Visual outcomes of topography-guided photorefractive keratectomy for treatment of patients with irregular cornea

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Background
Irregular corneal astigmatism has caused a challenge to the refractive surgeons for a long time. Conventional laser ablation is usually not useful in treatment of corneal irregular astigmatism. Advanced topography-guided ablation which deals with the corneal irregularity has shown good results in the past few years.

Aim
To evaluate the efficiency of the topography-guided photorefractive keratectomy (PRK) for the treatment of irregular corneas with respect to the visual acuity and quality.

Settings
A prospective interventional case series study was performed at El Noor Ophthalmology Center from March 2017 to March 2018.

Patients and methods
This study included 20 consecutive eyes of 12 patients with irregular cornea who were deemed candidates for PRK correction. All patients underwent advanced topography-guided PRK. Visual acuity and refractive errors were assessed. Topographic examination with asphericity and regularity were evaluated using Pentacam.

Results
At 3 months, the mean uncorrected visual acuity improved from preoperative 0.13±0.12 (Decimal) (range: 0.05–0.5) to 0.79±0.12 at 3 months postoperatively (Decimal) (range: 0.6–0.9). The refractive error improved from preoperative sphere of −3.1±1.7 D (range: −5.75 to +3.00 D) to −0.03±0.36 D (range: −0.25 to +1.25 D) at 3 months postoperatively and from preoperative cylinder of −1.32±1.1 D (range: −4.5 to −0.5 D) to −0.28±0.4 D (range: −1.75 to 0.00 D) at 3 months postoperatively. Corneal asphericity, as measured by the *Q* value, improved from 0.34±0.31 preoperatively to −0.45±0.28 at 3 months postoperatively. Index of surface variance showed a decrease from 25.2±12.3 to 20.4±3.8.

Conclusion
Advanced topography-guided PRK using OCuLink is a good method in the treatment of irregular cornea owing to different reasons, with improvement of both visual acuity and quality.

Keywords:
irregular cornea, OCuLink, photorefractive keratectomy, topography guided

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Introduction

Irregular astigmatism was and is still a major challenge for ophthalmology surgeons. Poor visual quality achieved with glasses is a source of great frustration to the patients with irregular astigmatism owing to high-order aberration (HOAs). However, rigid contact lenses (CLs) are a good substituent for glasses, and most of the patient came back to the clinic with discomfort and noncompliance [1].

Conventional laser surgeries were really a revolution in the treatment of the refractive errors, but it still cannot deal with HOA [2].

This forced ophthalmology surgeons to seek an alternative method to treat irregular astigmatism, a method that ensures satisfactory visual acuity and also quality of vision [3–5].

Ultimately, technological advances led us to two most promising customized approaches: based on wavefront measurements and based on corneal topography. Topography-guided ablation can deal with aberrations that are higher than the ability of the current wavefront sensors [6].

The advantage of OCuLink treatment is that the Oculyzer can record a large number of data points from the corneal surface, especially within the pupil area [7].

Patients and methods

In a prospective interventional case series study, 20 (nine right and 11 left) consecutive eyes of 12 patients underwent advanced topography-guided photorefractive keratectomy (PRK) using OCuLink (TG-PRK) (Oculink, version II, Alcon, Fortworth, Texas, USA) between March 2017 and March 2018. Mean patients' age was 25.9 ± 3.7 years (range: 22–31 years). Included patients were candidate for PRK, above 18 years old, with irregular cornea owing to irregular ablation in pervious surgery, shallow corneal scars, and trauma.

Exclusion criteria were corneal scars or haze that disturbs the quality of topographic images, corneal ectasia, pervious ablations leaving a residual corneal thickness bed less than 280 μm after treatment, and autoimmune diseases. All patients were informed to the experimental nature of the study, and written consent was obtained before surgery. The study received the approval of Assuit Medical School Ethical Review Board with approval number IRB00008718 and is registered on ClinicalTrials.gov ID: NCT03140046.

