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Surgically induced astigmatism after phacoemulsification with and without correction for posture-related ocular cyclotorsion

Randomized controlled study

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PURPOSE: To report the impact of posture-related ocular cyclotorsion on 1 surgeon's surgically induced astigmatism (SIA) results and the variance in SIA.

SETTING: Institute of Eye Surgery, Whitfield Clinic, Waterford, Ireland.

METHODS: This prospective randomized controlled study included eyes that had phacoemulsification with intraocular lens implantation. Eyes were randomly assigned to have (intervention group) or not to have (control group) correction for posture-related ocular cyclotorsion. In the intervention group, the clear corneal incision was placed precisely at the 120-degree meridian with instruments designed to correct posture-related ocular cyclotorsion. In the control group, the surgeon endeavored to place the incision at the 120-degree meridian, but without markings.

RESULTS: The intervention group comprised 41 eyes and the control group, 61 eyes. The mean absolute SIA was 0.74 diopters (D) in the intervention group and 0.78 D in the control group; the difference between groups was not statistically significant (P > .5, unpaired 2-tailed Student t test). The variance in SIA was 0.29 D² and 0.31 D², respectively; the difference between groups was not statistically significant (P > .5, unpaired F test).

CONCLUSIONS: Attempts to correct for posture-related ocular cyclotorsion did not influence SIA or its variance in a single-surgeon series. These results should be interpreted with full appreciation of the limitations of currently available techniques to correct for posture-related ocular cyclotorsion in the clinical setting.

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Postural changes, such as moving from an upright to a supine position, can induce a mean ocular cyclo-
torsional effect of 0.4 to 4.2 degrees (range 0 to 16 de-
gres),\(^6\) and this effect can be cycloptorsional or
eccyloptorsional.\(^8\) However, keratometry is typically
recorded with the patient upright, whereas ocular sur-
gery is performed with the patient supine. As a conse-
quence, it has been recommended that preoperative
corneal markings of the 0- to 180-degree-meridian us-
ing specifically designed instruments should be made
with the patient upright and that the markings should
then be aligned with the 0- to 80-degree-meridian of
a fixation ring with the patient supine, from which
the meridian of the toric IOL to be implanted is
marked with a meridian marker. Furthermore, vari-
bility in the site of the surgical incision is likely to
be influenced by other, as yet unidentified, causes in-
cluding idiosyncratic ocular factors, corneal size, and
the type of speculum used. Therefore, and for the
above reasons, it would appear that SIA should be
calculated in a setting in which these sources of vari-
ability are controlled as much as possible. This is espe-
cially true as we enter the era of toric IOLs.

To date, studies describing the calculation of SIA
typically failed to take the precise wound meridian
into account in their analysis. Two studies by Altan-
Yaycioglu et al.\(^4,5\) did report marking the cornea pre-
operatively with the patient upright. However, the
studies were retrospective and did not specify how
the cornea was marked; therefore, no meaningful con-
clusions can be made about the contribution of preop-
erative corneal markings to SIA calculation.

Variance is the square of the standard deviation (SD)
and gives an idea of the difference between the sample
and the mean. A set of data distributed near the mean
will have a small variance, whereas a more widely
dispersed set of data may have the same mean but
a significantly larger variance.

We performed a study designed to calculate the im-
 pact of attempts to correct for posture-related ocular
cyclo torsion on SIA and the variance in SIA in a sin-
gle-surgeon setting.

PATIENTS AND METHODS

This prospective randomized controlled study comprised
consecutive patients scheduled for phacoemulsification
with IOL implantation. The South East Regional Ethics Com-
mittee approved the study, which adhered to the tenets of
the Declaration of Helsinki. All patients were given a written
information leaflet regarding the nature of the study, and all
provided written informed consent before recruitment.

Exclusion criteria were previous surgery or trauma, intra-
ocular or otherwise, in the eye scheduled for surgery; ante-
rior segment pathology other than cataract; intraoperative
complications, including minor ones (eg, discont inuous cap-
sulorhexis, placement of a corneal suture); and a history of
connective tissue disorders or immunosuppressive therapy.
An additional exclusion criterion in analyses in which post-
operative visual performance was an outcome measure
was non- cataractous visually consequential ocular pathology
(ie, age-related macular degeneration, diabetic macular
edema, advanced glaucoma, vitreomacular traction syn-
drome, amblyopia).

