Differential time-course tear film quantitative changes following limbal relaxing incisions

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Abstract

Background: The study aims at evaluating the time-course changes of pre-corneal tear film after simultaneous phacoemulsification and limbal relaxing incisions (LRIs) performed in 2 groups of patients; group-A had vertical and group-B had horizontal LRIs.

Methods: Forty-two eyes of 28 patients with co-existing cataract and corneal astigmatism were studied before and after simultaneous cataract surgery and LRIs (at weeks 1, 4 and 12), patients were classified into 2 groups according to the orientation of LRIs; vertical (A) and horizontal (B) groups. Pre-corneal tear film stability was assessed by measuring the tear break-up time (TBUT) and the tear volume was determined using Schirmer’s I test (Basic Schirmer’s test; BST), both preoperatively and postoperatively.

Results: TBUT was significantly reduced in both the study groups ($P = 0.001$) without significant reduction regarding basic Schirmer’s test values except for the first postoperative week in the horizontal LRI group-B ($P = 0.04$).

Conclusions: Precorneal tear film stability is altered in the early postoperative period after simultaneous cataract and LRI incisions shown by TBUT measurement values. These changes do not appear to differ significantly depending on the orientation of LRI incisions.

Keywords: Corneal astigmatism, Limbal relaxing incisions (LRIs), Basic Schirmer’s test (BST), Tear break-up time test (TBUT)

Background

Microscopic damage to the ocular surface during cataract surgery is a widely established theory of postoperative dry eye syndrome resulting in ocular discomfort and dissatisfaction [1].

Conical astigmatism of variable degree; ranging between 1and 3 diopters; has been found to be coexistent in up to 29% of patients who are complaining of lenticular opacities and probably would undergo cataract surgery [2–4].

Phacoemulsification; the modern cataract surgery; with intraocular lens implantation has been considered the gold standard treatment of cataract. The standard cataract procedure was simply targeting to correct spherical equivalent refractive error without considering a coexisting corneal astigmatism. Cataract surgery could be an aggravating factor of a pre-existing corneal astigmatism for the incisional nature of the procedure or a precipitating factor for a de novo surgical-induced astigmatism of a variable degree. Postoperative patient’s satisfaction after cataract surgery is basically related to achieving optimal postoperative distant visual acuity without the need to be spectacle or being contact lens-dependent.

Despite recent improvements in surgical techniques,
they run in the horizontal direction \([14]\). According to that, hours) direction and after a second bifurcation again, they do travel in the vertical (6 and 12 o’clock) positions \([12, 13]\); however; other authors reported that nerve fiber bundles in the sub-basal plexus across the central and mid-peripheral cornea run first in the horizontal direction, then after bifurcation, they do travel in the vertical (6 and 12 o’clock hours) direction and after a second bifurcation again they run in the horizontal direction \([14]\). According to that we postulated that there may be differential changes after performing LRIs in different orientations regarding the ocular surface quality profile. The aim of this study is to longitudinally assess the pre-corneal tear film changes in eyes undergoing simultaneous phacoemulsification and LRI procedures and to investigate whether these changes may vary according to the orientation of LRIs.

**Methods**

**Study design**

Prospective observational case series.

**Subjects**

Forty-two eyes of 28 patients were prospectively examined; patients were further classified according to the orientation of the LRIs into 2 groups: group-A who had LRIs performed along the vertical meridian (vertical LRIs) and Group-B who had the LRIs performed along the horizontal meridian (horizontal LRIs). Inclusion criteria for the current study were: patients of both genders and undergoing cataract surgery with preoperatively documented mild to moderate corneal astigmatism (0.50–1.75 D) excluding those with severe corneal astigmatism (>1.75 D) whom planned to have toric IOL implantation for correcting the pre-existing corneal astigmatism or not preferring to have the LRI procedure, patients with evident dry eye syndrome, severe ocular surface disorders, or systemic disease compromising the quality of the ocular surface (Steven-Johnson syndrome, systemic lupus erythematosus), autoimmune disorders or corneal degenerative conditions associated with peripheral corneal thinning such as rheumatoid arthritis and pellucid marginal degeneration that render LRI to be unsafe procedure with unpredicted outcomes.