Preoperative measurements included uncorrected visual acuity (UCVA), best spectacle-corrected visual acuity, manifest and cycloplegic refraction, slit-lamp examination with fundus evaluation, and corneal topography.

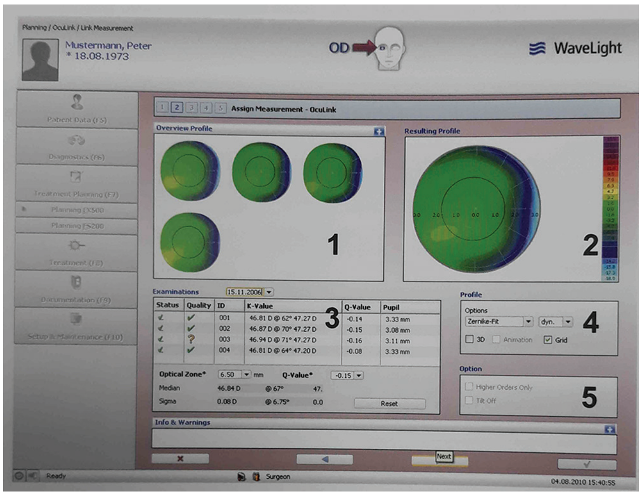
Five repeatable and highly reproducible topography maps were obtained, aligning the measurement to the line of sight that passes through the pupil center. Only topographies with QS = OK of the corneal surface mapped were included as data for the treatment. The topography height maps were exported to the WaveLight laser system using OCuLink software (Fig. 1).

One drop of proparacaine 0.5% was instilled in each eye 5 min before and just before the procedure. Eyelashes were isolated by a drape and a speculum. The corneal epithelium was removed with a hockey-knife. The ablation profile is calculated from height maps obtained with the Oculyzer and exported to the WaveLight Laser System by the OCuLink.

To perform the surgical plans, a protocol was followed stepwise according to topography neutralization technique in one-step ablation technique with no modification [8].

(1) Initially, the surgeon evaluated the treatment plans produced by the Oculyzer (OCuLink) (Oculyzer, Wave Light, Alcon, Fortworth, Texas, USA) without information about manifest refraction (manifest refraction is entered as zero or plano). The correction of the irregularity induces a shift in refraction. Manifest refraction should not be initially entered; otherwise, it can induced a refractive error.
(2) Second, the induced change in sphere and the needed amount of treatment to compensate for it were identified. This is performed by adjusting the spherical equivalent (C12) and sphere (C4) (from the Zernike profile) until they are similar.
(3) Finally, the manifest refraction was added to calculate the final treatment.

Figure 1



Allegretto WaveLight EX500 Laser system showing exported images obtained by the Oculyzer and exported by OCuLink [9].

The ablations were made with the Allegretto EX500 (WaveLight EX500; Alcon, Fort Worth, Texas, USA), which used a flying spot laser of 0.95-mm diameter with a Gaussian energy profile, 500-Hz repetition rate, and an active videobased 250-Hz eye tracker (Fig. 2).

Stroma was copiously irrigated by 10 ml of chilled BSS to inhibit keratocytes apoptosis. Chilled or iced BSS is believed to decrease the postoperative haze and pain. Finally, a soft bandage CL was placed.