Randomization

Patients were randomly assigned to 1 of 2 groups. In the
intervention group, the precise meridian of the clear corneal
incision (CCI) was calculated to correct for posture-related
oculocyclotorsion. In the control group, the surgeon did
not make corneal markings for ensuring the CCI was pre-
cisely at the 120-degree meridian to correct for posture-
related oculocyclotorsion.

Preoperative Evaluation

All patients had a comprehensive preoperative ophthal-
omic examination that included uncorrected (UDVA) and cor-
corrected (CDVA) distance visual acuities; contrast sensitivity
(computerized Pelli-Robson chart); manifest refraction by
autorefraction (AR-360A, Nidek); keratometry, anterior
chamber depth (ACD) measurement, and corneal topogra-
phy by Scheimpflug imaging (Pentacam, Oculus Optikger-
äte GmbH); and axial length measurement by partial
coherence interferometry (IOLMaster version 5, Carl Zeiss
Meditec). Astigmatism was assessed preoperatively and
postoperatively based on the keratometry readings of the
central 6.0 mm area on corneal topography using the
Scheimpflug imaging device.

Surgical Technique

All phacoemulsification procedures were performed by
a right-handed surgeon (S.B.) between October 2008 and
March 2009 using topical anesthesia (proxymetacaine hydro-
chloride 0.5%). In the intervention group (posture-related
ocular cyclotorsion corrected), the cornea was marked pre-
operatively at the 0- to 180-degree meridian using a Blake-
well BubbleLevel preoperative marker (Mastel, Inc.) with
the patient seated upright. Then, under the operating
microscope, the 0- to 180-degree meridian of a Gimbel Men-
dez fixation ring (Mastel, Inc.) was aligned; this meridian
was marked with the preoperative marker, and the site of
the intended wound site was marked using a Bores meridian
(axis) marker (Mastel, Inc.). The 120-degree meridian was
chosen because this site seemed natural to the operating sur-
geon when he performed the first case in the intervention
group; this meridian was used in all subsequent cases in
that group. A corneal incision site (centered at 120 degrees)
was created using a 2.75 mm full-annged knife (Alcon,
Inc.). A 1.0 mm paracentesis was created 3 clock hours to
the left of the CCI (not specifically measured); this was
the paracentesis site regardless of whether surgery was in a right
eye or the left eye. In the control group, the surgeon endeav-
ored to make the CCI and paracentesis at the same sites (120
degrees and 3 clock hours, respectively, to the left of the CCI)
but without the aid of the instrumentation described above.

The same surgical technique was then used in both
groups. After a 2-step CCI (2.00 mm long, 2.75 mm wide)
was created in the perillimbal region at the 120-degree meri-
dian using the markings in the intervention group and the sur-
gone’s estimate in the control group (a 1.0 mm paracentesis
was created 3 clock hours to the left of the CCI). Then, sodium
hyaluronate 1% (Healon) was injected into the anterior
chamber and a 6.0 mm continuous curvilinear capsulorhexis
was created. After hydrodissection, phacoemulsification of
the nucleus was performed using an Infiniti phaco unit
(Alcon, Inc.) and the soft lens mallet was aspirated. Next,
sodium hyaluronate 1% was injected to inflate the capsular
bag and anterior chamber. Then, an IOL (Tecnis ZA9003,
Abbott Medical Optics, Inc.) was implanted in the capsular
bag using an unfolder and cartridge (AMO EmeraldT Series,
Abbott Medical Optics, Inc.). The remaining ophthalmic vis-
surgical device in the anterior chamber and posterior
chamber was evacuated using the phaco unit’s irrigation/
aspiration system. Stromal hydration was performed to
achieve wound integrity, and intracameral cefoxetine
1 mg in 0.1 mL of sterile water for injection was administered
via the paracentesis. A single drop of apraclonidine 1% and
an aliquot of fucidic acid ointment 1% were administered
to the corneal surface and a cartella shield (BD Visitec Uni-
versal Eye Shield, Becton, Dickinson & Co.) was placed over
the eye.

