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Vector analysis of changes in corneal astigmatism following lateral tarsal strip procedure in patients with involutional ectropion or entropion

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Abstract

Purpose To perform vector analysis of changes in corneal astigmatism and evaluate changes in corneal topographic parameters following the lateral tarsal strip (LTS) procedure in patients with involutional ectropion or entropion.

Methods Nineteen eyes of 15 patients (10 eyes with ectropion and 9 eyes with entropion) were included in this prospective nonrandomized interventional case series. Corneal topographic measurements (Tomey TMS 4a topographer, Tomey Corp, Nagoya, Japan) were performed at the baseline and 3 months after the LTS procedure. Relevant changes in the topographic astigmatism magnitude or axis (defined as a change more than 0.2 D or a shift in the axis greater than 10°, respectively) were analyzed following surgery. Polar astigmatic vector analysis was performed using the Astig PLOT software to calculate surgically induced astigmatism (SIA).

Results There were no significant changes in average keratometry, steep and flat meridian keratometric values, absolute cylinder, surface regularity index and surface asymmetry index after the surgery (All $P > 0.05$). A relevant change in the magnitude of astigmatism and an axis change greater than 10° occurred in 14 (73.6%) and 10 (52.6%) of the operated eyes, respectively. Polar vector analysis revealed that SIA was 0.47 ± 1.34 D at $91 \pm 23°$, indicating induction of "with the rule" astigmatism following the surgery.

Conclusion The LTS procedure for the correction of involutional ectropion or entropion could induce relevant changes in corneal astigmatism, sufficient to affect visual function in short term. Longer-term follow-up is required to further characterize the effect of LTS procedure on the corneal topographic features.

Keywords Lateral tarsal strip · Corneal astigmatism · Vector analysis

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Introduction

Ectropion is defined as outward rotation of the eyelid margin, and entropion is any form of the inverted lid margin. The most prevalent form, involutional ectropion or entropion are common age-related eyelid malpositions affecting 3 and 2% of the elderly population, respectively [1]. The primary pathology in both conditions is attributed to the horizontal eyelid laxity [2]. Several procedures have been introduced to combat lid laxity including horizontal lid shortening,

resection of the orbicularis muscle with or without tightening, reattachment of lid retractors (in case of entropion) and lateral tarsal strip (LTS procedure). The latter is a well-recognized procedure that addresses horizontal eyelid laxity, as a major contributing factor in involutional ectropion and entropion, by fixation of the tarsus to the periosteum of the lateral orbital rim [3].

There is evidence that eyelid morphology exerts a significant effect on the corneal shape, including corneal astigmatism [4–6]. Several investigations after different surgeries like ptosis surgery [7, 8], chalazion excision [9] and orbital decompression [10, 11] have shown that lid position changes after surgery could affect the corneal shape. The change in the amount and direction of pressure following surgery applied by the eyelid onto the cornea is the probable explanation for these observations. The main goal of the LTS procedure is to decline laxity and restore the tightened lid at the right position; therefore, it is rational to assume that corneal topographic measurements might change after surgery.

Although several investigations have evaluated the effect of various eyelid surgical procedures on corneal topography and refraction [4–11], there is limited data about topographic changes following the LTS procedure in patients with involutional lid pathology [12]. Moreover, to the best of our knowledge, this is the first study to compare the effect of lid repositioning in two common involutional lid pathologies, ectropion and entropion. In addition, we performed vector analysis that provides data regarding the effect of surgery on probable shifts of power and axis in astigmatism.

Materials and methods

This prospective nonrandomized interventional study was performed to investigate the effect of the LTS procedure on the corneal topographic parameters. The study was conducted in Farabi Eye Hospital, a tertiary center in Tehran, Iran, between December 2015 and October 2016. Local Ethic Committee of Tehran University of Medical Sciences approved the design and protocol of the study and written informed consent was obtained from all participants. All procedures were consistent with the tenets of Helsinki Declaration.

Study population

Patients with involutional ectropion or entropion who had horizontal lid laxity with no cicatricial changes of the lower lid skin and conjunctiva were included in this study. Horizontal lid laxity was evaluated with the snap-back test (defined as the delayed return of the lower lid following retraction from the corneal surface) and pinch test (the ability to retract the lower lid more than 6 mm from the corneal surface). Exclusion criteria were ocular surface pathologies including significant dry eye, corneal abrasion, pterygium, corneal scar and opacity, irregular pattern on topography, other forms of ectropion/entropion including significant medial canthal laxity and cicatricial changes, and any history of lid or eyeball surgery and trauma. The medial canthal tendon laxity was assessed by the lateral distraction test. Patients with more than moderate medial canthal tendon laxity, as defined by observation of the lower punctum crossing from the medial limbal border, were excluded from the study.