Postoperatively, we told each patient that there would be a period of discomfort the first few days following the procedure. Patients were warned to wear sunglasses and avoid extreme sun exposure during the first postoperative year, as there is a direct link between UV exposure and increased corneal haze following surface ablation. Antibiotic eye drops were administered four times a day for 2 weeks. Artificial tears eye drops were administered six times a day for a month. Steroid eye drops is typically tapered over a period of 4–8 weeks based on the amount of treatment and the postoperative refraction. The dosage of the steroid is adjusted based on (a) corneal haze and (b) refractive outcome. The follow-up was performed at 24 h, 1 week, 1, and 3 months. The statistical significance of outcomes [visual acuity, refraction, Q value and index of surface variance (ISV)] from the data sample was determined by Student's t-test of SPSS software version 22.0 (IBM Corporation, Armonl, New York, USA). P values less than 0.05 were considered statistically significant. ISV is the unit-less SD of individual corneal sagittal radii from the mean curvature. ISV is thus an expression of the corneal surface irregularity. According to the manufacturer's user manual, it is elevated in all types of corneal surface irregularity (e.g. scars, astigmatism, and deformities caused by CLs) [9].

Results

The mean UCVA kept improving during the follow-up at 1 week, 1 and 3 months. At 3 months, the mean UCVA improved from 0.13 ± 0.12 (Decimal) (range: 0.05–0.5) preoperatively to 0.79 ± 0.12 (Decimal) (range: 0.6–0.9) postoperatively. Using Student t-test of SPSS software, a statistically significant increase was noted in UCVA at 1 week, 1, and 3 months compared with preoperative UCVA (P = 0.002, 0.001, and 0.001, respectively) (Table 1).

The UCVA reached significance compared with preoperative BCVA only at 3 months postoperatively (P = 0.005). No eyes lost more than two lines of visual acuity. One eye lost one line, and one eye lost two lines. Eight eyes maintained their visual acuity (Fig. 3).

Ten eyes gained two, three, and four lines of VA, respectively. The mean gain at 3 months was 1.2 line of VA.

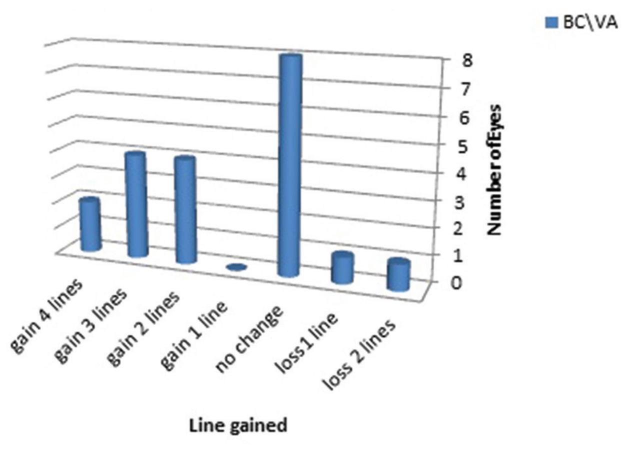
The mean refractive error (sphere and cylinder) kept improving during the follow-up at 1 week, 1, and 3 months. At 3 months, the refractive error improved from preoperative sphere of −3.1 ± 1.7 D (range: −5.75 to + 3.00 D) to −0.03 ± 0.36 D (range: −0.25 to + 1.25 D) postoperatively and from preoperative cylinder of −1.32 ± 1.1 D (range: −4.5 to −0.5 D) to − 0.28 ± 0.4 D (range: −1.75 to 0.00 D) postoperatively. Using Student t-test of SPSS software, an improvement was noted in sphere at 1 week, 1, and 3 months compared with preoperative sphere (P = 0.002, 0.001, and 0.001, respectively) (Table 2).

There was also a statistically significant decrease in cylinder (P = 0.004, 0.002, and 0.001, respectively). Spherical equivalent was −3.79 ± 1.66 D (range: −6.75 to −1.125 D) preoperatively and improved to −0.18 ± 0.27 D (range: −0.375 to –0.8 D) at 3 months (Fig. 4).

Figure 2

Allegretto WaveLight EX500 Laser system showing the ablation profile [9].

Figure 3



Gain and loss of lines of visual acuity at 3 months after advanced topography-guided (OCuLink) photorefractive keratectomy. BCVA, best-corrected visual acuity.

