the suction ring the cornea must be dry).
- Flap creation using either Microkeratome (after microkeratome assembly and trial).
- Flap reflection (while creating the flap the cornea must be wet).
- Laser ablation.
- Flap replacement.

Postoperative Treatment and Follow Up:

1- Antibiotics (moxifloxacin 0.5) used four times per day.

2- Steroids

3- Lubricants

The patients were examined immediately after surgery to detect any flap misplacement or wrinkles.

First postoperative follow up was one day, one week then one month after surgery and finally after 6 months.

Post-Operative Examinations Included:

Complete ocular examination was done including:

- Visual Acuity Measurement:
  - Uncorrected visual acuity (UCVA).
- Slit lamp examination:
  - Any possible complications eg; diffuse lamellar keratitis (DLK), microstriae.
- Autorefraction:
  - To detect any residual refractive errors.
- Wavefront analysis: using the ZY Wave (Hartmann-Shack Aberrometer) to **assess** higher order aberrations after one week of surgery, one month and six months of surgery.

Statistical Analysis:

The collected data was tabulated, coded and analyzed using SPSS program for Widnows 7, version 23, continuous variables were presented as mean values -/+ standard deviation (SD), and categorical variables were presented as percentages.

Comparisons amongst data were done using suitable statistical tests. ***P***-values < 0.05 were considered as statistically significant.

3. Results:

- **Pre operative patient data:**

1. Higher order aberrations:

HOA (6mm) was significantly higher among the eyes that underwent **Zyoptix HD** ablation as compared with eyes that underwent **Proscan** ablation, (0.58 ±0.3 vs. 0.23 ±0.1) in Zyoptix HD and Proscan ablation respectively; (p-value= 0.012).

2. Visual acuity:

VA was significantly lower among the eyes that underwent **Proscan** ablation as compared with eyes that underwent **Zyoptix HD** ablation, (0.57 ±0.3 vs. 1.10 ±0.4) logMAR in Zyoptix HD and Proscan ablation respectively; (p-value= 0.005).

3. Spherical Equivalent:

Spherical Equivalent was significantly higher among the eyes that underwent **Proscan** ablation as compared with eyes that underwent **Zyoptix HD** ablation, (-3.10 ±1.9 vs. -5.95 ±3.1) in Zyoptix HD and Proscan ablation respectively; (p-value= 0.025).

4. Pupil Size:

Pupil Size was significantly larger among the eyes that underwent Zyoptix HD ablation as compared with eyes that underwent Proscan ablation, (7.23 ±0.8 vs. 6.38 ±0.6) in Zyoptix HD and Proscan ablation respectively; (p-value= 0.012).

Table (1): Demographic data and Preoperative assessment of the studied cases

	Zyoptix HD N= 25	Proscan Ablation N= 25	Total	P-value
Age and sex				
Mean ±SD	30.72±7.34 **M/F: 1/3**	28.12±6.05 **M/F:1/4**		
Sphere				
Mean ±SD	-2.26±2.03	-3.28±5.2	-2.77 ±3.9	0.462
Cylinder				
Mean ±SD	-1.93 ±1.3	-1.34±0.9	-1.63 ±1.2	0.277
HOA (5mm)				
Mean ±SD	0.35±0.2	0.24±0.1	0.29 ±0.2	**0.030***
HOA (6mm)				
Mean ±SD	0.60±0.3	0.21±0.1	0.41 ±0.3	**0.001***
VA				
Mean ±SD	0.58±0.3	1.16±0.4	0.87 ±0.4	**0.001***
Spherical Equivalent				
Mean ±SD	-3.28±1.9	-6.20±2.9	-4.74 ±2.8	**0.001***
Pupil Size				
Mean ±SD	7.25 ±0.8	6.39 ±0.6	6.82 ±0.8	**0.001***

** P-value ≤ **0.05** is considered significant by (Mann–Whitney U test).*

- **Post operative results:**

Group A:

1. Higher order aberrations:

HOA (6mm) was (0.21 ±0.1) and (5mm) was (0.24 ±0.1) in Proscan which became post operative (5mm) was (0.39 ±0.3) and (6mm) became (0.28 ±0.1), no statistically significant difference in HOA(5mm) and (6mm) after 1 week, 1 month and 6 months post operative.

2. Visual acuity:

VA was (1.10 ±0.4) logMAR which improved to (0.13 ±0.1) with (p-value = 0.001) statistically significant.

3. Spherical Equivalent:

Spherical Equivalent was (-5.95 ±3.1) which improved to (-0.50 ±0.5) with (p-value 0.001) statistically significant.