Table 1 shows the study population groups’ demographic data.

The study protocol was approved by the institutional review board of Minia Faculty of Medicine Research Ethics Committee (FMREc) and compiled with the tenets of the Declaration of Helsinki. All study participants signed a written informed consent to participate in the study and for publication of data before being enrolled in the study; after explaining the nature and details of the study procedures.

All participants had the standard cataract surgery (phacoemulsification) performed simultaneously with LRIs. The horizontal axis (0–180°) was marked at the slit-lamp preoperatively while the patient was in sitting position to compensate for potential cyclotorsion when shifting to the supine position. The incisions were performed in the steepest corneal axis at the limbus just anterior to the palisades of Vogt for correcting preoperative corneal astigmatism which was documented preoperatively by the corneal topographer (ATLAS-9000, Carl Zeiss Meditec, Germany). LRIs were performed according to the modified Gills’ nomogram at the commencement of surgery using a guarded micrometer diamond blade set at 500 μm as paired arcuate incisions. At the end; the incisions were irrigated with a balanced salt solution (BSS). A standard phacoemulsification technique was performed thereafter through a clear corneal temporal 2.8 mm incision; consisted of anterior continuous curvilinear capsulorrhhexis (CCC), nucleus emulsification, and cortex irrigation-aspiration and implantation of an acrylic IOL implant. Postoperatively, topical antibiotic (Ofloxacin 0.3%) and

| Parameter                  | Group-A | Group-B | P-value |
|----------------------------|---------|---------|---------|
| Number of patients         | 13      | 15      | –       |
| Number of eyes             | 21      | 21      | –       |
| Gender (Female)            | 7       | 7       | 0.97    |
| Age (Years)                | 70.65 ± 9.50 | 75.25 ± 8.51 | 0.15    |
| Preoperative TBUT (Sec)    | 7.41 ± 2.48 | 8.81 ± 5.59 | 0.73    |
| Preoperative BST (mm)      | 14.71 ± 8.86 | 16.13 ± 9.32 | 0.61    |

TBUT Tear Break-up time test, Sec second, mm millimeter, BST Basic Schirmer’s test

Table 1 Preoperative demographic data of the study population groups; Group-A: vertical LRIs and Group-B: horizontal LRIs.
steroid (Prednisolone acetate 1%) medications were administered four times daily for 2 weeks and the dose was steadily reduced thereafter. As these medications were used temporarily only, we assumed that they were not a confounding factor contributing to the postoperative ocular surface changes; moreover topical steroids have been recently considered a main line in treating meibomian gland dysfunction and dry eye syndrome.

Tear film stability was assessed by the tear break-up time test which measures the interval between instillation of a sterile fluorescein strip moistened with saline applied to the inferior cul-de-sac and appearance of the first dry spots on the cornea; examination done using the cobalt-blue filter of the slit-lamp counting time in seconds needed for the first break of the precorneal tear film in a steady maintained gaze.

Tear volume was determined using basic Schirmer’s test in which sterile graded Schirmer’s paper strips placed in the lower fornix while the patient is asked to close his eyes for 5 min after which the paper is removed and amount of wetting is measured.

We quantitatively assessed the tear film stability and production by TBUT and basic Schirmer’s test respectively both preoperatively; at 1, 4 and 12 weeks postoperatively.

**Statistical analysis**

The Statistical Package of Social Sciences (IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp.) was adopted for tabulation and analysis the obtained data. Quantitative data were presented as mean ± standard deviation while qualitative data were expressed as number (n) and percentage (%). Kolmogorov- Smirnov for normality test was used to differentiate between parametric and non-parametric data.

Paired Samples Student T-test was used to compare preoperative and postoperative values. Repeated measures analysis of variance (ANOVA) was used to evaluate the changes over time. A P value less than 0.05 was considered statistically significant.

The sample size in the study provided 95.6% statistical power at the 5% level to detect a 1-s difference in tear break-up time (TBUT), when the standard deviation (SD) of the mean difference was 1 s.

