

Effectiveness of Technolas torsional eye tracking system on visual outcomes after photorefractive keratectomy

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Abstract

Purpose: To investigate the efficacy of Technolas 217Z eye tracking system (*torsional component*) in corneal surface irregularity and high order aberrations (HOAs) after photorefractive keratectomy

Methods: Patients with compound myopic astigmatism among persons demanding refractive surgery in Khatam-al-Anbia Eye Hospital with the mean age of 29 years were enrolled in this double-blind randomized interventional study. The mean spherical equivalent (SE) of refractive error was -4.75 diopters(D) (range: -1.5 to -7.0), and the mean astigmatism was 3 D (range: $1.0-4$). Many studies were performed for each patient including: A complete eye examination, visual acuity and Monocular contrast sensitivity evaluation, and refraction. Corneal topography, Orbscan II, and wavefront aberrometry were conducted. One eye was randomly assigned for aspheric treatment and applying eye tracking system. The other eye was treated without torsional eye tracking system. The outcome measures were uncorrected visual acuity (UCVA), best corrected visual acuity (BCVA), contrast sensitivity, corneal irregularity index in 3 mm and 5 mm optical zones in Orbscan II, and mean total HOAs at the 6-monthvisit.

Results: Fifty eyes of 25 patients were enrolled. Mean UCVA was improved significantly in both the study and control groups in the 6-month post-operative follow-up. There was no significant difference between the 2 groups in UCVA and BCVA ($P = 0.185$ and $P = 0.176$, respectively). Total HOAs increased in both groups after PRK. However, they were lower in eyes treated with the eye tracking system ($P < 0.001$). Corneal irregularity index in 3 mm and 5 mm central zones in Orbscan II was significantly lower in the study group ($P = 0.045$ and $P = 0.031$ respectively). Contrast sensitivity function was not different in the 2 groups ($P = 0.15$).

Conclusion: Our study findings suggest that applying 'Technolas 217z' eye tracker system (Bausch and Lomb Advanced) results in a more regular anterior surface of cornea. Therefore, we recommend it for surface laser refractive surgery.

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Keywords: Photorefractive keratectomy; Visual function; Dynamic correction

Introduction

Excimer laser refractive surgery is one of the most popular procedures in the field of ophthalmology in recent decades. New techniques and new systems are developing constantly in this surgery to promote visual outcomes because most patients are young individuals who expect excellent results to enjoy the best possible quality of vision. The patient's unavoidable eye micro-movements is one of the problems that affects the post-operative

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quality of vision because it causes glare or astigmatism despite precise pre-operative measurements.^{1,2} Eye tracking systems have been developed to overcome this shortcoming; however, when we encounter patients with excessive eye movements, we still cannot be sure about the efficacy of these systems.

Dynamic registration can be achieved by engaging the laser radar eye tracker, which registers the wavefront determined laser shot pattern to its corresponding position on the cornea by overlaying the identification reticles. The first reticle is the limbus ring, which provides the xy alignment, and dynamically maintains that alignment throughout the tracking of the dilated pupil margin. The second reticle is the cyclorotation alignment, which is implemented by rotating the image of the limbus ring taken from the orientation marks recorded during the wavefront capture. They are overlapped with the actual ink marks that still remain on the eye.

In this way, true registration can be achieved dynamically, not only in XY orientation, but also statically with regard to cyclorotation. Registration and tracking based on iris detail will provide a alternative for dynamic capture of cyclorotation, as well.³

In order to understand the eye tracking systems, a number of terms need to be defined. These include sampling rate, latency, tracker type, and closed vs open loop tracking.

Sampling rate describes how often the tracker measures the eye's location. Tracking frequencies vary from 60 Hz, based on the frame rate of certain video camera trackers, up to 4000 Hz seen with laser-radar tracking.

Latency is the time required to determine the eye's location calculate the required response, and move the laser tracker mirrors to compensate for the new location.

Typical video camera eye tracking uses infrared light illumination of the iris against a dark pupil in most refractive surgical systems.^{3,4}

In 1994, Molebny presented an eye tracker system for excimer laser. He claimed his system provided an accuracy of 0.1 mm in eyes with ± 2 mm micromovements.³ Although several other eye tracking systems have been introduced to improve the accuracy of laser beam centeration, there is still a need for proving their efficacy.

After reviewing several databases including Pubmed, Scopus, and Google Scholar, to our knowledge, there is no comparative study on 'Technolas 217z' eye tracker system (Bausch and Lomb Advanced). This system is a dynamic rotational program that tracks and simultaneously adjusts the ablation pattern accordingly during the entire procedure.