All patients underwent a thorough ophthalmic examination including slit-lamp biomicroscopy, visual acuity testing, intraocular pressure measurement, automated refraction and corneal topographic assessment.

Corneal topography assessments

Corneal topography was assessed using the Tomey TMS 4a topographer (Tomey Corp, Nagoya, Japan) by a single experienced technician. A standard map with an absolute scale was used to obtain topography scans. In order to eliminate the effect of minimal tear abnormalities on topographic findings, artificial tears were instilled before imaging. Topography was obtained at least four times; then, the parameters were checked for reproducibility and the best quality image was selected. The following topographic parameters were evaluated: simulated keratometry with average keratometry (AveK), steep keratometry (Ks), flat keratomery (Kf), steepest axis (SA), total corneal cylinder (Cyl), surface asymmetry index (SAI) and surface regularity index (SRI).

Surgical technique

The standard LTS procedure [3] was performed by a single surgeon (MJT). Under local anesthesia, a lateral canthotomy cut was made to the orbital rim. The eyelid was split to separate the anterior lamella from the posterior lamella. The tarsus was freed from the retractors and conjunctiva along the inferior border and posterior surface and a strip of the marginal epithelium were cut. The tarsal strip was attached to the periosteum of the lateral orbital rim with a 4.0 Mersilene suture. The lateral canthal angle was reformed, and the skin was sutured with 6.0 vicryl suture. After the operation, patients were treated with topical steroid and antibiotic.

Outcome measures

Three months after the surgery, corneal topography was repeated. Changes in corneal topography indices were compared with baseline measurements. A relevant change in astigmatism was defined as a change more than 10° in the axis and more than 0.2 D in power, since lower changes of the axis and power might not affect visual acuity significantly [10, 13]. Polar astigmatic vector analysis was done using the Astig PLOT software to calculate surgically induced astigmatism (SIA).

Statistical analysis

PASW Statistics for Windows version 18.0 (SPSS, Inc., Chicago, IL, USA) was used for statistical analysis. The normality of the data was checked with the Kolmogorov–Smirnov test. Chi-square test was used to compare proportions. Data with normal distribution were analyzed with t test and paired t test. In case of nonparametric distribution of the data, Wilcoxon Rank and Mann–Whitney U tests were used for comparison. A P value less than 0.05% was considered statistically significant.

Results

Nineteen eyes of 15 patients with involutional ectropion or entropion (10 and 9 eyes, respectively) were recruited in this study. Mean age was 82.6 ± 5.2 years, and 12 (80%) of patients were male. Statistical analysis revealed no significant difference among patients with ectropion and entropion in the baseline topographic measurements except for SRI (1.29 ± 0.73 and 0.22 ± 0.17, respectively ($P = 0.02$). LTS procedure was successful in all patients with occasional negligible overcorrection or under correction.

Table 1 demonstrates topographic values of AveK, Ks, Kf and Cyl parameters following LTS procedure. Compared to baseline measurements, none of these values had a significant change. Keratometry of steep meridian was 45.95 ± 1.33 D before surgery and 46.12 ± 2.02 D following surgery ($P = 0.11$). Baseline flat meridian keratometry was 44.33 ± 1.97 D and 44.50 ± 1.24 D following surgery ($P = 0.41$). As depicted in Fig. 1, although the LTS procedure is suggested to have a steepening effect on corneal topography in patients with both ectropion and entropion, these effects were not statistically significant ($P = 0.22$). The absolute cylinder power (Cyl) was 1.62 ± 1.27 D before surgery and remained relatively unchanged following the surgery (1.60 ± 1.03 D, $P = 0.92$). There was no statistically significant difference in the changes of these parameters between ectropion and entropion groups (Table 1).

Fourteen eyes (73.6%) had relevant changes in the astigmatism power more than 0.2 D. Six patients (66%) with ectropion and 4 out of 10 patients with entropion had an axis change more than 10° (Table 2 and Fig. 2). Since the dominant effect in both eyes was clockwise rotation, it is conceivable that the effect of surgery is incyclotorsion in the right eye and excyclotorsion in the left.

Figure 3 demonstrates the scatter plot of polar astigmatic vectors of preoperative, postoperative, and calculated postoperative surgically induced astigmatism. Vector analysis showed that mean baseline astigmatism was 1.07 ± 1.79 D with a mean axis of $3 \pm 16°$ which changed to a mean power of 0.61 ± 1.84 D with a mean axis of $5 \pm 19°$ postoperatively. Accordingly, surgically induced astigmatism was 0.47 ± 1.34 D with an axis of $91 \pm 23°$, indicating that the procedure induces with-the-rule (WTR) astigmatism.

