

Evaluation Study of Different Methods of Refraction in Hyperopic Lasik

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ABSTRACT

Background: hyperopia, also known as far-sightedness, is a common type of refractive error in which light is focused behind, instead of on, the retina. This causes close objects to be blurry, while far objects may appear normal.

Aim: this was evaluation study between different methods of preoperative refraction detection in hyperopic lasik including cycloplegic, manifest and wave front refraction for all patients and according to best-corrected visual acuity we do refractive surgery and analyze postoperative refraction outcome. **Patients and Methods:** the current study was carried out on thirty-four eyes of eighteen patients. All patients had primary hyperopia with or without hyperopic astigmatism. All patients were informed about the limitations and risks of the procedure. All patients signed an informed consent. **Results:** In hyperopic spherical group, the mean preoperative spherical equivalent regarding wave-front refraction was $+3.36 \pm 1.26$ (range $+1.70$ to $+5.39$ D). 6 months post operatively, it became $+0.35 \pm 0.36$ (range $+0.12$ to $+0.90$ D). In hyperopic astigmatic group, the mean preoperative spherical equivalent regarding wave-front refraction was $+3.13 \pm 2.08$ (range $+1.0$ to $+5.63$ D). 6 months post operatively, it became $+0.74 \pm 0.43$ (range $+0.12$ to $+1.63$ D) and for Cycloplegic auto-refraction, it became $+0.92 \pm 0.46$ (range $+0.25$ to $+1.74$ D).

Conclusion: laser in situ keratomileusis for hyperopia, hyperopic astigmatism is a safe, effective and predictable technique. However, modification in the nomogram is needed in order to achieve good results.

Keywords: Wavefront, hyperopia and manifest refraction.

INTRODUCTION

Hyperopia, also known as far-sightedness, is a common type of refractive error in which light is focused behind, instead of on, the retina. This causes close objects to be blurry, while far objects may appear normal. As the disease worsens, objects at all distances may be blurred ⁽¹⁾. Other symptoms may include headaches and eyestrain. People with hyperopia can also experience accommodative dysfunction, binocular dysfunction, amblyopia, and strabismus ⁽²⁾. Depending on whether the magnitude of physiological hyperopia is moderate or severe, it can lead to additional visual impairments such as strabismus, amblyopia or other ocular complications that constitute a significant health problem ⁽³⁾. The prevalence of hyperopia decreases as age increases, with a summary prevalence measure of 5% at age 7, 2-3% between age 9 and 14 and around 1% at age 15 ⁽⁴⁾. Moreover, refractive errors like hyperopia are conditions with high economic costs associated with their correction ⁽⁵⁾.

Astigmatism is a type of refractive error in which the eye does not focus light evenly on the retina; this results in distorted or blurred vision at all distances ⁽⁶⁾. In Europe and Asia astigmatism affects between 30 and 60% of adults ⁽⁷⁾. People of all ages can be affected. Hyperopic astigmatism is a type of astigmatism in which one or both principal meridians are farsighted; it is further classified to simple, compound and mixed astigmatism. Eyeglasses, contact lenses, and refractive surgery are the primary options to treat the visual symptoms of those with hyperopia or hyperopic astigmatism. Lens implants are now available offering an alternative to glasses or contact lenses for hyperopic for whom laser surgery is not an option. Several laser and non-laser refractive surgical procedures have been

used to modify the shape of the cornea and correct a refractive error, thereby restoring the focus plane of parallel light on the retina. The safety, efficacy, and predictability of the surgical outcomes have greatly improved since the introduction of the excimer laser. Despite these advances however, certain limitations and complications (infection, ectasia, diffuse lamellar keratitis, sub-epithelial haze, dry eye, epithelial ingrowth, buttonholed flap, free cap etc.) still exist ⁽⁸⁾.

In hyperopia, there are difficulties in preoperative evaluation of refraction so we must take in our consideration not only the manifest refraction, but also cycloplegic refraction to uncover any latent hyperopia ⁽⁹⁾ and also wave front refraction is needed. Comparison between these three parameters may lead to proper estimation of preoperative refraction.

Wavefront refraction has been recognized as an optical science by Scheiner's and Newton's observations of aberrated light in the 17th and 18th centuries ⁽¹⁰⁾. The modern wavefront aberrometer applies a form of high-resolution autorefractometry across the entire area of the patient's pupil, giving the wavefront error (WFE) in terms of micrometers of deviation (root-mean-square [RMS]) from the ideal wavefront plane ⁽¹¹⁾. The irregular portion of the WFE is termed higher-order wavefront error (HO-WFE) that is not correctable with traditional spherocylindrical spectacles. Wavefront testing is used to detect higher order aberrations that may degrade vision. Standard LASIK procedures cannot treat patients with significant amounts of wavefront abnormalities, which may leave them with unwanted visual symptoms after surgery. Wavefront guided LASIK may be the better choice to reduce higher order aberrations, subsequently giving the patient a better visual outcome ⁽¹²⁾.

AIM OF THE WORK

This was evaluation study between different methods of preoperative refraction detection in hyperopic Lasik including cycloplegic, manifest, and wave front refraction for all patients, and according to best-corrected visual acuity we do refractive surgery and analyze postoperative refraction outcome.

PATIENTS AND METHODS

Thus, this study was carried out on thirty-four eyes of eighteen patients. All patients had primary hyperopia with or without hyperopic astigmatism. All patients were informed about the limitations and risks of the procedure. All patients signed an informed consent.

Approval of the Ethical Committee was obtained.

Inclusion criteria

- Age: at least twenty one years.
- Refraction: hyperopia between + 1.00 D and + 6.00 D and hyperopic astigmatism less than or equal to + 1.5 D.

Exclusion criteria:

- Any active anterior or posterior segment disease (corneal ulcer, infective conjunctivitis, uveitis, macular scar: 2 eyes, optic atrophy, vitreous hemorrhage.....).
- Thin cornea: 2 eyes, (the remaining corneal thickness must be more than 400µ).
- Dense corneal opacity: 1eye, impending keratoconus.
- Dry eye syndrome, diagnosed by Schirmer test for the patients who had symptoms of dry eye “irritation, foreign body sensation, burning sensation, stringy mucus discharge and transient blurring of vision”. In those patients, wetting of the filter paper was measured after 5 minutes, a normal result was over 15 mm. Between 6 and 10 mm was border line and less than 6 mm indicate impaired secretion.

Preoperative evaluation:

Every patient in this study was subjected to the following:

1. History taking.

- Age and Sex.
- Previous ocular problems
- Systemic health problems.

2. Complete ophthalmic examination.

- Visual acuity testing: the uncorrected visual acuity (UCVA) and the best spectacle corrected visual acuity (BCVA) were measured.
- Refraction:
 - ✓ Manifest refraction: equals to correction with the most accepted plus spherical power that gives the best corrected visual acuity.
 - ✓ Cycloplegic refraction: cyclopentolate hydrochloride 1% eye drops was installed twice "45 minutes before refraction". Cycloplegic refraction was used as a base to the surgical plan, and to compare pre-operative and post-operative results.
 - ✓ Wave front refraction.
 - ✓ Slit lamp bio-microscopy: to exclude anterior segment disorders.

- ✓ Fundus examination: to exclude posterior segment problems.
- ✓ Applanation tonometry: using Goldman’s applanation tonometer.
- ✓ Corneal topography using computer videoeratography (NIDEK OPD scan) to obtain a color-coded topographical map of the corneal surface. The dioptric powers of the steepest and flattest meridia and their axes are also calculated and displayed.