Table 1 Mean values of visual acuity of patients before advanced topography-guided (OCuLink) photorefractive keratectomy and after 1 week, 1, and 3 months of follow-up

	Preoperative	One week (UCVA)	One month (UCVA)	Three months (UCVA)
UCVA (Decimal)	0.13±0.12	0.48±0.15 P=0.002 (S)	0.67±0.17 P=0.001 (S)	0.79±0.12 P=0.001 (S)
BCVA (Decimal)	0.68±0.2	0.48±0.15 P=0.09 (NS)	0.67±0.17 P=0.127 (NS)	0.79±0.12 P=0.005 (S)

Data were expressed in the form of mean±SD. P; Student t-test was used to compare between visual acuity before treatment with topography-guided photorefractive keratectomy and after 1 week, 1, and 3 months of follow-up. BCVA, best-corrected visual acuity; UCVA, uncorrected visual acuity. P<0.05, statistical significant (NS; S; significant).

Table 2 Mean values of refractive errors of patients before advanced topography-guided (OCuLink) photorefractive keratectomy and after 1 week, 1, and 3 months of follow-up

	Preoperative	One week	One month	Three months
Sphere (D)	−3.1±1.7 (−5.75 to 3.00)	−0.58±0.87 (−1.25 to 1.75) P=0.002 (S)	−0.27±0.54 (−0.75 to 1.25) *P*=0.001 (S)	−0.03±0.36 (−0.25 to 1.25) *P*=0.001 (S)
Cylinder (D)	−1.32±1.11 (−4.5 to−0.5)	−0.77±0.75 (−3.5 to−0.25) P=0.004 (S)	−0.54±0.54 (−2.5 to 00) *P*=0.002 (S)	−0.28±0.4 (−1.75 to 00) *P*=0.001 (S)
Spherical equivalent	−3.79±1.66 (−6.75 to 1.125)	−0.9±0.6 (−1.6 to 0.5) P=0.003 (S)	−0.54±0.39 (−1.00 to 0.375) *P*=0.002 (S)	−0.18±0.27 (−0.375 to 0.8) *P*=0.002 (S)

Data were expressed in the form of mean±SD. *P*; Student *t*-test was used to compare between refractive errors before treatment with topography-guided photorefractive keratectomy and after 1 week, 1 month, and 3 months of follow-up. *P*<0.05, statistical significant (NS; S, significant).

Table 3 Mean values of *Q* value and index of surface variance of patients before advanced topography-guided (OCuLink) photorefractive keratectomy and after 1 week, 1, and 3 months of follow-up

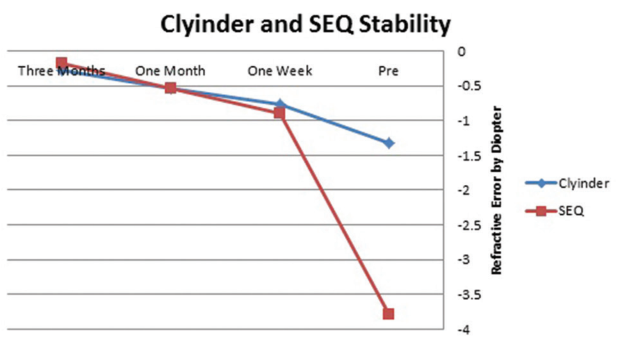
	Preoperative	One week	One month	Three months
Q value	0.34±0.31	−0.45±0.33	−0.50±0.37	−0.45±0.28 *P*=0.009 (S)
Index of surface variance	25.2±12.3	22.9±5.7	22.75±6.85	20.4±3.28 *P*=0.3 (NS)

Data were expressed in the form of mean±SD. *P*; Student *t*-test was used to compare between *Q* value and index of surface variance before treatment with topography-guided photorefractive keratectomy and after 1 week, 1, and 3 months of follow-up. *P*<0.05, statistical significant (NS; S, significant).