We have compared 21 eyes of 15 patients who had vertical LRIs (Group-A) to age-matched 21 eyes of 13 patients who had horizontal LRIs (Group-B) simultaneously with phacoemulsification; we found statistically significant reduction in the tear film stability measured by TBUT preoperatively; at 1, 4 and 12 weeks postoperatively (P = 0.001). No statistically significant differences regarding Schirmer’s test except in the first postoperative week in Group-B (P = 0.04).

In group-A who had vertically-oriented LRIs; the preoperative TBUT was 7.41 ± 2.48 s; 4.94 ± 2.36, 4.82 ± 1.94 and 5.59 ± 1.77 s, 1, 4 and 12 weeks postoperatively, (ANOVA, p = 0.01). the preoperative Schirmer’s test value was 14.71 ± 8.86 s; 12.88 ± 8.05, 13.53 ± 8.97 and 12.35 ± 8.20 s, 1, 4 and 12 weeks postoperatively, (ANOVA, p = 0.88).

In group-B who had horizontally-oriented LRIs; the preoperative TBUT was 8.81 ± 5.59 s; 6.38 ± 3.79, 7.19 ± 6.45 and 4.50 ± 3.48 s, 1, 4 and 12 weeks postoperatively, (ANOVA, p = 0.04). the preoperative Schirmer’s test value was 16.13 ± 9.32 s; 10.56 ± 5.16, 10.63 ± 4.77 and 9.75 ± 6.57 s, 1, 4 and 12 weeks postoperatively, (ANOVA, p = 0.05).

Table 2 shows the preoperative TBUT and tear volume values compared to the postoperative values as well as analysis of the time-course changes compared between both study groups.

To analyze the course of changes over time, we used the multiple comparison test which was found to be significant for TBUT in both groups A and B (P = 0.01 and 0.04 respectively) but not for tear volume production (P = 0.88 and 0.05 respectively).

**Discussion**

Dry eye symptoms which are commonly encountered after all types of corneal refractive procedures could disturb patients’ optimal visual function and hence performing their daily life activities; such morbidity increases proportionately with the severity of symptoms [15]. It was hypothesized that the most important factor in the pathophysiology

| Table 2 Postoperative tear film time-course changes compared to preoperative values between study groups |
|---------------------------------------------------------------|
| **Group-A** | Preoperative | 1-Week | 4-Weeks | 12-Weeks | Overall | Preop. Vs 1 WK | Preop. Vs 4 Wks | Preop. Vs 12 Wks |
| TBUT (Sec) | 7.41 ± 2.48 | 4.94 ± 2.36 | 4.82 ± 1.94 | 5.59 ± 1.77 | 0.01 | 0.01 | 0.003 | 0.001 |
| BST (mm) | 14.71 ± 8.86 | 12.88 ± 8.05 | 13.53 ± 8.97 | 12.35 ± 8.20 | 0.88 | 0.39 | 0.62 | 0.16 |
| **Group-B** | Preoperative | 1-Week | 4-Weeks | 12-Weeks | Overall | Preop. Vs 1 WK | Preop. Vs 4 Wks | Preop. Vs 12 Wks |
| TBUT (Sec) | 8.81 ± 5.59 | 6.38 ± 3.79 | 7.19 ± 6.45 | 4.50 ± 3.48 | 0.04 | < 0.001 | 0.03 | 0.001 |
| BST (mm) | 16.13 ± 9.32 | 10.56 ± 5.16 | 10.63 ± 4.77 | 9.75 ± 6.57 | 0.05 | 0.04 | 0.18 | 0.05 |

TBUT Tear Break-up time test, Sec second, BST Basic Schirmer’s test, mm millimeters
of corneal refractive surgery-induced dry eye syndrome is
the transection of corneal nerves that occurs during all
these incisional procedures [16].

Park et al. have studied changes in ocular surface pa-
rameters, meibomian gland function and tear inflam-
atory mediators following phacoemulsification; they
reported worsened ocular dryness symptoms but with
gradual recovery of TBUT and corneal sensitivity thresh-
old at 1 and 2 months postoperatively. One of the 2
study groups they included had evident dry eye before
surgery which was one of the exclusion criteria for the
current study [17].