Surgical procedure:

Topical anesthesia using Benoxinate hydrochloride 0.4 eye drops was instilled preoperatively. One drop every 5 minutes for 3 times.

A- Laser parameters and calibration:

- **AMO Visx S4 IR** excimer laser was used (Fig. 1).
- Laser calibration was checked before the procedure; this served to evaluate the energy emitted by the laser. It is also used to evaluate the uniformity of the energy distribution, and therefore the uniformity of the laser.



Figure (1): AMO Visx S4 IR excimer laser

B- Data entry:

- Patient demographics (name, sex, age) and refractive data were entered into the computer.
- Optical zone diameter was 5.5 mm and transitional zone diameter was 8.5 mm.
- Preoperative keratometry was done and according to it the suction ring size was chosen (table. 1).

Table (1): Intraoperative Lasik complication

Steepest K	Ring	Stop	Flap diameter (mm)	Hinge size (mm)
39	-1	7.5	8.8	4.5
40	-1 -1	7.5 8*	9.0 9.0	5.0 4.1
41	-1 0	8 7.5	9.3 8.8	4.6 4.5
42	-1 0	8 7.5	9.5 9.0	5.1 5.0
43	-1 0 1	8.5 8 7.5	9.8 9.3 8.8	4.8 4.6 4.5
44	0 1	8 7.5	9.5 9.0	5.1 5.0
45	0 1	8 7.5	9.8 9.3	5.6 5.4
46	2 2	7.5 8*	9.0 9.0	5.0 4.1
47	2 3	7.5 7.5	9.3 8.8	5.4 4.5
48	3	7.5	9.0	5.0
49	3	7.5	9.3	5.4

Select the stop value indicated by "*" only if a large ablation zone is needed.

C- Checking of the microkeratome:

The microkeratome (Moria M2) was used. Correct assembly of the microkeratome was checked. The gears were checked before every procedure.



Figure (2): Moria M2 Microkeratome system

D- Position and preparation of the patient:

- The patient was asked to lie on the bed, his head was directed toward the surgeon and the patient had to stare correctly at the fixating light under the operating microscope.
- The skin of the eyelid was sterilized with a solution of iodine, then carefully dried.
- Surgical drape was applied.

E- Surgical technique:

- A wire lid speculum that gives maximum exposure to the globe was put in place. A Para radial corneal marking was used which helped in re-positioning of the corneal flap at the end of the procedure, the extra pigments were removed by wet sponge.
- The patient was instructed to fix his eye and to maintain fixation to a flickering green light.
- The suction ring was centered and suction was activated. Elevation in the intraocular pressure due to activation of the suction was checked by the surgical tonometer. The patient was informed that the flickering light's intensity would disappear.
- The microkeratome head was engaged to the pneumatic ring. The forward pedal had been pressed to make a corneal flap, and then the reverse pedal was pressed to get it back. During this step patient was informed that there will be a period of non-seeing and should be assured that this is normal.
- The microkeratome head was disengaged.
- The suction ring was kept in place with low suction to help in globe fixation.
- The corneal flap was everted up and was examined regarding its diameter, edge, regularity, tears, and completeness.
- Excimer laser was focused on the center of the corneal stromal bed. Any excess fluid blood or debris are removed using a dry sponge.
- The Excimer Laser form **AMO Visx S4 IR** was used to ablate the optical zone. Foot switch was pressed to perform ablation. It was released whenever re-centering and refocusing is required and repressed to continue the procedure.
- Hyperopic and mixed astigmatism was corrected by cross cylinder technique, which consists of flattening the steep meridian doing a cylindrical ablation, in combination with a paracentral ablation over the flat meridian to steepen it (negative and positive cylinder ablation) and then applying hyperopic spherical ablation for the spherical component error.

- The stromal bed and underside of the flap were irrigated with balanced salt solution.
- Replacement of the flap gently over the bed.
- The Para radial corneal marks were aligned across the incision.
- One drop of antibiotic-steroid combination eye drop was instilled into the eye (Dexamethazone disodium 1 mg, chloramphenicol 5 mg, tetrahydrozoline hydrochloride 0.25 mg and hydroxypropyl methyl cellulose).
- Removal of the lid speculum. Patients were instructed to blink quickly and gently.
- Patients were examined half an hour after the procedure to assess positioning of the flap, regularity of the surface, edge of the flap and interface deposits.

Post operative procedures:

A) Postoperative treatment:

Dexamethazone – disodium phosphate 1 mg, chloramphenicol 5 mg, tetrahydrozoline hydrochloride 0.25 mg and hydroxypropyl methylcellulose was used every two hours in the first post – operation day, then postoperatively five times per day for, seven days.

B) Postoperative follow up:

Patients were examined half an hour after the procedure, first postoperative day, 1 week, one month, three months, six months and three months thereafter if patients were available for follow up visits.

The post operative examination included the following:

A) Slit lamp biomicroscopy

To assess

- Positioning of the flap
- Regularity of the surface
- Edge of the flap
- Interface deposits
- Haze

B) Refraction:

Manifest and cycloplegic refraction were done postoperatively to be compared with the preoperative refraction, and also wave front refraction.

C) Uncorrected and Best spectacle corrected visual acuity.

D) Corneal topography:

Was done at 1st, 3rd and 6th months postoperatively to show the amount of steepening and to verify cases of decentration and to show differences between pre and postoperative value

RESULTS

Preoperative data:

This study included 34 eyes of 18 patients who had primary hyperopia (14 eyes, 41.2%), hyperopic astigmatism (20 eyes, 58.8%) (Table 2). There were eight females (14 eyes, 41.2%) and 10 males (20 eyes, 58.8%). Patient's age ranged from 22 to 50 years old, the mean age was 30.4 ± 9.76 years (Table 3). Sixteen patients (88.9%) had bilateral surgery and 2 patients (11.1%) had unilateral surgery.

Table (2): Age, sex and hyperopia types' distribution among the study groups

Parameter	Primary Hyperopia	Hyperopia with hyperopic astigmatism	Total
Number of Eyes N (%)	14 (41.2)	20 (58.8)	34 (100)
Sex			
Male N (%)	8 (23.5)	12 (35.3)	20 (58.8)
Female N (%)	6 (17.7)	8 (23.5)	14 (41.2)
Age			
Average (Y)	22 – 50	25 – 50	22 – 50
Mean (Y)	31.2 ± 8.03	29.6 ± 11.5	30.4 ± 9.76

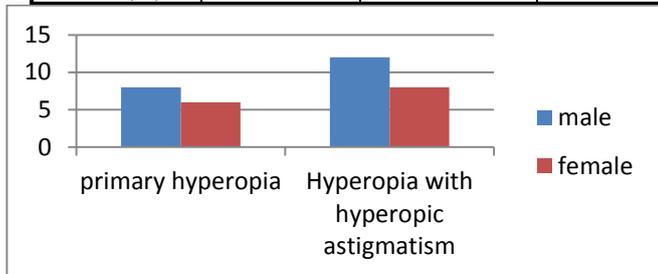


Figure (3): Percentage of types of hyperopia among male and females

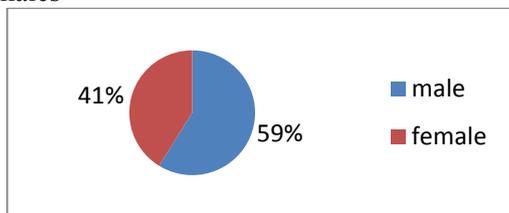


Figure (4): Sex distribution among the study

Table (3): Preoperative uncorrected visual acuity and best-corrected visual acuity of all eyes

