The goal of all cataract surgeons is to achieve emmetropia, which requires two key elements to be taken into consideration: the first, correct intraocular lens (IOL) calculation and second, the care of the patient’s astigmatism before and after surgery. Astigmatism can be managed using different techniques such as radial keratotomy, limbal relaxing incisions, toric IOL and laser-assisted in-situ keratomileusis (LASIK). The size, architecture and location of the corneal incision are also fundamental elements for the induced astigmatism.

Each method requires accurate predictive equations for postoperative astigmatism.

Using calculations in the three-dimensional schema makes it possible to represent the induced astigmatism as a two-dimensional vector analysis, which is achieved by converting the cylindrical measurement into vectors with direction and magnitude. Other more complex methods convert the cylinder into polar values instead of vectors, with the analysis performed using matrices that describe the linear optic.

Surgically-induced astigmatism (SIA) usually increases when the corneal incisions are larger than 4 mm if compared to temporal and scleral incisions of similar size. Studies comparing the results of incisions on the corneal meridian show that temporal incisions on the clear cornea reduce the induced astigmatism, although with no major improvements in visual acuity. Hydration and placement of the stitches should also be taken into consideration as variables of the induced astigmatism.

The aim of the current study was to analyze the effect of clear corneal microincision (2.2 mm) on vector direction and magnitude, as well as on SIA.
MATERIALS AND METHODS

This prospective, longitudinal, interventional cohort study was conducted in the department of ophthalmology, Laserlens Institute, Ioannina, Greece. The study followed the principles of the Declaration of Helsinki. The protocol was presented to the research ethics committee at Laserlens Institute, and each patient signed a non-disclosure agreement. This research includes the analysis of 100 eyes from 100 male and female patients aged 40 years or older, who were diagnosed with cataract (LOCIII) NO2 or NO3, NC2 or NC3, P4 or P5 and had uneventful phacoemulsification surgery. Patients with a history of eye injury, tear film abnormalities or eye diseases such as uveitis, glaucoma, corneal and retinal disease were excluded.

Preoperatively, all patients had a full ophthalmologic examination including evaluation of the refractive status, uncorrected (UDVA) and corrected (CDVA) distance visual acuity (Snellen charts), slit-lamp evaluation, Goldman applanation tonometry and funduscopic. In addition to these basic clinical tests, all keratometry readings were obtained using corneal topography (Orbscan IIZ, Bausch & Lomb, Rochester, NY, USA) read by a single observer, while surgery was performed by the same anterior segment specialist surgeon (ESD).

The surgical procedure was carried out under topical anaesthesia with 2% sodium tetracaine. The corneal incision was made with a 2.2-mm steel blade, regardless of the patient’s astigmatic axis, and a dispersive-cohesive viscoelastic material was then injected to maintain and pressurize the anterior chamber (DiscoVisc, Alcon Laboratories Inc, Fort Worth, TX, USA). Continuous curvilinear capsulorhexis (CCC) was carried out, followed by hydrodissection. In some cases, pre-fracture of the nucleus was performed using the karate chop technique; when this was not possible because of the hardness of the nucleus, a second 1-mm incision was made. Cataract phacoemulsification was performed using torsional ultrasound alone or combined with longitudinal ultrasound, according to the hardness of the nucleus. The same viscoelastic material was injected in the bag to allow implantation of a 6-mm hydrophobic acrylic foldable IOL (Alcon Acrysof SN60WF, Alcon Laboratories Inc.) using an injector system (Monarch III, Alcon Laboratories Inc.); the anterior chamber was formed and the wound was checked for leakage and left unsutured. Postoperative topical therapy included topical moxifloxacin 0.5% plus dexamethasone 0.1%.

Postoperative examinations were performed on Days 1, 11, 30, 90 and 180, and included UCVA and best corrected visual acuity (BCVA), anterior segment evaluation and binocular indirect ophthalmoscopy. Corneal topography was also performed using the Orbscan IIZ, and SIA was calculated by vector analysis using the Holladay-Cravy-Koch formula. The data was captured in a spreadsheet in Microsoft Excel version 2003 and analyzed using SPSS 11.0 (Chicago, INN). For statistical analysis, non-parametric variance tests were performed (ANOVA, Friedman and Levene’s test) as well as a simple correlation (Y and X) and a mathematical correlation factor R² (R squared) equal to or greater than 80%. In all cases, p ≤ 0.05 was considered statistically significant.

RESULTS

One hundred (100) eyes were included from 100 consecutive patients who met the inclusion/exclusion criteria; 63% were men, with mean patient age (mean ± SD) 69.0 ± 13.2 years.

The mean cylinder (correlation of the cylinder in diopters) before and after surgery was 1.04 ± 0.60, and in percentage (preoperative and 180 days postoperatively) was significantly different, 0.03 ± 0.59 (ANOVA; p = 0.005); this means that the magnitude of the astigmatism (cylinder) changed over time (Friedman; p = 0.00) (Figure 1, Table 1). The positive values of the magnitude could represent overcorrection of the astigmatism; if the magnitude had been negative, it could be described as undercorrection.