Methods

This was a double-blind randomized interventional study. Twenty-five patients with compound myopic astigmatism were enrolled. The mean age was 29 years old (range: 18–40). The mean spherical equivalent (SE) of refractive error was -4.75 diopters (D) (range: -1.5 to -7.0), and the mean astigmatism was 3 D (range: 1.0–4). Patients with relative or absolute contra indications of refractive surgery including corneal ecstatic disorders, corneal haze and scar, autoimmune

disease, pregnancy, breast feeding, and moderate to severe dry eye were not enrolled. Exclusion criteria were: Best corrected visual acuity (BCVA) less than 10/10, more than 0.5 D inter-ocular refractive error disparity, unstable refractive error (>0.5 D change through the last year), high order aberrations (HOA) <0.2 and >0.5 μm root mean square (RMS), and inter-ocular disparity in HOAs more than 0.05 μm . Patients were excluded with central corneal thickness (CCT) <490 μm and predicted CCT <400 μm , also. Contact lens users were asked to cease wearing them from 1 month before imaging.

The study adhered to the tenets of the Declaration of Helsinki. The protocol was approved by the institutional review board and ethics committee of the Mashhad University of Medical Sciences and was designed and performed from June to January 2013 in Khatam-al-Anbia Eye Hospital.

A complete eye examination including uncorrected visual acuity (UCVA) and BCVA evaluation with Snellen chart, manifest, and cycloplegic refraction (Autokeratorefractometer TOPCON KR8800), contrast sensitivity assessment (CSV 1000, Haag-Streit, Harlow, UK), slit lamp examination, and applanation tonometry were performed. Corneal topography (TMS4, Tomey, USA), elevation-based corneal topography, Orbscan (Orbscan II Bausch & Lomb Germany), and wavefront aberrometry (Zywave II, Technolas, Bausch & Lomb Germany) were provided for each patient preoperatively. For the purpose of analysis, UCVA and BCVA were converted to a logarithm of minimum angle of resolution (logMAR).

Wavefront analysis was performed under mesopic conditions in the room light with a pupil diameter of approximately 6 mm. Total high order aberrations (3rd and 4th orders) were expressed as Zernike polynomial coefficient values and presented as RMS in micrometers.

Monocular contrast sensitivity evaluation was provided with best corrected distance vision. Correction spectacles without glare were put on for each patient. The standard 8-foot distance between the patient and chart was considered in all examinations. Contrast sensitivity values were presented in curves and then transformed into a logarithmic scale. Final analysis was based on area under log contrast sensitivity function (AULCSF).

One eye was randomly assigned for PRK with the eye tracker system 'on' and the other eye underwent laser ablation with torsional eye tracker 'off'. This allocation was not based on refraction, high order aberrations or eye dominance. The ablation protocol was 'aspheric' in both eyes. The patients and the examiners were masked to know which eye would be in the study group.

Post-operative visits were scheduled on days 1, 3, and 7 and the first, 3rd and 6th months after surgery. The outcome measures were UCVA, BCVA, contrast sensitivity, corneal irregularity index in 3 mm and 5 mm optical zones in Orbscan II and mean total HOA at the 6th months visit.

Treatment protocol

All the surgeries were performed by two experienced surgeons (S.Z.G & H.G) with Technolas 217z (Bausch & Lomb

Germany) flying spot excimer laser which applies laser in 193 nm wavelength. Pulse repetition was fixed at the rate of 100 Hz, and laser spot diameter was 1–2 mm. After sterile draping, corneal anesthesia was provided by tetracaine 0.5% eye drops, and the speculum was placed. Laser ablation (ablation zone: 6 mm) was first applied to the right eye and then to the left eye. The cornea was exposed to mitomycin-C 0.02% for 5 s per Diopter of treatment at the end of ablation. Bandage contact lenses were placed on the corneas after copious irrigation with balanced salt solution. Chloramphenicol 0.5% and betamethasone 0.1% eye drops 4 times daily were prescribed postoperatively. The contact lenses were removed after complete re-epithelialization (usually on the 7th day postoperatively). Chloramphenicol was discontinued as soon as the contact lens was removed, and betamethasone was replaced with fluorometholone 0.1% eye drop after 1 month. Fluorometholone was tapered over the next 2 months. Patients were encouraged to instill preservative-free artificial tears frequently in the first few months.

Statistical analysis: For statistical analysis, Snellen acuities were converted to a logarithm of the minimum angle of resolution (LogMAR) equivalent values. Statistical testing was performed with the Statistical Package for the Social Sciences, Windows version 16 (SPSS, Inc., Chicago, IL). Variables were expressed as mean ± standard deviation. ANOVA with repeated measures was performed for comparison of preoperative to postoperative data including refractions, aberrations, and contrast sensitivity. An independent sample T-test was used for comparisons between the groups. A *P*-value of ≤0.05 was considered statistically significant.