Corneal asphericity, as measured by the *Q* value, improved from 0.34 ± 0.31 preoperatively to −0.45 ± 0.28 at 3 months postoperatively, with a statistically significant difference (*P* = 0.009). ISV mean of values showed a decrease from 25.2 ± 12.3 preoperatively to 20.4 ± 3.8 at 3 months postoperatively, without reaching a statistically significant difference (Table 3 and Fig. 5).

The subjective symptoms such as glare, haloes, ghost images, and monocular diplopia disappeared in 13 (65%) eyes of patients. A total of five (25%) eyes of the cases showed obvious alleviation of the symptoms. Only two (10%) eyes showed the presence of the symptoms with no change. One of the problems faced by us in the use of the topography-guided PRK was in the ability to have topography images, with QS = Ok in cases of irregular cornea after pterygium surgery, even after 6 months of follow-up (Fig. 6).

Figure 4



Stability of spherical equivalent (SEQ) refraction and cylinder over time after advanced topography-guided photorefractive keratectomy (OCuLink).

Discussion

Irregular astigmatism was always an issue that forced ophthalmologists to seek an effective method not only to improve the visual acuity but also to give a quality of vision and correct the HOA by smoothening the corneal surface [10].

In this study, 20 eyes of 12 patients underwent advanced topography-guided PRK (OCuLink). We performed PRK because it remains an excellent option for mild to moderate corrections, particularly for cases associated with thin corneas in previously operated patients and recurrent erosions.

Lin *et al.*[8] evaluated the clinical outcomes of custom topographic neutralizing technique in treating highly aberrated eyes using the WaveLight Allegretto Wave Excimer Laser retrospectively and reported that safety was acceptable for small optical zone and decentered ablation retreatments. In this study, we used custom topographic neutralizing technique.

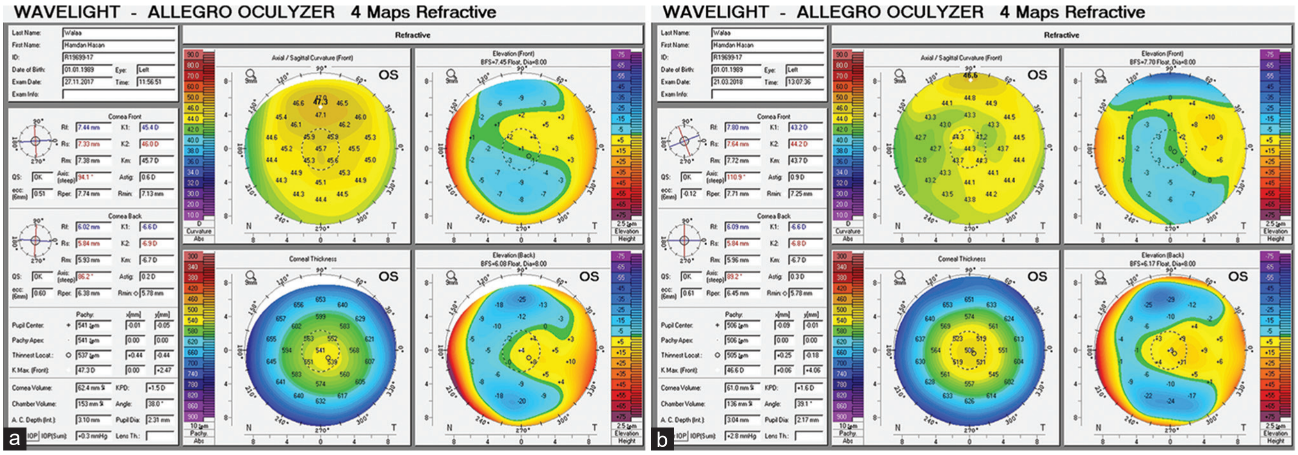
In this study, there was an improvement, with a statistically significant difference in visual acuity at 1 week, 1, and 3 months compared with BCVA before surgery (*P* = 0.002, 0.001, and 0.001, respectively, using Student *t*-test of SPSS).