Visual acuity	UCVA		BCVA	
	No of eyes	%	No of eyes	%
0.1	1	2.9	-	-
0.2	3	8.8	-	-
0.3	15	44.1	-	-
0.4	5	14.7	-	-
0.5	6	17.7	1	2.9
0.6	2	5.9	3	8.8
0.7	2	5.9	3	8.8
0.8	-	-	4	11.9
0.9	-	-	5	14.7
1.0	-	-	18	52.9

Regarding the preoperative uncorrected visual acuity (UCVA), tow eyes (5.9%) had a preoperative UCVA of 0.7, tow eyes (5.9%) had a preoperative UCVA of 0.6, six eyes (17.7%) had preoperative UCVA of 0.5, five eyes (14.7%) had a preoperative UCVA of 0.4, fifteen eyes (44.1%) had a preoperative UCVA of 0.3, three eyes (8.8%) had a preoperative UCVA of 0.2 and finally one eye (2.9%) had a preoperative UCVA of 0.1 or less (Table 4). Regarding the preoperative best corrected visual acuity (BCVA), one eye (2.9%) had a preoperative BCVA of 0.5, three eyes (8.8%) had a preoperative BCVA of 0.6, three eyes (8.8%) had a preoperative BCVA of 0.7, four eyes (11.9%) had a preoperative BCVA of 0.8, five eyes (14.7%) had a preoperative BCVA of 0.9 and finally

eighteen eyes (52.9%) had a preoperative BCVA of 1.0 (Table3).

Compared with subjective manifest refraction in the spherical equivalent, there was a significant myopic shift of Cycloplegic wave front refraction while Cycloplegic auto-refraction was not significantly different from subjective manifest refraction

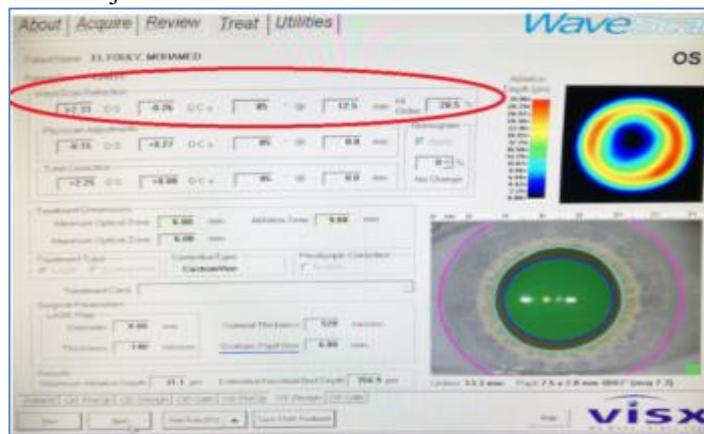


Figure (5): Wave front refraction

Regarding hyperopic spherical group, the mean preoperative spherical equivalent in manifest refraction was + 3.51 ± 1.28 (range + 2.26 to + 6.0 D) while in cycloplegic wave-front refraction, it was + 3.36 ± 1.26 (range + 1.70 to + 5.39 D) with a different of -0.14 ± 0.02 D between the two methods of measurement and S.E of Cycloplegic auto-refraction was + 3.54 ± 1.29 (range + 2.0 to + 5.5D).

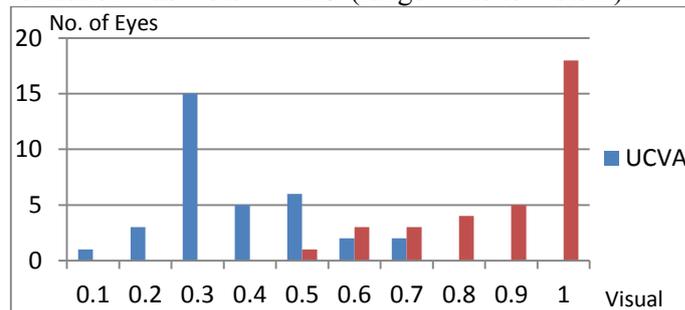


Figure (6): Pre-operative uncorrected and best-corrected visual acuity.

This spherical equivalent 6 month post operatively for manifest refraction became + 0.49 ± 0.38 (range + 0.51 to +1.5D), for cycloplegic wave-front refraction, it became + 0.35 ± 0.36 (rang + 0.12 to +0.90 D) and for cycloplegic auto-refraction, it became + 0.53 ± 0.39 (range + 0.25 to +1.0 D) (Table 4).

Regarding hyperopic astigmatic group, the mean preoperative spherical equivalent in manifest refraction was + 3.28 ± 2.10 (range + 1.51 to +6.25D), while in cycloplegic wave-front refraction, it was + 3.13 ± 2.08 (range + 1.0 to +5.63D) with a different of -0.15 ± 0.02 D between the two methods of measurement. S.E of cycloplegic auto-refraction was + 3.31 ± 2.11 (range + 1.25 to +5.75D).This spherical equivalent 6 month post operatively for manifest refraction became + 0.89 ± 0.45 (range + 0.51 to + 2.24D), for cycloplegic wave-front refraction, it became + 0.74 ± 0.43 (range + 0.12 to + 1.63D) and for cycloplegic auto-refraction it became + 0.92 ± 0.46 (range + 0.25 to + 1.74D) (Table 4)

Table (4): Preoperative and 6 month postoperative of sphere, cylinder and spherical equivalent of three measurements:

		Manifest refraction		Cycloplegic refraction		Wave front refraction	
		Preoperative	Postoperative	Preoperative	Postoperative	Preoperative	Postoperative
Spherical Hyperopia	Spherical errors (D) - Mean ± SEM - Range	+ 3.51 ± 1.28 + 2.26:+ 6.0	+ 0.49 ± 0.38 + 0.51: +1.5	+ 3.54 ± 1.29 +2.0: + 5.5	+ 0.53 ± 0.39 + 0.25: +1.0	+ 3.36 ± 1.26 +1.70:+5.39	+ 0.35 ± 0.36 + 0.12: +0.90
	Cylindrical errors (D) - Mean ± SEM - Range	-----	-----	-----	-----	-----	-----
	SE (D) - Mean ± SEM - Range	+ 3.51 ± 1.28 + 2.26:+ 6.0	+ 0.49 ± 0.38 + 0.51: +1.5	+ 3.54 ± 1.29 + 2.0: + 5.5	+ 0.53 ± 0.39 + 0.25: +1.0	+ 3.36 ± 1.26 +1.70:+5.39	+ 0.35 ± 0.36 + 0.12: +0.90
Hyperopic astigmatism	Spherical errors (D) - Mean ± SEM - Range	+ 2.73 ± 1.91 +1.0: + 5.50	+ 0.55 ± 0.41 + 0.25: +1.50	+ 2.83 ± 1.92 +1.0: + 5.0	+ 0.65 ± 0.42 + 0.25: +1.25	+ 2.67 ± 1.89 +0.77:+5.29	+ 0.49 ± 0.39 + 0.02: +1.54
	Cylindrical errors (D) - Mean ± SEM - Range	+ 0.96 ± 0.45 +0.50:+1.50	+ 0.27 ± 0.23 + 0.0: + 0.50	+ 0.96 ± 0.45 +0.50:+1.50	+ 0.27 ± 0.23 + 0.0: + 0.50	+ 0.79 ± 0.42 +0.31:+1.98	+ 0.10 ± 0.83 + 0.0: + 0.95
	SE (D) - Mean ± SEM - Range	+ 3.28 ± 2.10 +1.51:+6.25	+ 0.89 ± 0.45 + 0.51: + 2.24	+ 3.31 ± 2.11 +1.25:+5.75	+ 0.92 ± 0.46 + 0.25: + 1.74	+ 3.13 ± 2.08 + 1.0: +5.63	+ 0.74 ± 0.43 +0.12:+1.63

The mean preoperative spherical equivalent for all eyes was + 3.42 ± 1.39 (range +1.0 to +5.75D), the mean preoperative spherical equivalent for the primary hyperopic eyes “without astigmatism” was + 3.54 ± 1.29 (range + 2.0 to + 5.5 D) and the mean preoperative SE of hyperopic astigmatism group was + 3.31 ± 2.11 (range + 1.25 to + 5.75D) (Table 5).