Postoperative Evaluation

All eyes were examined 2 weeks and 6 weeks postopera-
tively. Outcome measures were recorded at the 6-week post-
operative visit and included UDVA, CDVA, contrast
sensitivity, manifest refraction by autorefraction, keratome-
try, ACD, and corneal topography measured using the
same devices as preoperatively.

Statistical Analysis

Surgically induced astigmatism was calculated using the
arithmetic and vector analysis methods. The SIA in both
groups was calculated and compared (unpaired 2-tailed
Student t test), as was the variance in SIA (unpaired F-test, var-
iance ratio test). A P value less than 0.05 was considered
statistically significant.

Refraction is usually written as sphere, cylinder, and axis.
This conventional format may characterize a single refrac-
tion but is not suited to statistical analysis. There are no
problems with analysis of the spherical component; the
difficulties reside with the astigmatism. Astigmatism is
characterized by a magnitude expressed in diopters (D)
and a direction reported in degrees. For statistical analysis,
these incommensurable entities must be converted to vectors
or similar entities (such as polar values). In

In arithmetic analysis, the magnitudes of cylinders are
added together to calculate a mean. Even if the absolute
value is taken, the direction component of the resultant cyl-
inder cannot be derived by this method. Therefore, arithme-
tic analysis, while convenient, is wholly inaccurate used.

Vector analysis treats cylinder as a vector with magnitude
and direction. The refractive error is expressed in sphere/
cylinder × axis format. Two or more vectors can be com-
pared with these techniques. In this study, SIA was deter-
mapped using a free online SIA calculator that uses the
Holladay method of vector analysis (http://doctor-hill.

RESULTS

This study evaluated 102 eyes (54 left, 48 right) of 86
patients. The mean age of the 34 men (40%) and 52
women (60%) was 70.5 years ± 10.2 (SD).

In all eyes, the mean UDVA was 0.72 ± 0.65 logMAR
preoperatively and 0.15 ± 0.30 logMAR postopera-
tively and the mean CDVA, 0.38 ± 0.48 logMAR and
0.04 ± 0.28 logMAR, respectively; the UDVA and
CDVA were statistically significantly better postopera-
tively than preoperatively (P <.001, paired 2-tailed
Student t test). The mean log of contrast sensitivity im-
proved significantly from 1.15 ± 0.43 log units preopera-
tively to 1.59 ± 0.10 log units postoperatively
(P <.001, paired 2-tailed Student t test).

The mean absolute preoperative astigmatism was
1.04 ± 0.59 D in the intervention group and 1.08 ±
0.71 D in control group; the difference between the
groups was not statistically significant (P >.5, un-
paired 2-tailed Student t test). The mean absolute
spherical equivalent (SE) was statistically significantly
lower postoperatively (0.59 ± 0.48 D) than preoper-
a tively (2.72 ± 3.15 D) (P <.001, paired 2-tailed
Student t test), with a mean prediction error of 0.51 ± 0.45 D
(range -1.95 to +1.16 D). There was no significant dif-
derence in the mean change in absolute SE between the
intervention group (2.45 ± 2.15 D) and the control
group (2.37 ± 2.71 D) (P >.5, unpaired 2-tailed
Student t test).

Using the arithmetic method of analysis, the mean
absolute SIA was 0.51 ± 0.53 D in the intervention
group and 0.48 ± 0.39 D in the control group; the
difference between groups was not statistically signifi-
cant (P >.5, unpaired 2-tailed Student t test). How-
ever, the variance in SIA was significantly greater in
intervention group (0.28 D²) than in the control group
(0.16 D²) (P =.05, unpaired F-test).