Preoperative SRI and SAI values were 0.86 ± 0.78 and 1.78 ± 2.41 that changed to 0.80 ± 0.72 and 1.73 ± 2.02 after the procedure, respectively ($P > 0.05$). Postoperatively, despite the decrease in

Table 1 Corneal topographic measurements at baseline and following lateral tarsal strip procedure

	Baseline				Postoperation			
	Total (mean ± SD)	Ectropion (mean ± SD)	Entropion (baseline) (mean ± SD)	P value (between groups baseline)	Total (mean ± SD)	Ectropion (mean ± SD)	Entropion (mean ± SD)	P value (between groups post-op)
Ks	45.95 ± 1.33	45.99 ± 1.99	45.92 ± 1.49	0.90*	46.12 ± 2.02	46.17 ± 1.22	46.08 ± 1.34	0.88*
Kf	44.33 ± 1.97	43.99 ± 2.46	44.72 ± 1.29	0.44*	44.50 ± 1.24	44.33 ± 1.95	44.70 ± 1.67	0.66*
AveK	45.14 ± 1.55	45.00 ± 1.76	45.31 ± 1.39	0.53*	45.79 ± 2.47	45.2 ± 1.51	46.39 ± 3.24	0.33*
Cyl	1.62 ± 1.27	2.00 ± 1.65	1.20 ± 0.48	0.18*	1.60 ± 1.03	1.82 ± 1.17	1.36 ± 0.87	0.35*
SRI	0.86 ± 0.78	1.29 ± 0.73	0.22 ± 0.17	0.02*	0.80 ± 0.72	1.10 ± 0.81	0.35 ± 0.20	0.07[†]
SAI	1.78 ± 2.41	2.27 ± 2.81	0.38 ± 0.16	0.14*	1.73 ± 2.02	2.55 ± 2.33	0.52 ± 0.16	0.08[†]

Ks, steep keratometry; Kf, flat keratometry; AveK, average keratometry; Cyl, total astigmatism; SRI, surface regularity index; SAI, surface asymmetric index

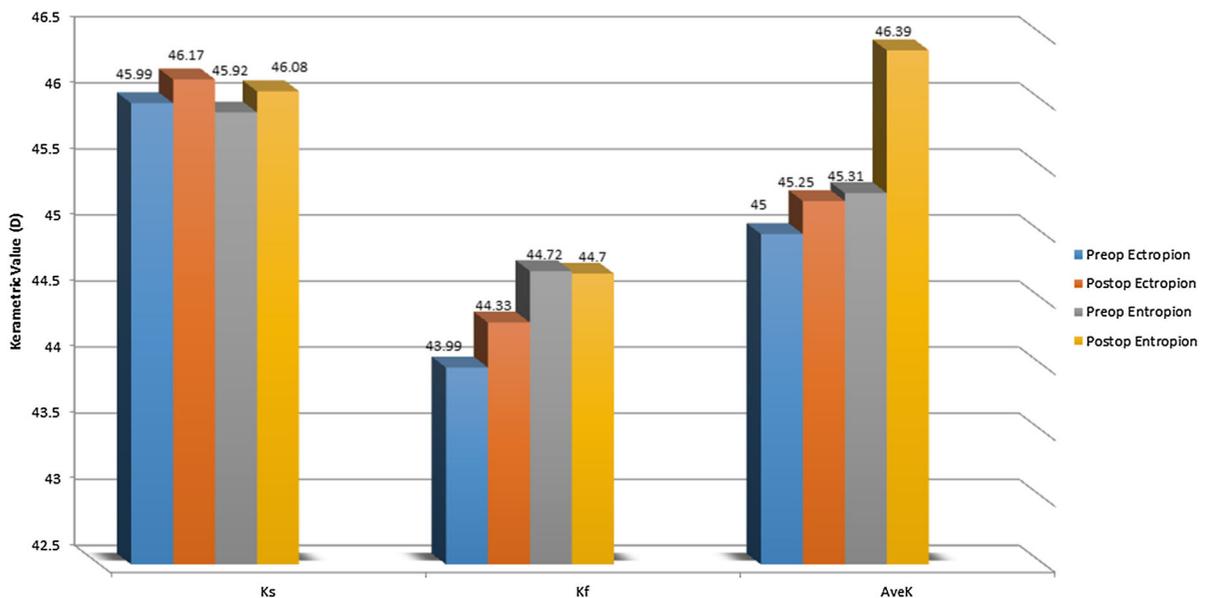*Groups compared with *t* test, [†]groups compared with Mann–Whitney *U*

Fig. 1 Alterations of keratometry values following LTS procedure in patients with ectropion and entropion. Ks, steep keratometry; Kf, flat keratometry; AveK, average keratometry

SRI and increase in the SAI in the ectropion group, and increases in SRI and SAI in the entropion group, the changes were not statistically significant ($P > 0.05$) (Table 1).