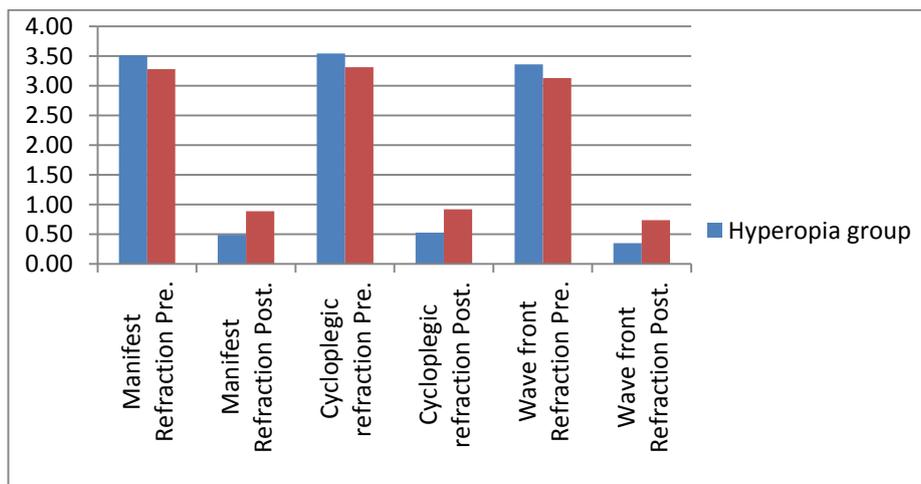


Figure (7): Preoperative and 6 month postoperative of sphere, cylinder and spherical equivalent of the three measurements

The mean preoperative spherical hyperopia in primary hyperopic eyes was $+3.54 \pm 1.29$ (range $+2.0$ to $+5.5$ D). It became $+0.53 \pm 0.39$ (range $+0.25$ to $+1.0$ D) 6 months postoperatively. The mean preoperative hyperopic astigmatism in hyperopic astigmatic group was $+0.96 \pm 0.45$ (range $+0.50$ to $+1.50$ D). It became $+0.27 \pm 0.23$ (range $+0.0$ to $+0.50$ D) 6 months postoperatively. Regarding the preoperative spherical hyperopia in hyperopic astigmatic group, it was $+2.83 \pm 1.92$ (range $+1.0$ to $+5.0$ D). It became $+0.65 \pm 0.42$ (range $+0.25$ to $+1.25$ D) 6 months postoperatively (Table 5).

Change in refraction and visual acuity outcome
Primary hyperopia group

This group included 14 hyperopic eyes with a preoperative hyperopic refraction of $+3.54 \pm 1.29$ (range $+2.0$ to $+5.5$ D). At the first postoperative week, the mean spherical equivalent refraction was $+0.40 \pm 0.28$ (range 0.25 to $+1.0$ D). This gradually increased to $+0.53 \pm 0.39$ (range $+0.25$ to $+1.25$ D) at 6 months after

LASIK (Table 5). Regression between one week and 6 months postoperatively was $0.13D$ (difference in SE between 1 week and 6 months after LASIK). In this group, 28.6% were within $\pm 0.5D$ of emmetropia, 85.7% were within $\pm 1.00D$ and all eyes were within $\pm 2.0D$, at six months after H- LASIK.

Hyperopic astigmatism group

This group included 20 eyes with a mean value of preoperative SE of $+3.31 \pm 2.11$ (range $+1.25$ to $+5.75D$). At the first postoperative week, the mean value of SE was $+0.56 \pm 0.22$ (range $+0.25$ to $+1.53$ D). This gradually increased to $+0.92 \pm 0.46$ (range $+0.25$ to $+1.74$ D) at 6 months after LASIK (Table 5). Regression between 1 week and six months postoperatively was $+0.29D$. In this group, 26.7% were within $\pm 0.5D$ of emmetropia, 66.7% were within $\pm 1.00D$ and all eyes were within $\pm 2.0D$ at 6 months after H- LASIK.

Table (5): Preoperative and 6 month postoperative different cycloplegic refractive parameters

		Sphere		Cylinder		S.E.	
		Preoperative	Postoperative	Preoperative	Postoperative	Preoperative	Postoperative
Spherical Hyperopia	Mean \pm SEM	$+3.54 \pm 1.29$	$+0.53 \pm 0.39$	-----	-----	$+3.54 \pm 1.29$	$+0.53 \pm 0.39$
	Range	$+2.0:+5.5$	$+0.25:+1.0$			$+2.0:+5.5$	$+0.25:+1.0$
Hyperopic astigmatism	Mean \pm SEM	$+2.83 \pm 1.92$	$+0.65 \pm 0.42$	$+0.96 \pm 0.45$	$+0.27 \pm 0.23$	$+3.31 \pm 2.11$	$+0.92 \pm 0.46$
	Range	$+1.0:+5.0$	$+0.25:+1.25$	$+0.50:+1.50$	$+0.0:+0.50$	$+1.25:+5.75$	$+0.25:+1.74$

All eyes

At first postoperative week all eyes showed reduction in hyperopia, the mean spherical equivalent refraction was $+0.50 \pm 0.25$ (range $+0.25$ to $+1.53D$). With follow up all eyes showed initial decrease in the effect of the surgery so that the mean spherical equivalent refraction increased gradually to $+0.89 \pm 0.43$ (range $+0.25$ to $+1.74$ D) at 6 months after LASIK (Table 7). Of all eyes, 31.3% were within ± 0.50 D of emmetropia, 71.9% were within ± 1.00 D and all eyes were within $\pm 2.0D$, at six month after LASIK.

Eyes included in this study had improvement in uncorrected visual acuity from the preoperative values. At 6 months, the mean postoperative UCVA for all eyes was 0.83 ± 0.18 (range 0.4 to 1.0). This was 0.32 ± 0.26 (range 0.1 to 0.7) preoperatively (Table 6).