Results

Fifty eyes of 25 patients with the mean age of 29 years (rang: 18–40) were enrolled. There was no statistically significant difference between 2 eyes of each patients in terms of refractive error (sphere, cylinder, SE) (Fig. 1), keratometric power, central corneal thickness, and HOAs (*P* < 0.05, independent samples T-test). Table 1 shows the baseline characteristics of the study group and the control group.

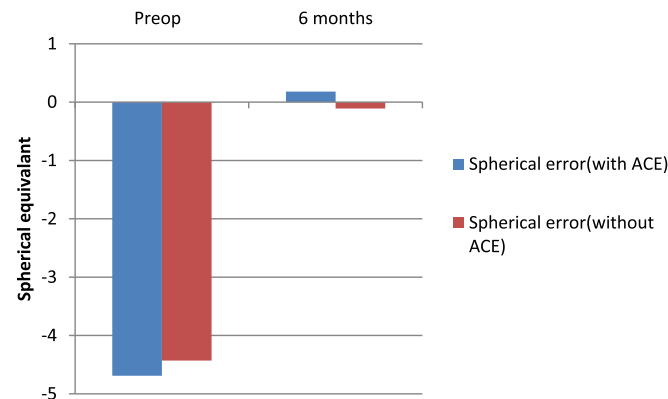


Fig. 1. Comparison spherical equivalent with and without applying torsional eye tracker. (ACE:Advanced Controlled Eye).

Table 1
Baseline characteristics of the study group and controls.

	With eye tracking system	Without torsional eye tracking system	<i>P</i> value
Mean spherical equivalent (D) ± SD	-4.69 ± 0.278	-4.43 ± 0.269	0.121
Mean cylinder (D) ± SD	2.81 ± 0.25	3.11 ± 0.19	0.076
UCVA (LogMAR) ± SD	0.86 ± 0.05	0.82 ± 0.05	0.114
BCVA (LogMAR) ± SD	0.001 ± 0.003	0.004 ± 0.004	0.153
HOAs(RMS) ± SD	0.08 ± 0.004	0.11 ± 0.03	0.081
Irregularity in 3 mm zone ± SD	0.58 ± 0.2	0.65 ± 0.3	0.088
Irregularity in 5 mm zone ± SD	0.79 ± 0.3	0.86 ± 0.3	0.102
AULCSF ± SD	2.791 ± 0.076	2.620 ± 0.058	0.073

In the 6th-month post-operative visit, the mean UCVA improved from 0.86 ± 0.05 to 0.004 ± 0.001 LogMAR in the eyes that underwent PRK with eye tracker kept ‘on’ (*P* < 0.001, paired samples T-test). In the second group (without torsional eye tracker system) the mean UCVA was 0.82 ± 0.05 before surgery and 0.005 ± 0.015 LogMAR (*P* < 0.001, paired samples T-test) (Fig. 2). There was no statistically significant difference in post-operative UCVA between the study group and the control group after 6 months (*P* = 0.185, independent samples T-test) (Table 2). Sixth-month post-operative BCVA was 0.002 ± 0.005 LogMAR in the study group and 0.008 ± 0.003 in the control group (*P* = 0.176, independent samples T-test).

Total high order aberrations increased in both groups after PRK. They were significantly lower in the study group (with eye tracker) than the control group (0.12 ± 0.006 VS 0.21 ± 0.1 RMS, *P* < 0.001) (Fig. 3).

Corneal irregularity index in 3 mm and 5 mm central zones in Orbscan II was compared postoperatively between the two groups. Eyes in the study group had a statistically significant lower irregularity in both the 3 mm and 5 mm central corneal zones (*P* = 0.045 and *P* = 0.031 respectively). Corneal haziness did not occur in any eye during the course of study.

The area under log contrast sensitivity function (AULCSF) analysis did not show a significant change after surgery, and

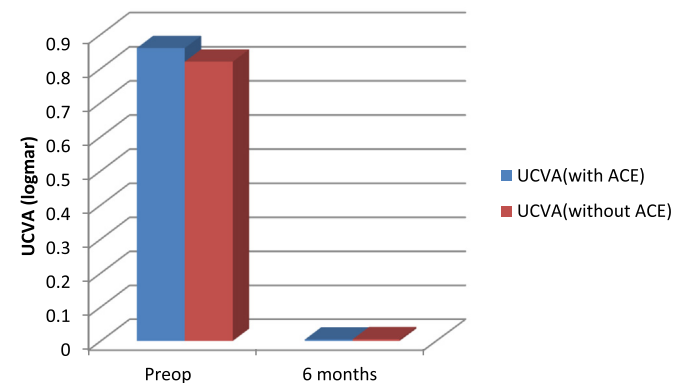


Fig. 2. Comparison UCVA, with and without applying torsional eye tracker. (ACE:Advanced Controlled Eye).