Using vector analysis, the mean SIA was 0.72 ±
0.54 D with a variance of 0.32 D² in the intervention
group and 0.70 ± 0.56 D with a variance of 0.17 D²
DISCUSSION
This study found that for the same surgeon, attempts to correct for posture-related ocular cyclotorsion did not affect SIA or its variance. The mean SIA in our cohort of 102 eyes was 0.76 ± 0.54 D. This is comparable with results in previous phacoemulsification studies in which the postoperative SIA ranged from 0.30 to 1.55 D but in which no attempt was made to correct for posture-related ocular cyclotorsion.

In a retrospective study of surgical outcomes of 3 right-handed surgeons, Altan-Yaycioglu et al. found a statistically significant difference in mean SIA after uneventful cataract surgery between right eyes (1.08 ± 0.93 D) and left eyes (1.36 ± 1.00 D (P < .001). These levels were significantly higher than in our study (0.68 ± 0.49 D and 0.84 ± 0.59 D, respectively). Altan-Yaycioglu et al. did not describe the preoperative corneal marking method with the patient upright. Furthermore, although the initial incision was 2.85 mm in their study, it was enlarged to 4.00 mm for IOL implantation. We used a 2.75 mm incision size, which is closer to that necessary for implantation of commonly used toric IOLs. We believe reason for the discrepancy in the magnitude of the SIA between the 2 studies is because ours was a single-surgeon series; however, we believe the difference is mainly attributable to the significantly smaller incisions in our study.

We found a trend toward a greater mean SIA and its variance in left eyes than in right eyes, and this trend approached statistical significance (P = .096, unpaired 2-tailed Student t test). The greater SIA in left eyes, which was statistically significant in the Altan-Yaycioglu et al. study, was in the eye that was contralateral to the surgeon’s dominant and operating hand. In both studies, the CCI was located in the superotemporal quadrant in right eyes and the superonasal quadrant in left eyes, and this may have contributed to the influence of laterality on SIA. Nasal CCIs are associated with greater SIA than temporal CCIs because they are closer to the visual axis; this may account for the effect of laterality on SIA in both studies.

The calculation of a given surgeon’s SIA is an essential step in the preparation for toric IOL implantation. The free online toric IOL calculator we used incorporates the surgeon’s SIA (magnitude), site of CCI (direction), and patient’s biometry in its calculations to recommend a given power and orientation of the toric IOL to be implanted. It is somewhat reassuring that our study suggests that attempts to correct for posture-related ocular cyclotorsion do not influence the calculation of SIA or its variance.

However, our results must be interpreted with full appreciation of the limitations inherent in the method of marking the cornea preoperatively in an attempt to achieve consistent meridional location of the CCI. If, for example, the marking error (between the 2 steps involved) is imprecise by 0.4 to 4.0 degrees, the potential benefit of such markings is forfeited. In other words, a more precise technique of correcting for posture-related ocular cyclotorsion (eg, binocular 3-dimensional infrared videokeriography) might have yielded different results.

In conclusion, and with full appreciation of the limitations inherent in the technique of marking the eye preoperatively to ensure the CCI is made at a given meridian, calculation of SIA (or the variance in such calculations) was not adversely affected by failing to correct for posture-related ocular cyclotorsion.

Table 1. Mean SIA by group.

<table>
<thead>
<tr>
<th>SIA</th>
<th>Correction Attempt Made</th>
<th>No Correction Attempt Made</th>
<th>Correction Attempt Made</th>
<th>No Correction Attempt Made</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Right Eyes</td>
<td>Left Eyes</td>
<td>Right Eyes</td>
<td>Left Eyes</td>
</tr>
<tr>
<td></td>
<td>(n = 17)</td>
<td>(n = 32)</td>
<td>(n = 25)</td>
<td>(n = 28)</td>
</tr>
<tr>
<td>Mean (D)</td>
<td>0.63</td>
<td>0.70</td>
<td>0.81</td>
<td>0.87</td>
</tr>
<tr>
<td>SD (D)</td>
<td>0.41</td>
<td>0.53</td>
<td>0.63</td>
<td>0.55</td>
</tr>
<tr>
<td>Variance (D^2)</td>
<td>0.17</td>
<td>0.28</td>
<td>0.40</td>
<td>0.30</td>
</tr>
</tbody>
</table>

SIA = surgically induced astigmatism
REFERENCES