No eyes lost more than two lines of visual acuity, whereas ten eyes gained two, three, and four lines of visual acuity, respectively.

Cummings and Mascharka[7] in their study showed that most patients (55%, 11 patients) achieved a UCVA of 20/15, but BCVA preoperatively and postoperatively were the same.

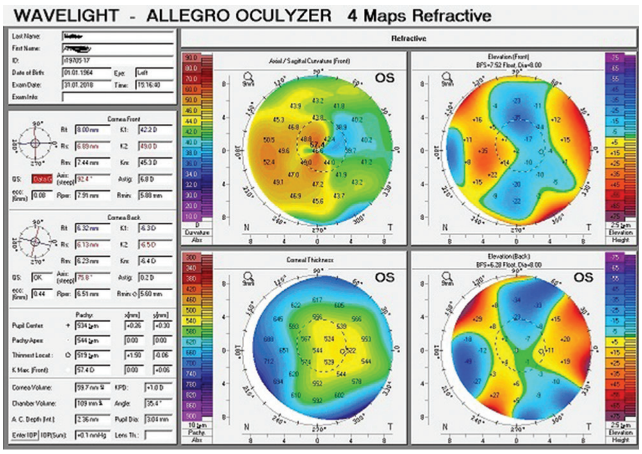
Gao *et al.*[11] in their study using OCuLink for treatment of irregular astigmatism showed

Figure 5



(a) Allegro Oculyzer data showing preoperative topographic image of one of patient included in the study. (b) Allegro Oculyzer data showing postoperative topographic Image.

Figure 6



Allegro Oculyzer data showing topographic image after pterygium surgery at 6 months of follow-up.

improvement in the refractive error sphere at 1 month and cylinder at 6 months. Spherical equivalent also improved. There was no significant difference between postoperative 1 and 6 months in the spherical equivalent ($P = 0.05$). Unexpected refractive error of 1 D spherical was induced, causing the loss of one line of UCVA.

This study showed a decrease in the error of refractions (sphere, cylinder, and spherical equivalent), with a statistically significant difference at 1 week, 1, and 3 months compared with those before surgery [in sphere, $P = 0.002$, 0.001, and 0.001, respectively; in cylinder, $P = 0.004$, 0.002, and 0.001, respectively; and in spherical equivalent, $P = 0.003$, 0.002, and 0.002, respectively).

In this study, corneal asphericity, as measured by the Q value, improved from 0.34 ± 0.31 preoperatively to −0.45 ± 0.28 at 3 months, with a statistically significant difference ($P = 0.009$). Although the desired Q value was not exactly met in most cases, a shift of the Q value toward the targeted direction was noted (i.e. more negative Q-values provided more prolate corneas). Gao *et al.*[11] in their study using OCuLink for treatment of irregular astigmatism showed that corneal asphericity, as measured by the Q value, improved from 1.71 to 0.61 (range: 1.30–2.68) preoperatively to 0.74 to 0.72 (range: 20.58–1.85) at 6 months, with a statistically significant difference ($P = 0.019$) [8]. Cummings and Mascharka[7] in their study customized the Q-value with primary treatments, and the targeted Q value was entered as the preoperative value.

One of the problems faced by us in the use of the topography-guided PRK was in the ability to have topography images, with QS = Ok in cases of irregular cornea after pterygium surgery even after 6 months of follow-up. This results showed a significant value to use topography-guided PRK in the treatment of irregular cornea owing to scars, trauma, and pervious refractive surgeries (irregular ablation), with improvement in visual acuity, refractive state, and corneal topography and also improvement of quality of vision. Overall, this technique was shown to be a valuable method, and further studies of larger sample sizes and longer follow-up are warranted to further evaluate the role of this surgery in the management of patients with irregular astigmatism.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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