Table (6): Visual acuity and mean refractive outcome

	Parameter	Refraction S.E			UCVA		
		Primary H. (14 eyes)	H.astigmatism (20 eyes)	Total (34 eyes)	Primary H. (14 eyes)	H.astigmatism (20 eyes)	Total (34 eyes)
Preoperative	- Mean \pm SEM	$+3.54 \pm 1.29$	$+3.31 \pm 2.11$	$+3.42 \pm 1.39$	0.3 ± 0.21	0.35 ± 0.16	0.32 ± 0.26
	- Range	$+2.0:+5.5$	$+1.25:+5.75$	$+1.25:+5.75$	$0.1:0.7$	$0.1:0.7$	$0.1:0.7$
Postoperative 1 week	- Mean \pm SEM	$+0.40 \pm 0.28$	$+0.56 \pm 0.22$	$+0.50 \pm 0.25$	0.67 ± 0.26	0.76 ± 0.19	0.72 ± 0.18
	- Range	$+0.25:+1.0$	$+0.25:+1.53$	$+0.25:+1.53$	$0.3:0.9$	$0.4:1.0$	$0.3:1.0$
1 month	- Mean \pm SEM	$+0.49 \pm 0.67$	$+0.67 \pm 0.87$	$+0.58 \pm 0.57$	0.70 ± 0.23	0.77 ± 0.19	0.74 ± 0.20
	- Range	$+0.25:+1.0$	$+0.25:+1.88$	$+0.25:+1.88$	$0.4:1.0$	$0.4:1.0$	$0.4:1.0$
3 month	- Mean \pm SEM	$+0.51 \pm 0.86$	$+0.86 \pm 0.24$	$+0.69 \pm 0.44$	0.72 ± 0.21	0.78 ± 0.88	0.75 ± 0.25
	- Range	$+0.25:+1.0$	$+0.25:+1.65$	$+0.25:+1.65$	$0.4:1.0$	$0.4:1.0$	$0.4:1.0$
6 month	- Mean \pm SEM	$+0.53 \pm 0.39$	$+0.92 \pm 0.46$	$+0.89 \pm 0.43$	0.84 ± 0.32	0.82 ± 0.78	0.83 ± 0.18
	- Range	$+0.25:+1.0$	$+0.25:+1.74$	$+0.25:+1.74$	$0.4:1.0$	$0.4:1.0$	$0.4:1.0$

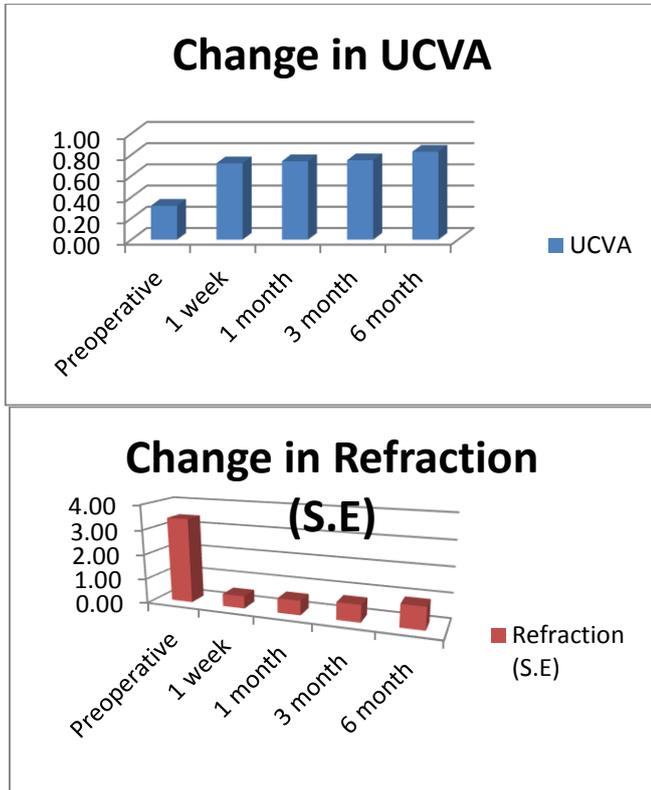


Figure (8): Visual acuity and mean refractive outcome

Corneal topography:

Corneal topography showed postoperative central steepening in all eyes and improved sphericity. Topography showed a mean preoperative keratometric reading of 42.35 ± 2.26 (range 40.1 to 45.3 D). At 6 months postoperatively, the mean was 47.30 ± 2.85 (range 40.4 to 49.8 D), which indicated steepening in all eyes compared to the preoperative values (Table 7). Corneal topography helped in evaluating residual and induced astigmatism and in verifying cases of decentration.

Table (7): Pre and postoperative Keratometry in diopters

Time	Mean \pm SEM	Range (D)
Preoperative	42.35 ± 2.26	40.1 – 45.3
1 month postoperative	46.32 ± 3.24	39.8 – 48.6
3 month postoperative	46.50 ± 3.71	39.2 – 48.2
6 month postoperative	47.30 ± 2.85	40.4 – 49.8

Complication:

Intraoperative complications:

During surgery, none of the eyes suffered from sight threatening complications. Four eyes suffered from bleeding from corneal pannus. This bleeding was self-limited and it stopped in few minutes. One of those four eyes had blood in the interface. One patient was apprehensive, with poor fixation and was squeezing his eyes during the surgery, which led to subconjunctival hemorrhage in his both eyes. There were no serious complications related to the microkeratome (perforation, incomplete primary cut and irregularity in thickness of

the resection). There were no free caps, and no damage or destruction to the flap. Decentration of ablation was seen in two eyes of one patient who was poor fixator. This was confirmed by postoperative corneal topography.

Postoperative complications

One eye showed rolled flap edge immediately postoperatively which was treated immediately. The patient said that he rubbed his eye. Two patients suffered from severe postoperative pain and photophobia, which disappeared by the second postoperative day. One eye had blood in the interfere, which resolved within two weeks after LASIK. Initially five patients suffered from night glare. This was transient and disappeared within one month postoperatively.

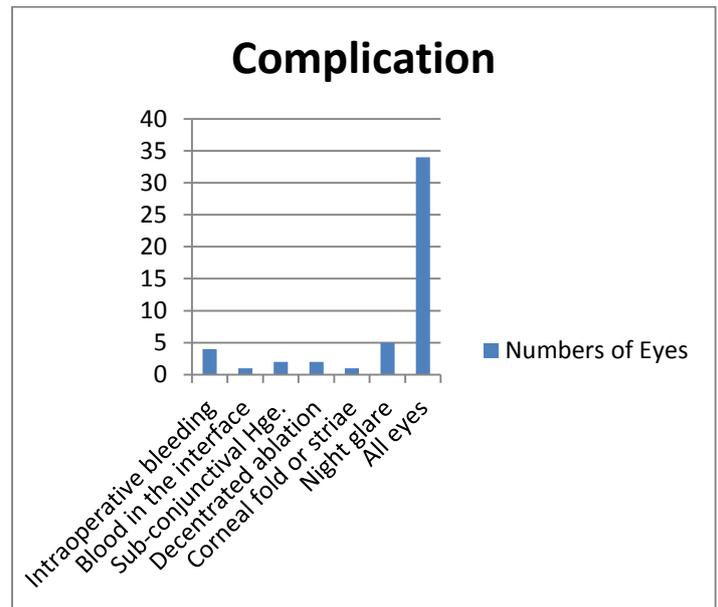


Figure (9): Summary of complication

All eyes showed regression of the effect of surgery up to six months after LASIK. This was more in patients who had higher degrees of hyperopia (>4.0 D), being 0.31 (difference between SER 6 months after LASIK and preoperative SER). However, this loss of the surgical effect did not continue in patients who were followed up for more than 6 months after LASLK. This denotes that refractive stability was reached within 6 months postoperatively. None of the eyes that were included in this study showed a reduction of best spectacle corrected visual acuity more than two lines. Only two eyes (5.8%) had a reduction of best spectacle corrected visual acuity by two lines from its preoperative level, and nine eyes (26%) lost one line of the preoperative BCVA.

Topographic abnormalities were seen in two eyes (5.8%) in the form of decentered ablation zone. This was seen in the two eyes, which suffered from persistent glare, halos and poor quality of vision.

