**INTRODUCTION**

The advantages of intraocular lens (IOL) design could be limited, cancelled, or even turned into disadvantages by decentration and/or rotation (see Montes-Mico et al\(^1\) for a review). The advantages of asphericity, for instance, are lost when decentration is more than 0.50 mm\(^2,3\). In the case of toric IOLs, the importance of lens rotation is extremely high. It has been estimated that approximately 1 degree of off-axis rotation results in a loss of up to 3.3\% of the lens cylinder power. Rotation more than 10 degrees implies a reduction of the intended astigmatic effect in more than 30\%, with the resulting clinically significant consequences\(^4,5\).

Implantation of Artisan/Artiflex toric phakic IOL (pIOL) (Ophtec BV, Netherlands) is one of the options to correct high astigmatic errors. Two months after the surgery the patient reported worse vision with her left eye, with residual refractive error of \(+1.25 -2.00 \times 135^\circ\) yielding a corrected visual acuity of 1.0. Pre-operative and post-operative refractions in vectorial notation were subtracted and the result changed back into clinical notation, the resulting refraction being \(-8.98 -4.03 \times 15^\circ\), which was the same amount as attempted but rotated 15 degrees counterclockwise. A second procedure to rotate the position of the lens clockwise by this amount resulted in a residual error of \(+0.50 -0.75 \times 105^\circ\) and uncorrected visual acuity of 1.0–.

**KEY WORDS:** Vector analysis, axis misalignment, toric phakic IOL.

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**CASE REPORT**

Power vector analysis as an aid to correct a rotated Artiflex toric phakic intraocular lens

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**ABSTRACT:** We describe the use of power vector analysis in quantifying the amount of lens rotation and assessing the subsequent correction in a case of rotated Artiflex toric phakic intraocular lens (pIOL) (Ophtec BV, Netherlands). A 33 year old patient was corrected by bilateral implantation of Artiflex toric pIOLs for high myopia and astigmatism. Two months after the surgery the patient reported worse vision with her left eye, with residual refractive error of \(+1.25 -2.00 \times 135^\circ\) yielding a corrected visual acuity of 1.0. Pre-operative and post-operative refractions in vectorial notation were subtracted and the result changed back into clinical notation, the resulting refraction being \(-8.98 -4.03 \times 15^\circ\), which was the same amount as attempted but rotated 15 degrees counterclockwise. A second procedure to rotate the position of the lens clockwise by this amount resulted in a residual error of \(+0.50 -0.75 \times 105^\circ\) and uncorrected visual acuity of 1.0–.

**KEY WORDS:** Vector analysis, axis misalignment, toric phakic IOL.

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Some reports show good efficacy and predictability of the Artiflex pIOL design for the correction of spherical refractive errors\(^\text{16,17}\), and its implantation has also been reported to provide faster visual recovery than Artisan pIOL\(^\text{18}\). However, there are no peer-reviewed papers on the toric design to date. Whenever the lens design, placing it properly is of utmost importance, particularly for higher degrees of astigmatism, where minimal misalignment greatly reduces the corrective value of the lens\(^\text{19}\).

A case report showing the impact of pIOL misalignment on the visual outcome in a patient implanted with the Artiflex toric pIOL is presented here. Power vector decomposition was used to quantify the contribution of lens rotation to the residual refractive error after initial surgery and to plan a second correcting surgery for this situation. To the best of our knowledge this is the first report describing the use of power vector analysis in a case of rotated Artiflex toric pIOL.

**CASE REPORT**

A 33 year old woman attended the clinic demanding refractive surgery. She was a regular soft contact lens wearer (Toric Soflens\(^\text{®}\) , Bausch & Lomb, USA) for about 12 hours a day on average despite having tolerance and dryness problems. By the time of the visit she had not worn her contact lenses for 6 days. She had not known allergies nor was she having any medication or had any remarkable family history of ocular conditions.

Retinoscopy examination reported objective refraction values of \(-9.50 \pm 3.50 \times 180^\circ\) and \(-9.00 \pm 3.50 \times 180^\circ\) for OD and OS, respectively. In both eyes retinoscopic reflexes were clean and well defined. Manifest refraction displayed similar values than retinoscopy of \(-10.00 \pm 3.50 \times 180^\circ\) (best corrected VA 1.0\(^\circ\)) and \(-9.00 \pm 3.50 \times 180^\circ\) (best corrected VA 0.9\(^\circ\)). Similarly, cycloplegic refraction values were \(-10.00 \pm 3.25 \times 180^\circ\) (VA 1.0\(^\circ\)) and \(-9.25 \pm 3.25 \times 180^\circ\) (AV 0.9\(^\circ\)) for OD and OS, respectively. Central corneal thickness yielded values of 500 and 510 microns for OD and OS (ultrasonic pachymetry); anterior chamber depths were 3.8 mm in both eyes (partial coherence interferometry); Goldmann intraocular pressure (IOP) was 15 mmHg in both eyes; and fundus examination was normal in both eyes. The power of each pIOL was calculated using the software provided by the manufacturer, resulting in a \(-11.00 \pm 3.00 \times 0^\circ\) for OD and a \(-10.00 \pm 3.50 \times 0^\circ\) for OS, to be implanted at meridian 0\(^\circ\)-180\(^\circ\) in both eyes. Informed consent was obtained before surgery.

