Management of Corneal Astigmatism by Limbal Relaxing Incisions during Cataract Surgery

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Abstract

**Purpose:** To evaluate the safety and efficacy of limbal relaxing incisions (LRIs) for corneal astigmatism correction during phacoemulsification

**Methods:** 24 eyes of 24 patients with the mean age of 65.71 years (range: 55 to 83 years) with senile cataracts and mean corneal astigmatism of 1.9±0.83 diopters (D) (range: 1.5 to 3.5 D) were included in this study. All LRIs were performed during phacoemulsification by one surgeon. Topography indices were recorded preoperatively and postoperatively in months 2 and 6.

**Results:** A statistically significant reduction in the mean corneal astigmatism was seen from 1.9±0.83 D preoperatively to 1.4±0.84 D and 1.4±0.92, 2 months and 6 months postoperatively (P<0.001). Surgical induced astigmatism (SIA) (the amount and axis of astigmatism change induced by the surgery) was 0.90±0.48 at 2 months and 0.96±0.59 at 6 months. Correction index (CI) (calculated by determining the ratio SIA/ target induced astigmatism (TIA)) was 0.55±0.41 and 0.57±0.32 at 2 and 6 months, respectively. Index of success (IOS) (ratio of topographic residual astigmatism and TIA) was measured 0.44±0.41 and 0.47±0.32 at months 2 and 6 correspondingly.

**Conclusion:** Combined LRI and phacoemulsification appears to be safe and fairly effective to correct mild to moderate corneal astigmatism. However, under correction is a common limitation that may be further managed by modified nomograms in future studies.

**Keywords:** Corneal Astigmatism, Limbal Relaxing Incision, Phacoemulsification


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Introduction

Cataract surgery is the most successful and most commonly performed ophthalmic procedure in the modern medical world.1,2

An increasingly important goal of modern cataract and implant surgery is to obtain the most desirable refractive outcomes for the patients and to decrease their dependence upon spectacle corrections.3 Novel techniques of cataract surgery to correct pre-existing astigmatism are presented. Hence, the uncorrected visual outcome of cataract patients has been improved and better refractive correction is possible now.1,4,5

In order to achieve better visual results, the effect of postoperative astigmatism should be minimized through several techniques including intraoperative relaxing incisions, toric intraocular lens implants (IOL) implantation or postoperative vision correction by ablative refractive surgery by excimer laser; each with its own advantages and disadvantages.

Herein, we report the safety and efficacy of limbal relaxing incisions (LRIs) for correction of pre-existing corneal astigmatism during phacoemulsification.

Methods

This prospective study was performed at department of ophthalmology of Farabi Eye Hospital, Tehran University of Medical Sciences from September 2007 to February 2008. Patients with senile cataracts and significant corneal astigmatism were included in this study. Informed consent was obtained from patients and the institute review board of ophthalmic research center approved the whole study.

The study’s inclusion criteria were cataract patients aged ≥50 years and 1.5 to 3.5 diopters (D) of regular corneal astigmatism documented by corneal topography.

Exclusion criteria were previous ocular surgery, ocular trauma, pre-existing ocular disease, high intraocular pressure (IOP), corneal opacity, strabismus, amblyopia, diabetes mellitus and irregular astigmatism.

All patients underwent the ophthalmic examinations that included uncorrected visual acuity (UCVA) and best corrected visual acuity (BCVA), manifest refraction, anterior segment slit-lamp biomicroscopy, application tonometry, indirect ophthalmoscopy, corneal topography (Astramax, LaserSight Technologies, Inc., Winter Park, Florida), limbal pachymetry (Tomy, Japan) and ultrasound biometry (Nidek, US, UF 2500, Japan). Phacoemulsification with concomitant LRIs was performed in 24 eyes by one surgeon. Patients were evaluated in follow-up examinations at months 2 and 6 and their data were evaluated.

Surgeries

All surgeries were performed by one surgeon. SRK-T formula was used for all patients for IOL power calculation. Cataract surgery was performed under retro bulbar anesthesia. Acrylic foldable IOLs (Alcon, SA 60 AT, USA) were implanted through a 2.8 mm temporal clear corneal incision without enlargement using the injector for all eyes.

Before surgery, 6 and 12 o’clock position of cornea were marked while the patient was sitting upright. The steepest meridian was marked at the beginning of surgery, on which LRIs were made according to the modified Gills nomogram (Table 1).

All LRIs were placed inside the surgical limbus at a depth of 600 µm before phacoemulsification with the LRI knife determined for 600 µm (Figure 1).