Table 2
Comparison of visual function and regularity parameters between study group and controls, 6 months after surgery.

	With eye tracking system	Without torsional eye tracking system	P value
Mean sphere (D) ± SD	+0.18 ± 0.06	−0.11 ± 0.04	0.08
Mean cylinder (D) ± SD	0.13 ± 0.03	0.22 ± 0.03	0.16
UCVA (LogMAR) ± SD	0.004 ± 0.001	0.005 ± 0.015	0.185
BCVA (LogMAR) ± SD	0.002 ± 0.005	0.008 ± 0.003	0.176
HOAs(RMS) in 6 mm zone ± SD	0.12 ± 0.006	0.21 ± 0.1	<0.001
Irregularity in 3 mm zone ± SD	1.1 ± 0.7	1.5 ± 0.9	0.045
Irregularity in 5 mm zone ± SD	1.1 ± 0.6	1.9 ± 0.5	0.031
AULCSF ± SD	2.821 ± 0.052	2.881 ± 0.049	0.091

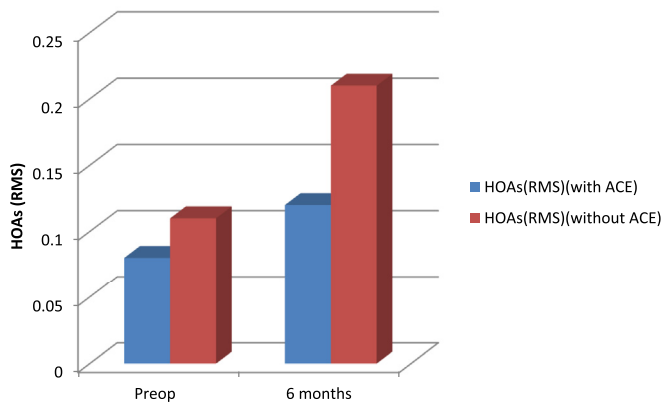


Fig. 3. Comparison RMS, with and without applying torsional eye tracker. (ACE:Advanced Controlled Eye).

there was no statistically significant difference between the study group and control group in terms of contrast sensitivity after 6 months ($P = 0.15$, T-test).

Discussion

In this study, we investigated whether or not new ‘Technolas 217z’ eye tracker system (Bausch and Lomb Advanced) could improve the HOA outcome and visual function after laser vision correction (LVC). Although UCVA was excellent in both the study group (with applying the eye tracker system) and the control group (without torsional eye tracker), total wavefront high order aberrations were significantly lower by applying the eye tracker system. Contrast sensitivity function was not different between the two groups.

LVC is believed to increase and induce new HOAs.⁴ Spherical aberration, an important component of HOAs, has a great influence on quality of vision after refractive surgery. Aspheric or Q-factor customized corneal ablation protocol has been developed to minimize the amount of spherical aberration.⁵ Wavefront-guided LVC was introduced several years ago to treat HOAs in addition to spherocylindrical refractive

errors. Although wavefront-guided treatment protocol is theoretically able to not only prevent induction of, but also reducing pre-existing HOAs, some previous studies did not prove this hypothesis. These studies have even reported an increase of 1.3–1.9 times in HOAs following Wavefront-guided LVC.^{6–9} A probable source of post-operative HOAs is subclinical decentration (lower than 1 mm), which does not affect refractive error correction. Mrochen et al⁴ suggested using eye-tracking systems to induce less HOAs by centering the ablation zone. Other studies have revealed an increase in cyclotorsional eye movements in supine position in comparison with upright position.^{5,10–12} Fea et al¹³ concluded that a 3D eye tracking system can improve surface ablation results when treating high astigmatism or applying wavefront guided protocol. Our study confirmed the results of the previous studies and showed lower HOAs when applying the eye tracking system in Technolas 217z. HOAs can impair visual performance despite good Snellen visual acuity. Contrast sensitivity is one of the aspects of visual performance which can be affected by excessive post-operative HOAs. Also the irregularity index in 3 and 5 mm optical zones was lower when applying the eye tracking system. These results show that using eye tracking system in surface ablation will result in a more regular cornea postoperatively. Although HOAs were significantly fewer in eyes that underwent PRK with eye tracking system in our study, visual acuity and contrast sensitivity function did not differ significantly between the study and control group. Therefore, we cannot conclude that applying the eye tracking system leads to better quality of vision after surface LVC.

Our study had some limitations. We did not evaluate other aspects of visual function which are important in daily life including night vision. The study population was also relatively small.

Our study findings suggest that applying ‘Technolas 217z’ torsional eye tracker system (Bausch and Lomb Advanced) results in a more regular anterior surface of cornea and is recommended for surface laser refractive surgery.

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