Table (2): Follow up changes among Proscan Ablation group

	Preoperative assessment	Post-operative Follow up			p-value
		After 1 week	After 1 months	After 6 months	
Sphere	-3.28 ±5.2	-0.25 ±0.5	-0.45 ±0.5	-0.44 ±0.4	**<0.001*** 0.010[1] 0.012[2] 0.013[3] 0.801[4] 0.801[5]
Cylinder	-1.34 ±0.9	-0.54 ±0.3	-0.39 ±0.5	-0.38 ±0.3	**<0.001*** 0.019[1] 0.002[2] 0.004[3] 0.999[4] 0.348[5]
HOA (5mm)	0.24 ±0.1	0.28 ±0.1	0.28 ±0.1	0.27 ±0.1	0.625 0.266[1] 0.253[2] 0.374[3] 0.266[4] 0.956[5]

** P-value ≤ **0.05** is considered significant*

Analysis done by Friedman test, Wilcoxon signed rank test with Bonferroni adjustment method for pairwise comparisons.

[1] preoperative vs. one week postoperative, [2] preoperative vs. one months postoperative, [3] preoperative vs. six months postoperative, [4] one week postoperative vs. one months postoperative, [2] one week postoperative vs. six months postoperative

Group B:

1. Higher order aberrations:

HOA (6mm) was (0.60 ±0.3) and (5mm) was (0.25 ±0.2) in Zyoptix HD which became post operative (5mm) was (0.35 ±0.2) and (6mm) became (0.14 ±0.1), no statistically significant difference in HOA(5mm) and (6mm) after 1 week, 1 month and 6 months post operative.

2. Visual acuity:

VA was (0.58 ±0.3) logMAR which improved to (0.15 ±0.1) logMAR with (p-value = 0.001) statistically significant.

3. Spherical Equivalent:

Spherical Equivalent was (-3.10 ±1.9) which improved to (-0.30 ±0.5) with (p-value 0.001) statistically significant.

Table (3): Follow up changes among custom HD Ablation group

	Preoperative assessment	Post-operative Follow up			p-value
		After 1 week	After 1 months	After 6 months	
Sphere	-2.26 ±2.0	-0.17 ±0.6	-0.06 ±0.4	-0.02 ±0.4	**<0.001*** 0.001[1] 0.001[2] 0.001[3] 0.728[4] 0.635[5]
Cylinder	-1.93 ±1.2	-0.74 ±0.4	-0.55 ±0.4	-0.57 ±0.3	**<0.001*** 0.001[1] 0.001[2] 0.001[3] 0.368[4] 0.420[5]
HOA (5mm)	0.35 ±0.2	0.14 ±0.1	0.14 ±0.1	0.14 ±0.1	**<0.001*** 0.023[1] 0.020[2] 0.021[3] 0.929[4] 0.993[5]
HOA (6mm)	0.60 ±0.3	0.25 ±0.2	0.23 ±0.2	0.23 ±0.2	**<0.001*** 0.015[1] 0.010[2] 0.009[3] 0.759[4] 0.742[5]

** P-value ≤* ***0.05*** *is considered significant*

Analysis done by Friedman test, Wilcoxon signed rank test with Bonferroni adjustment method for pairwise comparisons.

[1] preoperative vs. one week postoperative, [2] preoperative vs. one months postoperative, [3] preoperative vs. six months postoperative, [4] one week postoperative vs. one months postoperative, [2] one week postoperative vs. six months postoperative.

Table (4): Visual acuity pre and post-operative

	Pre-operative	Post-operative	p-value
Zyoptix HD, N= 25			
Mean ±SD	0.58 ±0.3	0.15 ±0.1	0.001
Proscan Ablation, N= 25			
Mean ±SD	1.10 ±0.4	0.13 ±0.1	0.001

Table (5): Spherical equivalent pre and post-operative

	Pre-operative	Post-operative	p-value
Zyoptix HD HD, N= 25			
Mean ±SD	-3.10 ±1.9	-0.30 ±0.5	0.001
Proscan Ablation, N= 25			
Mean ±SD	-5.95 ±3.1	-0.50 ±0.5	0.001

4. Discussion:

Laser *in situ* keratomileusis (LASIK) has become an efficient an commonly performed procedure in refractive surgery. However, a decrement of visual performance after the surgery has been reported, such as glare and halo under dim conditions, poor night vision and decrease of contrast sensitivity (CS) values.[9]

Therefore wavefront-guided LASIK was introduced to provide a solution of low vision quality related to laser ablations. The purpose of this study was to compare the visual acuity, higher- order aberration of wavefront-guided LASIK with iris-registration and conventional LASIK. [10]

This comparative study was conducted on 50 eyes of 27 Egyptian patients divided into two groups:

- **Group A:** Twenty five eyes of 14 patients (11 patients both eyes and 3 patients one eye) underwent conventional LASIK (**Proscan**). The mean preoperative refractive error was (-5.95 ±3.1) with average visual acuity (1.10 ±0.4) logMAR and HOA(6mm) (0.23 ±0.1). Average postoperative refractive error (-0.50 ±0.5), uncorrected visual acuity was (0.13 ±0.1) logMAR and HOA (6mm) was (0.28 ±0.1).