For patients with against-the-rule astigmatism (steep corneal meridian within 20 degrees around the 180 degree on corneal topography), the temporal hinge incision for phacoemulsification was oriented to align with placement of the LRI. A second LRI was performed on the nasal side before phacoemulsification. After IOL implantation and before removal of viscoelastic material, the original minimal LRI was extended according to the nomogram. In eyes with with-the-rule astigmatism, paired LRIs were placed on the steep meridian before phacoemulsification as dictated by modified Gills nomogram (Table 1).

Measures

The effectiveness of LRI was evaluated by comparing pre- and postoperative topographic astigmatism.16 Effectiveness was analyzed using the mean and standard deviation of the postoperative topographic astigmatism at months 2 and 6 after surgery. The vector
analysis method was used to evaluate the efficacy of astigmatic correction (method of Kaye and Patterson). The safety of the LRI procedure was evaluated by recording of the intra operative and postoperative complications and subjective symptoms. Stability of procedure was evaluated by the variability of the mean topographic astigmatism through 2nd and 6th months postoperative follow-up examinations (Figure 2).

Paired T-test was performed for statistical analysis and P≤0.05 was considered statistically significant.

Table 1. Modified Gills nomogram indicating the degrees of arc incised with paired LRIs centered on the steep axis. The length is titrated by keratometric cylinder and patient age; the incision depth is set at 600µm.

<table>
<thead>
<tr>
<th>Preoperative cylinder</th>
<th>Age (year)</th>
<th>Degree of ARC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>30-40</td>
<td>41-50</td>
</tr>
<tr>
<td>WTR astigmatism*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.50 to 2.25 D</td>
<td>60</td>
<td>55</td>
</tr>
<tr>
<td>2.50 to 3.00 D</td>
<td>70</td>
<td>65</td>
</tr>
<tr>
<td>≥3.25 D</td>
<td>80</td>
<td>75</td>
</tr>
<tr>
<td>ATR astigmatism†</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.50 to 2.00 D</td>
<td>70</td>
<td>65</td>
</tr>
<tr>
<td>2.25 to 2.75 D</td>
<td>90</td>
<td>80</td>
</tr>
<tr>
<td>≥3.00 D</td>
<td>90</td>
<td>90</td>
</tr>
</tbody>
</table>

WTR: With the rule
ATR: Against the rule
*: Steepest keratometry reading 46 to 135 degrees
†: Steepest keratometry reading 0 to 45 degrees or 136 to 180 degrees; the temporal incision includes the cataract incision.

Figure 1. All LRIs were placed inside the surgical limbus at a depth of 600 µm before phacoemulsification with the LRI knife determined for 600 µm as shown in this figure.

Figure 2. Preoperative and six months postoperative topography of a patient with preoperative corneal astigmatism and the difference map showing the effect of LRI.
Results
LRI was performed in 24 eyes (13 right eyes and 11 left eyes) of 24 patients. Mean patients age was 65.7±7.9 years (range: 55 to 83).

Data analysis demonstrated statistically significant reduction in the mean topographic astigmatism in the LRI eyes from 1.9±0.83 D (range: 1.40 to 3.20) preoperatively to 1.40±0.84 D (range: 0.50 to 2.60) and 1.4±0.92 D (range: 0.50 to 2.50) in 2nd and 6th postoperative months, respectively (P<0.001). There was no statistically significant difference between mean astigmatism at 2 months and 6 months after LRI (P=0.91) (Table 2).

Table 2. Vector analysis of postoperative astigmatism for eyes that underwent combined phacoemulsification and LRI (2 months and 6 months follow-up) (mean±SD)

<table>
<thead>
<tr>
<th></th>
<th>2 months postop.</th>
<th>6 months postop.</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIA</td>
<td>0.9±0.48</td>
<td>0.96±0.59</td>
</tr>
<tr>
<td>TIA</td>
<td>1.9±0.83</td>
<td>1.9±0.83</td>
</tr>
<tr>
<td>CI</td>
<td>0.55±0.41</td>
<td>0.57±0.32</td>
</tr>
<tr>
<td>IOS</td>
<td>0.44±0.41</td>
<td>0.47±0.32</td>
</tr>
</tbody>
</table>

SIA: Surgical induced astigmatism (the amount and axis of astigmatism change induced by the surgery).
TIA: Target induced astigmatism (the astigmatism changes that the surgery was intended to induce).
CI: Correction index (calculated by determining the ratio SIA/TIA [CI >1 is considered overcorrection, and CI <1 indicates under correction]).
IOS: Index of success (ratio of topographic residual astigmatism and TIA).