Discussion

Based on our findings, clinically relevant changes in the corneal astigmatism were observed following the LTS procedure. About 73.6% of the patients had relevant changes in astigmatism power more than 0.2 D and 52.6% of the patients exhibited an axis change more than 10°. The vector analysis also showed induction of WTR astigmatism with a mean cylinder

Table 2 Relevant astigmatism power and axis change following LTS procedure

	Ectropion	Entropion	P value
Astigmatism power change			
Number of relevant changes	8	6	
Relevant power change	0.79 ± 0.49	0.55 ± 0.73	0.15
Maximum decrease	1.6	0.9	
Maximum increase	1	2.4	
Astigmatism axis change			
Number of relevant change	6	4	
Mean axis change	23.2 ± 27.05	11.56 ± 9.82	0.90
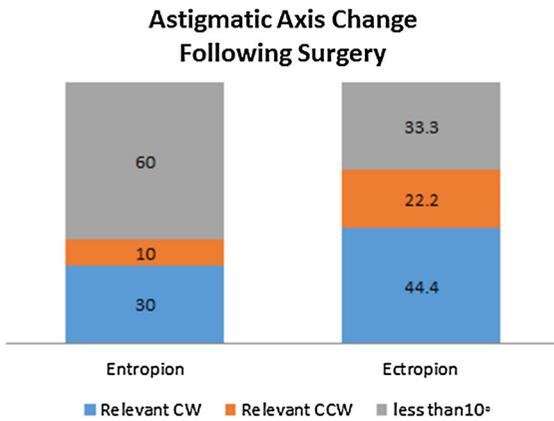
Fig. 2 Effect of surgery on axis change. Relevant axis change occurred in 66.6 and 40% of patients with ectropion and entropion, respectively. CW, clockwise; CCW, counter-clockwise

assessments in clinical practice like planning for astigmatic correction during cataract surgery, toric intraocular lens (IOL) implantation and refractive surgery, where accurate on-target results are of paramount importance.

We did not find significant changes in the average simulated keratometry after LTS surgery. Although a steepening trend was observed in both ectropion and entropion patients, the effect was not statistically significant which may be related to the small sample size and the wide range of variations in induced changes in our study. Similar effects on the average keratometry have been reported after upper eyelid blepharoplasty and ptosis surgery [14].

Polar astigmatic vector analysis using the Astig PLOT software showed a mean surgically induced astigmatism (SIA) of 0.47 ± 1.34 D with an axis of 91 ± 23°, suggesting that the procedure induced WTR astigmatism. It is also noteworthy that the magnitude of astigmatism measured by simulated keratometry did not change significantly after surgery,
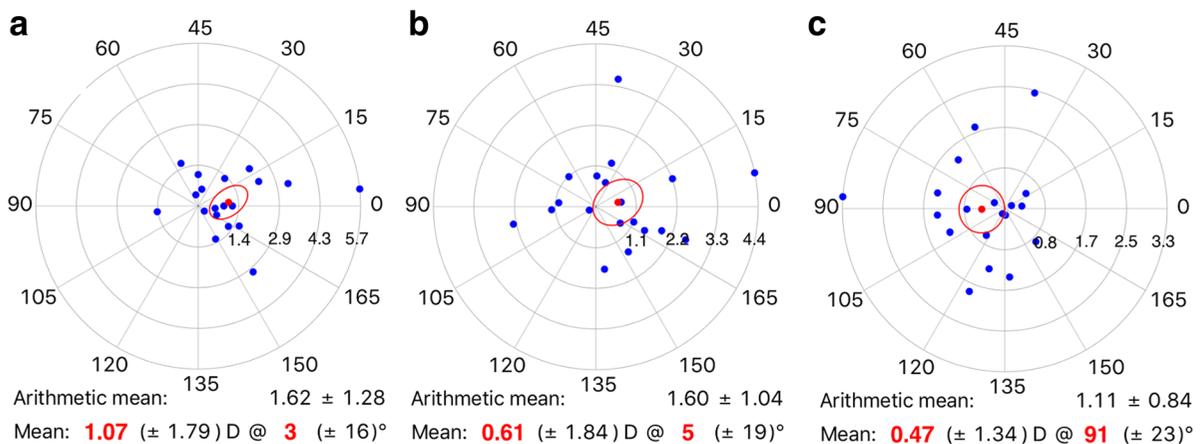
power of 0.47 D. These changes are not only enough to affect the visual function, but the magnitude of the changes is also sufficient to affect different aspects of