Table (8): Summary of complications

Complication	Number of eyes	%
Intraoperative bleeding	4	11.8
Blood in the interface	1	2.9
Sub-conjunctival Hge.	2	5.8
Decentered ablation	2	5.8
Corneal fold or striae	1	2.9
Night glare	5	14.7

Table (9): Summary of previously published hyperopic Lasik results

Author	Laser	Follow-up (months)	No. of eyes	Preop. S.E.R.	Cylinder	Postop. UCVA > 0.5 (%)	Postop. S.E.R. < ± 1 (%)	Loss of > 2 lines (%)
Spherical hypeopia								
<i>Stulting et al. (1998)</i>	MEL 60	12	20 23	+1.00 to + 4.00 +4.25 to + 8.00	- -	95 90	85 58	5 4.3
<i>Goker et al., (1998)</i>	Keracor 116	6	54	+4.25 to + 8.00	-	72.2	81.5	6.8
<i>Argento et al.(1999)</i>	Keracor 116/117	6	138 153 170	+1.25 to + 2.50 + 2.25 to + 4.75 +5.50 to + 8.50	- - -	94.1 100 87.8	100 95.3 71.4	0 2.0 0
<i>Arbelaez et al.(1999)</i>	Keracor 117/C	12	24 20 16	+1.00 to + 3.00 +3.10 to + 5.00 5.10 to +9.00	- - -	98 93 50	91 85 50	0 0 13
<i>Esquenazi et al.(1999)</i>	Keracor 117CT	6	92	+1.25 to + 8.50	-	81	71	6
<i>Zadok et al. (2000)</i>	Nidek EC-5000	6	45	+ 1.00 to < + 3.00	-	95.6	88.9	0
<i>Salz et al. (2002)</i>	LADARvision	12	27 88 29	+ 3.00 to + 5.00 +0.88 to + 2.99 +3.00 to + 6.00	- - -	77.8 97.2 88.5	51.8 93.2 85.7	1.4 4.5 0
Simple and compound hyperopic astigmatism and mixed astigmatism								
<i>Argento et al. (1997)</i>	Keracor 116/117	6	11 53 51	+1.00 to + 2.50 2.50 to + 4.25 -0.88 to + 4.25	+2.00 to 5.00 +2.00 to + 5.75 +0.50 to + 7.25	90.1 73.6 92.2	81.9 95.9 100	0 3.8 3.9
<i>Chayet et al. (1998)</i>	Nidek EC-5000	3	41*	+0.67 ± 1.33	-3.82 to ± 0.95	85	90	0
<i>Arbelaez et al. (1999)</i>	Keracor 117C	12	23 14 13	+1.00 to + 3.00 +3.10 to + 5.00 +5.10 to + 9.50	+1.00 to 7.50 +1.00 to + 7.50 +1.00 to + 7.50	78 82 25	83 85 17	0 14 15
<i>Lindstrom et al. (1999)</i>	VISX star 52	6	46	+0.50 to + 6.0	0 to +5.0	79	63	0
<i>Barraquer et al. (1999)</i>	Schwind-Keratom	6	18 30 18	+1.50 to + 3.50 +3.51 to + 6.00 +6.01 to + 10.0	0 to - 5.00 0 to - 4.50 0 to - 4.00	71 for all eyes	100 80 77	0 for all eyes
<i>Salz et al.(2002)</i>	LADARvision	12	54 20 38	+0.50 to + 2.99. +3.00 to + 5.75 1.75 to + 2.375	-0.50 to - 6.00 0.50 to - 6.00 -1.25 to - 6.00	95.7 88.2 94.4	92.6 80.0 94.7	1.9 0 0
Our study	AMO Visx S4 IR	6	34	+1.25:+5.75	+ 0.50:+ 1.50	90.6	84	0

UCVA= uncorrected visual acuity; SER= spherical equivalent refraction; Preop.= Preoperative; Postop= Postoperative; *= Includes simple myopic astigmatic eyes.

DISCUSSION

Wave front

Refractive surgery has become increasingly popular for the correction of unwanted refractive errors. The surgery aims to eliminate the presence of lower order aberrations, namely defocus and x- and y-astigmatism. Whilst most surgical interventions are successful in reducing or eradicating refractive errors, patients still present with visual disturbances especially in hyperopic patient.

The development of wave front aberrometers has allowed the thinking that higher order aberrations can also be corrected in time with refractive surgery via custom ablation or custom contact lenses. There are, however, already limitations to this notion. With current wave front analyzers, the ability to reproduce wave front measurements that are reliable has not yet been done successfully. Wave front aberrations are seen to be dynamic, which poses a problem for correction.

Refractive surgery, however, has been shown to increase higher order aberrations, often because of the induced corneal changes⁽¹³⁾ and particularly causes an increase in coma and spherical aberration. The symptoms that can present after refractive surgery include glare, halos, poor scotopic (night) vision, decreased contrast sensitivity and poor subjective refraction results⁽¹⁴⁾. The causes of glare and halos included an increase in scattered light entering the eye, an increase in spherical aberration and coma and corneal surface defects because of the surgery⁽¹⁵⁾. The increase in scattered light usually results from the size of the ablation zone chosen during surgery. Light will strike the cornea as well as the edge of the ablation zone, and these causes increased scattering of light and therefore becomes the source of the visual disturbance. Constriction of the pupil should in theory decrease the amount of scattered light⁽¹⁵⁾.

Spherical aberration has also been seen to increase after ablation refractive surgery. As mentioned above, spherical aberration is responsible for the presence of glare and halos, and therefore the increase in spherical aberration after refractive surgery would result in a heightening of this visual disturbance⁽¹⁵⁾. The amount and sign of spherical aberration differs for different refractive states. Myopic ablation patterns tend towards positive spherical aberrations whilst hyperopic ablation patterns are more negative⁽¹⁶⁾.

Refractive surgery causes changes to the corneal surface and can therefore induce unwanted aberrations. Striae or folds within the cornea can add to the increase in experienced glare and halos⁽¹⁵⁾.

Pre-operative higher order RMSwfe values provide surgeons with an indication as to which aberrations may increase after surgery. The smaller the higher order RMSwfe before surgery, the more likely that the procedure will increase aberrations post-operatively⁽¹⁷⁾. The discovery of an increase in higher order aberrations after refractive surgery has contributed

to the development and advancements in laser ablation technology during refractive surgery. In attempts to decrease the induced higher order aberrations after surgery, ophthalmic surgeons have begun using wavefront-guided excimer laser refractive surgery⁽¹³⁾. This form of surgery was introduced in the year 2000⁽¹³⁾ to decrease or eliminate total aberrations of the eye and not focus individually on lower or higher order aberrations. The principle behind this new technology was to take measurements using a wavefront aberrometer and to use the results to create an ablation pattern that effectively neutralizes existing aberrations⁽¹³⁾.

A study was conducted on three eyes of patients who had already received wavefront-based custom corneal ablation⁽¹⁸⁾. The study found that an unaided visual acuity of 6/3 was found in two of the three eyes whilst the remaining eye had better than 6/6 visual acuity. The wavefront deviations were also found to be decreased by 27%. In another study, 93.5% of patients had an unaided visual acuity of 6/6 or better⁽¹⁸⁾.

Whilst this method has not been perfected owing to the existence of external variables such as ablation zone placement, cyclotorsion of the eye and wound healing, this type of surgery is proving to provide patients with improved post-operative vision⁽¹⁵⁾.

In our study, we used just one parameter of wave front aberrometer, refraction detected by this aberrometer called wave front refraction. We used it to compare this refraction with other methods of refraction detection including manifest and cycloplegic refraction. Compared to subjective manifest refraction in the spherical equivalent, there was a significant myopic shift of cycloplegic wave front refraction while cycloplegic auto-refraction was not significantly different from subjective manifest refraction.