- **Group B:** Twenty five eyes of 13 patients (12 patients both eyes and 1 patient one eye) underwent custom LASIK **(Zyoptix HD**). The mean preoperative refractive error was (-3.10 ±1.9) with average visual acuity (0.58 ±0.3) logMAR and HOA(6mm) (0.60 ±0.3). Average postoperative refractive error (-0.30 ±0.5), uncorrected visual acuity was (0.15 ±0.1) logMAR and HOA (6mm) was improved to (0.14 ±0.1).

The results found in our study indicate that conventional LASIK surgery was associated with higher values of high order aberrations after surgery than custom LASIK. Compared to the preoperative status, we found that wavefront guided LASIK (**Zyoptix HD**) was effective in reduction of HOA than conventional LASIK with no statistically significant difference in HOA 1 week post operative compared to 1 month and 6 months post operative in both custom or conventional LASIK.

Although the conventional LASIK and custom LASIK were effective in improving pre operative uncorrected visual acuity and refractive errors.

In a study by ***Zhang et al.*** [11] the wavefront-guided customized ablation not only got a decrease in higher-order aberrations diagnosed before surgery, but also induced aberrations during surgery. The increase values of spherical and coma aberrations in wavefront guided LASIK group were statistically lower compared to conventional LASIK group, which indicated that wavefornt - guided optimized ablation was efficient in reducing higher order aberrations especially spherical and coma aberrations. The decrease in coma in wavefront guided LASIK group might be due to the eye-tracking and iris-registration systems which precisely minimized sub-clinical decentration and cyclotorsional eye motion.

Improved eye tracker with iris-registration which precisely establish the spatial relationship between the optics of the eye and the natural features of the iris can recognize and compensate for ocular torsional movements when patients changed from sitting position to clinostatism and for pupil center shift from scotopic condition to photopic condition, so that it could improve individual ablation adjustments for HOAs correction and improve visual performance after surgery.

In their study the predictability of wavefront guided LASIK was good. 95.7% eyes (90 of 94 eyes) in wavefront guided LASIK group achieved UCVA≥20/20, while 92.3% (108 of 117 eyes) in conventional group. The residual refractive errors were significantly lower in wavefront guided LASIK group ((-0.18±0.42)D) than in conventional group ((-0.40±0.68)D), and 91.4% eyes (86 of 94 eyes) were within ±0.5D SE in wavefront guided

LASIK group and 88.0% eyes (103 of 117 eyes) in conventional group. [11]

In a study by ***Oshika*** *(12)* to compare the correction of eye aberrations in custom and conventional LASIK treatments, a prospective randomized study of 74 eyes of 37 patients undergoing LASIK retreatment for correction of myopia and astigmatism was performed.

Each patient underwent retreatment of custom **Zyoptix** LASIK (Bausch & Lomb) in one eye and conventional **Planoscan** (Bausch & Lomb) in the contralateral eye. Correction of eye aberrations in custom and conventional treatment was compared.

In the **Zyoptix** group, there was a statistically significant decrease in defocus, astigmatism, coma, spherical aberration, second order (low order), third order, high order and total aberrations. Fifth-order aberrations showed a statistically significant increase and the other aberrations showed no significant difference between the preoperative and six-month postoperative periods.

In the **Planoscan** group, there was a statistically significant decrease in defocus, second order (low order) and total aberrations. There was a significant increase in secondary and fifth order aberrations, with no significant difference for the other aberrations.

When comparing the aberration values between the two groups, they observed that the **Zyoptix** group presented statistically lower averages for the defocus, trefoil, coma, second, third, high order and total aberrations in the studied period.

This suggests that custom LASIK treatment was superior to conventional retreatment in correcting these aberrations. [12]

5. Conclusion and Recommendations:

The use of wavefront analysis in ophthalmology has provided a great diagnostic and therapeutic advance in the field of refractive surgery. With this technology, it became possible to measure the low and high order aberrations of the optical system. From a practical point of view, low or second order aberrations - defocus and astigmatism, which are equivalent to the spherical-cylindrical components of clinical refraction - can be corrected clinically (through the use of glasses or contact lenses) or surgically (with conventional or custom ablation). High-order aberrations, however, can be corrected or surgically minimized with personalized ablation. [13]

Conventional refractive surgery based on the Munnerlyn formula is now known to tend to induce high-order eye aberrations while correcting low-order eye aberrations. The increase in these high-order aberrations correlates with visual quality complaints after conventional refractive surgery (glare symptoms and nocturnal halos). [14]

Personalized refractive surgery based on wavefront analysis aims to correct or minimize high order eye aberrations while correcting low order aberrations. Thus, by providing a more homogeneous postoperative ocular surface, it offers a better postoperative visual quality. [15]

So, **Zyoptix** custom HD treatment is superior to **Proscan** conventional treatment in the correction of low and high order eye aberrations.

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