Fig. 3 Scatter plot of polar astigmatism before surgery (**a**), after surgery (**b**) and surgical induced astigmatism (**c**)

and only vector analysis method could demonstrate a systematic change in the magnitude and vector of astigmatism after surgery, highlighting the role of applying an appropriate method in astigmatic change analysis.

Since cylinder power changes as small as 0.2 D or axis changes more than 10° might affect visual acuity, our results underscore the importance of explaining the refractive outcome and possible changes in corrective glasses in detail to patients before the procedure.

Other than keratometric parameters, our study evaluated the effect of LTS surgery on topographic irregularity indexes of the cornea. SAI and SRI measure various topographic characteristics of the anterior corneal surface. SAI detects alterations in corneal asymmetry by comparing areas of the cornea 180° apart, and the SRI is a quantitative measure of the central and paracentral corneal regularity derived from the summation of variations occurring in the corneal power along semimeridians of 10 central photokeratoscope mires [15, 16]. It has been demonstrated that both variables have a negative association with best corrected visual acuity [17].

Baseline irregularity was significantly higher in patients with ectropion as compared to those with entropion. The difference between regularity indices in ectropion and entropion can be explained by the effect of the lower eyelid on the corneal surface. As postulated by Detorakis et al. [12], the lower lid is everted in involutional ectropion; therefore, the overall effect of the lid position on the corneal surface is asymmetric. However, the support of the lower lid on the corneal surface is maintained in entropion patients in comparison with ectropion.

Lid repositioning enhances the symmetric effect of the lid on the corneal shape and restores tear film structure and lower tear meniscus in patients with ectropion, the effect that may explain the decreasing trend in the SRI and SAI in ectropion patients. These findings are consistent with a previous investigation conducted by Detorakis et al. [12]. They evaluated the effect of surgical correction of involutional ectropion on corneal topography 6 months after the surgery. Their results demonstrated that regularity of astigmatism increased after treatment.

As a possible explanation for the observed changes in corneal astigmatism, it could be hypothesized that the LTS procedure brings the lower lid in close approximation to the corneal surface. In the new position, the lower lid, which has undergone horizontal tightening, applies pressure across the inferior limbus and globe, inducing a localized flattening near the inferior limbus area parallel to the horizontal meridian, with subsequent steepening of the vertical meridian and flattening of the horizontal meridian (coupling effect) in the central part of the cornea and induction of WTR astigmatism. Similar changes in the corneal astigmatism following increased compressive forces near the limbus like induction of WTR astigmatism related to repositioning of the eyelid after ptosis surgery [18], effect of filtering surgery [19], or changes in the corneal astigmatic vector in the direction of scleral buckle after scleral buckling surgery [20–22] are in agreement with this argument.

Similar to our results, Detorakis et al. [12] reported an increase in the proportion of the eyes with WTR astigmatism after LTS for lower lid ectropion repair. However, they did not find a systematic change in the astigmatism axis after surgery. This difference could be attributed to differences in the methods used for astigmatic analysis. Unlike our study, they did not perform vector analysis which clearly demonstrated the rotation of the astigmatic axes toward the 90° meridian postoperatively in our patients.

There are several limitations to our investigation. Our study had a small sample size and a short-term follow-up after surgery. We neither adjusted for the effect of the severity of lid pathology on the results nor did we consider the quantitative status of the tear film that might affect imaging findings. The effect of the surgery on the position of the lower eyelid like changes in marginal reflex distance is another factor that may affect the results. In addition, wound healing could also have an impact on the topographic changes following surgery. In this study, we evaluated the topographic changes at 3 months after the surgery, which the relatively tight scar tissue could affect the corneal topography. Studies with larger sample sizes and longer follow-ups are needed to further characterize the effect of LTS procedure on the corneal topographic features.

In conclusion, our study demonstrated significant changes in corneal topographic astigmatism after the LTS procedure. A significant proportion of patients demonstrated relevant changes in the magnitude or a shift in the astigmatism axis, with the vector analysis demonstrating a significant WTR pattern of surgically

induced astigmatism. The observed changes in the corneal astigmatism are sufficient to affect visual function and planning for procedures like cataract and refractive surgery.

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