This point however, still a matter of controversy in clinical practice. For example, for younger patients (< 40 years) with a cycloplegic refraction that differed from the manifest refraction by more than 0.5 D⁽¹⁹⁾. Carried out the treatment with the aim of correcting the completely cycloplegic refraction. By contrast, for older patients (> 40 years) a correction of the manifest refraction was performed⁽²⁰⁾ recommended a treatment with 5 % below the cycloplegic refraction for younger patients⁽²¹⁾. Considered that farsighted patients between 20 and 35 embodied a population for whom the most difficulties in the correction of hyperopia occurred, and recommended that for this age group the cycloplegic and the manifest refraction should also be taken into consideration.

The manifest sphere and cylinder that we used to correct hyperopia resulted in a relatively precise adherence to the desired postoperative manifest SE for eyes with a preoperative difference of <1.00 D between the MSE and CSE. As already mentioned, with increasing difference between the preoperative MSE and CSE, the postoperative hyperopic regression after

LASIK became statistically significant. Nevertheless, a regression of 0.5 D hyperopia was only reached when the MCD was ~ 1.5 D or more. If this difference was 1 D or less (which statistically was the case for most of the eyes), the achieved SE deviated by less than 0.5 D. In the present study, patients were divided into 2 groups according to refraction. Spherical hyperopia group (group I) included 14 eyes having primary hyperopia. The preoperative spherical equivalent refraction ranged from +1.0 to + 5.75D (mean + 3.42 \pm 1.39 D). At 6 months post-operatively the mean refraction became + 0.53 \pm 0.39 (range + 0.25 to + 1.0 D). The change from one week to 6 months was 0.13D. **Stulting et al.** ⁽²¹⁾ using MEL 60 Excimer laser (Model, 94, Asculap, Medidec) reported a mean postoperative spherical equivalent refraction of + 0.33D for "Spherical hyperopia group" (+ 1.00 to + 4.00D), which is comparatively better than the results of our study since we reported + 0.73D at 6 months postoperatively in "Spherical hyperopia group". This difference between the two studies may be due to possible difference in distribution of refractive errors between + 1.00 and + 4.00 and due to difference in the laser system ⁽²¹⁾.

Ibrahim ⁽²²⁾ in his study reported results of 58 eyes that had undergone hyperopic LASIK. The mean preoperative spherical equivalent refraction was +3.75D (range + 1.00 to + 6.00D) becoming + 2.25D (range 0 to + 3.25D) at 6 months. Although in the present study, we included cases with almost a similar mean preoperative refraction (+2.78 vs. + 3.75D), we achieved better results at 6 months + (0.85D vs. + 2.25D). This difference between the two studies was observed.

Arbealaez and Knorz ⁽²³⁾ performed keratomileusis for hyperopia. They used automatic corneal shaper and the keracor 117C excimer laser system on 192 hyperopic eyes with astigmatism of less than 1.00D (spherical group). At 12 months after LASIK, the patients who had low spherical hyperopia (+ 1.00 to + 3.00D), 55% of them were within ± 0.50 D of emmetropia, with moderate spherical hyperopia (+ 3.10 to + 5.00D), 44% of them were within ± 0.5 D of emmetropia and with high spherical hyperopia (+ 5.10 to + 9.00D), 38% of them were within ± 0.5 D of emmetropia.

Walker and Wilson ⁽²⁴⁾ had a mean preoperative spherical equivalent refraction of +4.50 \pm 1.73D compared to + 2.78 \pm 1.97D in our study, becoming + 0.72 \pm 1.87D (range - 1.25 to + 2.50D) compared to + 0.85 \pm 0.44D (range + 0.25 to + 1.88D) in our study at 6 months after hyperopic LASIK.

In the present study, 31.3% were within ± 0.50 D of emmetropia, 71.9% were within ± 1.00 D and all eyes were within ± 2.0 D, at six month after LASIK.

Shawky et al. ⁽²⁵⁾ had a 24 hyperopic eyes with SER between + 1.5 and + 5.5D and astigmatism of less than or equal + 1.5D. The refractive outcome at 12

months was 87.5% within ± 1.00 D and 58.3% were within ± 0.5 D of emmetropia. **Esquenazi** ⁽²⁶⁾ reported in a 5 years after H-LASIK study, mean SER for the low hyperopia group (+1.0 to + 2.75D) was + 0.48 \pm 0.79D, mean SER for the medium hyperopia group (+ 3.0 to + 4.25D) was +1.52 \pm 1.45D, mean SER for the high hyperopia group (+4.5 to + 6.5D) was + 3.39 \pm 1.98D.

Regarding the low hyperopia group, 63% were within +0.5D of emmetropia, 42% for medium hyperopia group and 22% for high hyperopia group.

Regarding methods of refraction in hyperopic spherical group, the mean preoperative spherical equivalent in manifest refraction was + 3.51 \pm 1.28 (range + 2.26 to + 6.0 D). While in cycloplegic wave-front refraction, it was + 3.36 \pm 1.26 (range + 1.70 to + 5.39 D) with a different of -0.14 \pm 0.02 D between the two methods of measurement and S.E of cycloplegic auto-refraction was + 3.54 \pm 1.29 (range + 2.0 to + 5.5D).

This spherical equivalent 6 month post operatively for manifest refraction became + 0.49 \pm 0.38 (range + 0.51 to +1.5D), for cycloplegic wave-front refraction, it became + 0.35 \pm 0.36 (rang + 0.12 to +0.90 D) and for cycloplegic auto-refraction, it becomes + 0.53 \pm 0.39 (range + 0.25 to +1.0 D).

Regarding the astigmatism, in this study 20 eyes that had astigmatism were included. **In the hyperopic astigmatism group (group II)**, the mean preoperative SER was + 3.31 \pm 2.11 D (range + 1.25: + 5.75 D). This became + 0.92 \pm 0.46 D (range + 0.25: + 1.74 D) at 6 months after LASIK (Table 5) (Fig. 21). Hyperopic astigmatism was corrected by cross cylinder ablation, which consisted of flattening the steep meridian doing a cylindrical ablation in combination with a paracentral ablation over the flat meridian to steepen it (negative and positive cylinder ablation) and then applying hyperopic spherical ablation for the spherical component error. Regarding methods of refraction in hyperopic astigmatic group, the mean preoperative spherical equivalent in manifest refraction was + 3.28 \pm 2.10 (range + 1.51 to +6.25D). While, in cycloplegic wave-front refraction, it was + 3.13 \pm 2.08 (range + 1.0 to +5.63D) with a different of -0.15 \pm 0.02 D between the two methods of measurement, and S.E of cycloplegic auto-refraction was + 3.31 \pm 2.11 (range + 1.25 to +5.75D). This spherical equivalent 6 month post operatively for manifest refraction became + 0.89 \pm 0.45 (range + 0.51 to + 2.24D), for cycloplegic wave-front refraction, it became + 0.74 \pm 0.43 (range + 0.12 to + 1.63D) and for cycloplegic auto-refraction, it became + 0.92 \pm 0.46 (range + 0.25 to + 1.74D).