<table>
<thead>
<tr>
<th>Table 1. Vector analysis of the cylinder and axis at 180 days.</th>
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<tbody>
<tr>
<td>Cylindrical correction (diopters) ⋅</td>
</tr>
<tr>
<td>mean ± SD</td>
</tr>
<tr>
<td>1.04 ± 0.60</td>
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</tbody>
</table>

SD: standard deviation

ANOVA p = 0.005 (Friedman test p = 0.00); ANOVA p = 0.136 (Friedman test p = 0.469; p > 0.05); Levine’s test p = 0.021.

Figure 1. Comparative analysis of the pre- and postoperative cylinder. Levene’s test p-value = 0.021; ANOVA p-value = 0.005; Friedman p = 0.00.
The direction of the vector (axis) significantly changed over time \((p = 0.021)\) (Levine’s test; \(p < 0.05\)), with a mean cylinder in degrees \(-5.35 \pm 60.04\) (axis before and 180 days after surgery). These negative vector values should represent regression to the opposite quadrant and its real direction. The mean axis (direction) expressed in radian was not statistically significant: \(-0.07 \pm 0.88\) (ANOVA; \(p = 0.136\)), while the dispersion in the resulting axis direction (vector) measured in radians did not show any significant change (Friedman test; \(p = 0.469; p > 0.05\)) (Figure 2, Table 1).

Preoperatively, 59 patients had with-the-rule astigmatism and 41 patients had against-the-rule astigmatism \((0.00 \pm 1.00)\). Regardless of the patient’s astigmatism, the 2.2-mm incision was made at a comfortable forearm position of the surgeon on a clear cornea. The final axis of the astigmatism was: 3 patients remained with against-the-rule astigmatism, 17 with with-the-rule astigmatism, and 80 patients had their astigmatism neutralized with the incision \((0.29 \pm 0.58)\) (Table 2).

The different incision sites did not affect either the induced astigmatism or the final astigmatism \((R^2)\). This correlated result of \(R^2\) shows that the incision site affects the amount of SIA by less than 10%. The induction vector did not generate any obvious changes above the previous vector on the resulting cylinder after surgery \((0.11 \pm 0.35)\) (Figure 3). Moreover, the SIA was stable after surgery.

### DISCUSSION

The cornea is a flexible dome that allows modifications to the corneal curvature on the axis (direction) and cylinder (magnitude).

The astigmatism and the vectors share the same measurement units such as dioptre and degrees. It is important to understand that the astigmatism is a static entity, while the vector is a dynamic entity, in which two components of magnitude and axis cannot be measured but can be calculated.

The astigmatism secondary to cataract surgery primarily depends on the size, architecture and location of the incision. However, many surgeons noticed a higher astigmatism in the upper region compared to the temporal region. In contrast, our study included incisions between 60 and 120 degrees, and did not affect patient astigmatism\(^8\).

The preoperative astigmatism can be controlled and modified during the phacoemulsification surgery. Some studies have analyzed the effect on the induced astigmatism, and compared 3.5-mm, 3.2-mm and 3-mm temporal incisions to superior corneal incisions of the same length\(^9\). Other authors have reported that surgery with small incisions (<3.5 mm) is essentially astigmatically neutral, but the particular system used will affect incision stress and wound integrity, and may thus limit the reduction in incision size and astigmatism that is achievable\(^10\).

![Table 2](image.png)

**Table 2.** Changes to the axis due to the incision.

<table>
<thead>
<tr>
<th>Incision axis mean ± SD</th>
<th>Preoperative axis mean ± SD</th>
<th>Preoperative with/ against-the-rule astigmatism mean ± SD</th>
<th>Postoperative with/ against-the-rule astigmatism mean ± SD</th>
<th>Result with-the-rule mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>90.0 ± 24.6</td>
<td>85.9 ± 50.21</td>
<td>0.00 ± 1.00</td>
<td>-0.58 ± 0.81</td>
<td>0.29 ± 0.58</td>
</tr>
</tbody>
</table>

SD: standard deviation.
Corneal astigmatism and shape after 2.0-mm corneal incision cataract surgery are virtually the same as those after 2.0-mm scleral incision cataract surgery. In one study, no significant difference was found between the corneal incision cataract surgery and scleral incision cataract surgery groups in induced astigmatism or in irregular astigmatic components. Other studies showed that coaxial microincision cataract surgery (C-MICS) and standard coaxial small incision cataract surgery (C-SICS) were not only similar in terms of intraoperative parameters, but also in terms of postoperative BCVA, CCT increases, and anterior chamber inflammation levels. Switching from C-SICS to C-MICS is reasonable in order to achieve a smaller SIA. Furthermore, in our study, this SIA was minimized by the size of the incision, avoiding obvious changes in the resulting vector (cylinder resulting in dioptre) that changed over time (1.04 ± 0.60), independent of the axis where the incision was made (induction vector).

In conclusion, the present study analyzed the effect of microincision (2.2 mm) on the direction and magnitude of the vector. The results presented indicate that the direction of the vector did not significantly impact the SIA. Through surgery, it can be minimized by the size of the incision, avoiding obvious changes in the resulting vector (cylinder resulting in dioptres), independent of the axis where the incision was made (induction vector).

REFERENCES