Oh et al. found no difference between the mean pre-
operative and postoperative Schirmer’s test values fol-
lowing phacoemulsification; however, the TBUT values
were significantly decreased at 1 day postoperatively
but recovered to the preoperative level after 1 month. Inter-
estingly; they found a reduction in the mean goblet cell
density which was correlated with operative time and
had not recovered at 3 months postoperatively [18].

Liu et al. also reported initial significant reduction of
TBUT and increased Schirmer’s test values at 1 and 2
days postoperatively with later recovery to the preope-
rative values [19].

To the best of our knowledge we could not find previ-
ously published reports in literature studied the ocular
surface quality profile after scleral tunnel or small-
iccision cataract surgery. We postulate that it would not
have that much effect on ocular surface profile compar-
able to phacoemulsification surgery which may be ex-
plained by location of the main incision being through
the sclera and corneal stroma rather than incising
through the limbus or clear cornea which provide the
entry ports for the nerve endings.

Even with considering the latest technology of femtosec-
cond laser-assisted cataract surgery (FLACS); a study con-
ducted by Ju et al. reported that dry eye still could develop
immediately after that procedure with a peak severity on
day 7 postoperatively, most signs could return to basic
preoperative levels within 3 months after surgery. They
measured the tear film stability using OCULUS Kerato-
graph which was not used in the current study [20].

In a similar way; ocular surface changes after corneal
laser-assisted refractive procedures have been found to
be due to cutting of corneal nerves during refractive sur-
geries that subsequently result in suppression of the
aqueous component secretion from the lacrimal gland,
mucin expression on the corneal epithelial surface, and
frequent blinking, previously mentioned cascade occurs
because these homeostasis-maintaining mechanisms are
driven by a neuronal feedback loop that is mediated by
corneal sensitivity [13, 21].

Introducing the confocal microscopy technology has
helped better understanding of the dry eye pathophysiology
after such incisional surgeries like LRI s as it has been
proved that regeneration of the intrastromal corneal nerves
usually occur within 3 to 6 months which occurs in concur-
rence with the recovery of corneal sensitivity and restor-
ation of the ocular surface basic preoperative levels [22].

In a previous study, we reported reduced quality of the
ocular surface profile in terms of reduced tear film BUT
and tear volume production after simultaneous cataract
surgery with LRIs without largely affecting the corneal
sensation; however, we did not consider for selective
changes according to different location of the LRIs [11].

Limitations of the current study are the relatively small
sample size, the uncontrolled non-randomized design,
the relatively short follow-up time and the lack of a con-
trol group that consist of patients undergoing cataract
surgery without LRIs. The aforementioned limitations
raised the need for future longitudinal controlled cohort
studies with larger sample size and a longer follow-up
time is highly recommended.

Conclusions

In conclusion, the current study indicated that simulta-
eous LRIs with cataract surgery could result in dry eye
symptoms and reduced tear film stability which probably
would be transient during the early postoperative period
and then recover to around the basic preoperative levels
soon; those changes differ; however slightly; according to
the LRIs orientation. Adequate preoperative assessment
of the ocular surface quality parameters should be con-
sidered to optimize the postoperative outcome so not to
compromise the patient’s life style.

Abbreviations

LRIs: Limbal relaxing incisions; TBUT: Tear break-up time; BST: Basic Schirmer’s
test; IOL: Intracocular lens; BSS: Balanced salt solution; CCC: Continuous
curvilinear capsulorhexis; ANOVA: Analysis of variance; SD: Standard
deviation; n: Number; %: Percentage; sec : Second; FLACS: Femtosecond
laser-assisted cataract surgery

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Authors’ contributions

MA and AS performed the surgical procedures. MA analyzed the data, wrote
the original manuscript, and critically revised it during all submission process.
All authors read and approved the final manuscript.

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Availability of data and materials

The datasets analyzed during the current study are available from the
corresponding author on reasonable request.

Ethics approval and consent to participate

The research protocols were approved by the institutional review board at
Minia Faculty of Medicine Research Ethics Committee (FMREC), Minia
University, Egypt. All procedures performed in the study were in accordance
with the ethical standards of the institutional research committee and with
the 1964 Helsinki declaration and its later amendments or comparable
ethical standards. A written informed consent was obtained from all participants included to participate in the study.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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