In the present study, using cross cylinder ablation, mean preoperative hyperopic astigmatism was + 0.96 \pm 0.45 D (rang + 0.50: + 1.50 D). After 6 months, mean postoperative astigmatism was + 0.27 \pm 0.23 D (rang + 0.0: + 0.50 D). In a study done by **Ibrahim** ⁽²²⁾ using minus cylinder ablation, mean preoperative hyperopic astigmatism was + 2.75 \pm 1.5D. After 6 months, mean

postoperative astigmatism was $+ 1.25 \pm 0.18D$. In a study hold at Colombia by **Arbealaez and Knorz** ⁽²³⁾ stated the results of patients who had low hyperopic astigmatism with a mean preoperative cylinder of $+3.34 \pm 1.39D$ became $+ 0.12 \pm 1.23D$.

Regarding the visual acuity, Eyes included in this study had improvement in uncorrected visual acuity from the preoperative values. At 6 months, the mean postoperative UCVA for all eyes was 0.83 ± 0.18 (range 0.4 to 1.0) which was 0.32 ± 0.26 (range 0.1 to 0.7) preoperatively. **Suarez et al.** ⁽²⁷⁾ included eyes having simple hyperopia ranging from $+ 1.00$ to $+ 8.50D$. 72% of eyes were 0.5 or better and none of the eyes had a vision 0.2 or worse at 3 months. **Ibrahim** ⁽²²⁾ in his study which included 58 eyes reported that 76% had the same preoperative spectacle corrected visual acuity and 17% had improvement in spectacle corrected visual acuity. In 7%, although there were no changes in best spectacle corrected visual acuity they complained of bad quality of vision and glare. **Arbealaez and Knorz** ⁽²³⁾ working with the automatic corneal shaper and the keracor 117C excimer laser found that none of their patients who had low spherical hyperopia ($+ 1$ to $+ 3.00$) lost 2 or more lines of best spectacle-corrected visual acuity. In those who had moderate spherical hyperopia ($+3.10$ to $+ 5.00D$), none lost 2 or more lines. For high spherical hyperopia ($+ 5.10$ to 8.00), 13% lost 2 or more lines of best spectacle-corrected acuity from their preoperative value.

Lindstorm et al. ⁽¹⁹⁾ used VisxStar S2 excimer laser system to correct hyperopia and hyperopic astigmatism. The sphere ranged from $+ 0.50D$ to $+ 6.00D$. At 6 months they reported 79% of patients having UCVA of 0.5 or better which is a lower percentage compared to our study. This could be explained by the lower refractive errors that we included (up to $+ 5.50D$), the difference in distribution of patients, and the different laser system that was used, only one patient who lost 2 or more lines of spectacle corrected visual acuity. **Rosa and Febraro** ⁽²⁸⁾ worked with a similar mean preoperative spherical equivalent refraction which was $+ 2.72D$ (20 eyes). Only one patient lost one line, and six patients gained 1 to 3 lines from their preoperative spectacle-corrected visual acuity. **Asano-Kato et al.** ⁽²⁹⁾ reported an UCVA of 0.5 or better in 93.4% in 6 months of follow up after LAISK correction of spherical hyperopia up to $+ 6.00D$ with hyperopic and mixed astigmatism with the LADAR vision excimer laser system. **Fracensco et al.** ⁽²¹⁾ used LADAR vision with 7 to 10 mm ablation diameter. The mean preoperative SER was $+ 2.34 \pm 2.09D$. At 6 months postoperatively, UCVA of 0.5 or better was achieved by 94.3%, which is a higher percentage compared to our study. **Zadok et al.** ⁽³⁰⁾ reported an UCVA of 0.5 or better in all eyes (100%) in low hyperopia, (93.3%) in moderate hyperopia and (59.1%) in high hyperopia, (low hyperopia $< + 3.00D$, moderate hyperopia 3.00 to $6.00D$ and high hyperopia $> 6.00D$).

Regarding the complications,

Shawky et al. ⁽²⁶⁾ studied the results and complications of LAISK. They used Nidek EC-5000 or Planoscan excimer lasers. Nineteen eyes had low hyperopia ($+1.00$ to $+ 3.75D$) and twelve eyes had high hyperopia ($+4.25$ to $+ 7.37D$). Intraoperatively 3% had minor corneal bleeding, and 1% had a thin flap. Postoperatively, they reported punctate epithelial defect in 6% of eyes, small epithelial defect 1 day after the surgery in 5%, corneal topographic abnormalities in three out of twelve eyes had high hyperopia and loss of BCVA of two lines or more in three cases which had high hyperopia.

In this study, intraoperative complications showed that four eyes (11.8%) had minor corneal bleeding from pannus, none had a thin flap, and one eye (2.9%) had a rolled in flap edge. Postoperatively, none of our patients had punctate epithelial keratopathy and no epithelial defects. Two eyes (5.9%) had corneal topographic abnormalities. **Stulting et al.** ⁽²¹⁾ showed loss of 2 or more lines of BCVA in 5% of patients who had low hyperopia ($+1.00$ to $+ 4.00D$), and in 7.3% of patients who had high hyperopia ($+4.25$ to $+ 8.00D$). **Geker et al.** ⁽³¹⁾ demonstrated regression and under-correction of more than 2.00D in 12.9% of eyes. Also, they did not report a loss of 2 or more lines of BCVA. **Ibrahim** ⁽²²⁾ reported that 4 out of 58 eyes that were included in his study (6.9%) suffered from reduction in quality of vision due to decentered ablation. None of his patients suffered from sight threatening complications. **Rosa and Febraro** ⁽²⁸⁾ reported that none of their eyes lost two or more lines of BCVA they had only one patient (5%) who lost one line of BCVA. **Arbealaez et al.** ⁽²³⁾ reported a loss of two or more lines of BCVA in 13% of patients who had high spherical hyperopia ($+5.10$ to $+ 9.00D$). On the other hand, patients who had low hyperopia ($+1.00$ to $+ 3.00D$), and moderate hyperopia ($+3.10$ to $+ 5.00D$), none lost lines of BCVA. **Lindstorm et al.** ⁽¹⁹⁾ published results of H-LAISK. They had one primary hyperope (4.35%) who lost 2 lines of BCVA. They reported transient epithelial defect (6.5%), epithelial cells in the interface (4.3%), diffuse lamellar keratitis (4.3%), haze (2.2%), and mild irregular astigmatism 2.2%.

In this study, none had epithelial defects or keratitis. One eye had blood in the interface. No eyes had induced astigmatism. **Esquenazi** ⁽²⁶⁾ reported that eyes with chronic dry eye symptoms had a mean difference in SER from target refraction of $+1.43D$ compared to $+0.84D$ for eyes without dry eye symptoms. Five eyes (4%) lost 2 lines of BCVA at 5 years. The efficacy, predictability and safety of H-LASIK can be affected by many factors including the ablation zone diameter, ablation depth and diameter of the flap.

Regression after H-LAISK is a problem however; this was lessened by improvement of software, improving the ablation profile. Also increasing the optical zone diameter improved the results ⁽³²⁾.

Some patients included in our study had a disproportion between objective refractive results and subjective visual acuity and satisfaction. In those patients although objectively were not close to emmetropia, they had good visual acuity and were satisfied which is the aim of any refractive surgery.

CONCLUSION

Laser in situ keratomileusis for hyperopia, hyperopic astigmatism is a safe, effective and predictable technique. However, modification in the nomogram is needed in order to achieve good results.

In spite of the widespread use of wavefront-guided refractive surgery, the application of wavefront technology is still at an early stage in ophthalmology. Most of the aberrometers in the eye clinics are not used to evaluate the optical quality of the eyes but mainly for wavefront-guided refractive surgery.

In the future, we believe that wavefront analysis will be performed at the clinic not only for refractive surgery but also for the diagnosing and treating most of the eye diseases that will influence to the quality of vision of the eye.

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