UCVA was equal to 0.5 or more than 0.5 in 75% (18 cases) at month 2 after LRI, following 87% (21 cases) of patients at month 6 postoperatively. No patient lost any lines of UCVA or BCVA, which cannot be attributed solely to LRI efficacy as simultaneous cataract surgery was performed.

BCVA showed significant improvement at 2-month and 6-month follow-up evaluation. Average preoperative BCVA was 0.17±0.11 reaching 0.74±0.22 and 0.8±0.18, 2 and 6 months after LRI, respectively (P<0.001). BCVA was ≥0.7 in 79% of patients 6 months after LRI that might mostly be due to the cataract extraction and IOL implantation and not a consequence of the LRI surgery.

There was no intraoperative complication or postoperative subjective complaints (such as halo or glare) in our patients.

Discussion
Visual recovery and satisfaction of patients who underwent phacoemulsification is closely related to the appropriate IOL power calculation and management of postoperative astigmatism. Among patients undergoing cataract surgery, 15-20% have significant corneal astigmatism ranging from 1 to 3 D. With the introduction of aspherical intraocular lenses (IOLs) as an integral part of cataract surgery, better formula for IOL power calculation, and eliminating postoperative refractive astigmatism is the corneal astigmatism.

There are several options to reduce the postoperative astigmatism including intraoperative relaxing incisions, toric IOL implantation or postoperative vision correction by ablative refractive surgery by excimer laser each with its own benefits and drawbacks. Toric IOLs are rather expensive. Moreover, if postoperative rotation of the IOL occurs, there would be a significant induced astigmatism. Excimer laser vision correction after cataract surgery needs an additional operation with high expenses, possible complications and limitations in patients with thin cornea.

LRIs have been used to correct preexisting astigmatism at the time of cataract surgery. Simultaneously, one can benefit from lower costs and easy performance with minimal learning curve, without overcorrection. However, the predictability, stability and range of correction are rather limited.

According to Gills and Guyton LRIs are more effective in eyes with low to moderate, rather than high astigmatism. LRIs also appear to cause less distortion and irregularity at the limbus. They can provide more rapid postoperative visual acuity (VA) in compare with clear corneal incisions with less risk of glare and discomfort.

In this study, range of astigmatism correction is evaluated using vector analysis of surgical induced astigmatism (SIA) vector and target induced astigmatism (TIA) vector. SIA vector is the amount and axis of
astigmatic change that the surgery actually
induced.
TIA vector is astigmatic change (by
magnitude and axis) that the surgery was
intended to induce. Correction index (CI) is
calculated by dividing SIA by TIA. The CI is
preferably equal to 1.0. In overcorrection CI is
more than 1, and less than 1, in the case of
under correction. Difference vector (DV) is
calculated by TIA-SIA. Index of success (IOS)
is calculated by dividing the DV by the TIA
vector. The IOS is a relative measure of
success and is preferably zero.23

Considering the above mentioned ratios,
our study demonstrated that use of LRIs
during phacoemulsification, reduce corneal
astigmatism; however, there was a trend for
under correction. Under correction was not
uncommon in previous reports.18,19 Budak et al
studied 22 patients.20 They found a 44%
reduction of astigmatism in eyes treated with
LRI during phacoemulsification using the Gills
nomogram.

In study of Carvalho et al 6 a statistically
significant reduction in the mean topographic
astigmatism was seen in the cataract LRI
eyes from 1.93±0.58 D preoperatively to
1.02±0.60 D 6 months postoperatively
(P<0.05).

Multiple factors might cause under
correction of astigmatism in patients who are
treated with phacoemulsification and LRIs. We
minimized the surgeon factor by performing all
operations by only one surgeon. Another
cause may be the improper position of blade
(Oblique incision rather than perpendicular
incision on the limbus, that may result in the
wrong depth causing under correction).21
Under correction may be related to area of
limbal incision that is far from the corneal
center.22 However, more central clear corneal
incisions may cause more glare and higher
order aberrations for the patients.

Conclusion

In summary, simultaneous LRI during
phacoemulsifaction surgery appears to be
safe and fairly effective to correct mild to
moderate amounts of corneal astigmatism.
Under correction is a common limitation that
may be further managed by modified
nomograms in future studies adjusted by the
surgeon factors. Apart from the patient age,
multiple factors including ethnicity, gender,
corneal limbal thickness, course of
postoperative steroid regimen and surgeon
factors should be considered for adjustment of
future nomograms. We recommend surgeons
to apply nomograms that take patient age and
size of LRI in millimeter to decrease
preoperative corneal astigmatism. It seems
that LRI incisions can not full correct but
would cause more acceptable reduction in the
preoperative corneal astigmatism.

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