**Surgical technique**

Surgery was carried out under topical anesthesia and an Artiflex toric pIOL was implanted through a 3.2 mm clear-cornea incision placed at 12 o’clock in both eyes 24 hours apart. We used the marking technique previously reported by Graether\(^\text{20}\), which briefly consists of placing a a single ink mark at the limbus at 6 o’clock with the patient in upright sitting position during the preoperative preparation. A 360 degree gauge was applied to the eye having the patient lying down, and aligning the 90\(^\circ\)-270\(^\circ\) meridian with the mark previously made at 6 o’clock to compensate for a postural axis shift. A half circle axis marker was placed such that the index mark on the semicircle was aligned with the minus axis of the cylindrical correction (0\(^\circ\)-180\(^\circ\) meridian in both eyes), which was the axis where the Artiflex toric pIOL had to be fixated. Two 1-mm side port incisions were created at 0\(^\circ\)-180\(^\circ\) meridian to fixate the pIOL to the iris by means of forceps. At the end of the procedure a single 10/0 nylon suture was used to secure the incision in both eyes. Postoperative treatment included tobramycin and dexamethasone eyedrops (TobraDex, AlconLabs) 4 times daily for 14 days and then tapering it slowly during the following 3 weeks. Lubricant eyedrops (Acuolens, AlconLabs) were prescribed 3 to 4 times daily for 3 months.

**Post-operative examination**

Postoperative course was uneventful and 48 hours after surgery, open-field autorefraction values were +0.75 \(-0.75 \times 70^\circ\) and +1.00 \(-1.75 \times 130^\circ\) for OD and OS, giving spontaneous VA values of 1.0\(^\circ\) and 0.7\(^\circ\), respectively. Slit-lamp examination showed a slight incisional edema and sutures without Seidel phenomenon. Lenses were well centered with respect to pupil, although the pIOL inserted in OS was rotated about 15 degrees counterclockwise from intended. Postoperative IOP values were 12 mmHg in both eyes. A similar situation was found after one week and one month.

Two months after the surgery, stable and without sutures, the patient displayed uncorrected VA of 1.0 and 0.7\(^\circ\)\(^2\) for OD and OS, respectively. Manifest refraction values were +0.50 \(-0.50 \times 85^\circ\) and +1.25 \(-2.00 \times 135^\circ\) for OD and OS, yielding best corrected VA of 1.0 in both eyes. Overall the patient was very satisfied, but reported worse vision with OS.

Power vector analysis was used to quantify the contribution of lens rotation to the residual refractive error after initial surgery and to plan a second correcting surgery for this situation. The conversion to vectorial notation from clinical notation (Sph, Cyl, axis) was carried out following the expressions proposed by Thibos et al\(^\text{21}\); thus resulting in a spherical component M, equal to the mean spherical equivalent of the refraction, and two cylindrical components being represented by a Jackson cross cylinder at 0\(^\circ\), with a...
power \( J_{0} \) and a Jackson cross cylinder at 45°, with power \( J_{45} \):

\[
M = Sph + \frac{1}{2} Cyl
\]

\[
J_{0} = \frac{1}{2} Cyl \times \cos(2 \times \text{axis})
\]

\[
J_{45} = \frac{1}{2} Cyl \times \sin(2 \times \text{axis})
\]

The original spherocylindrical notation can be obtained by the following expressions:

\[
C = -2 \sqrt{J_{0}^2 + J_{45}^2}
\]

\[
S = M - \frac{C}{2}
\]

\[
\text{axis} = \frac{1}{2} \arctan \left( \frac{J_{45}}{J_{0}} \right)
\]

In the present case, pre-operative refraction in vectorial notation was:

\[
M = -10.75 \text{ D}
\]

\[
J_{0} = +1.75 \text{ Dp}
\]

\[
J_{45} = 0.00 \text{ Dp}
\]

Post-operative refraction in vectorial notation was:

\[
M' = +0.25 \text{ D}
\]

\[
J_{0}' = 0.00 \text{ Dp}
\]

\[
J_{45}' = -1.00 \text{ Dp}
\]

If subtracted \((M-M' = -11.00 \text{ Dp}; J_{0'} - J_{0} = +1.75 \text{ Dp}; J_{45}' - J_{45} = +1.00 \text{ Dp})\) and changed back into clinical notation, the resulting refraction values were \(-8.98 \text{ D} - 4.03 \times 15^\circ\), that is, almost the same amount as attempted but rotated 15° counterclockwise, agreeing with the observation made through slit-lamp.

A second surgery to correct the position of the lens in OS was performed under topical anesthesia. A single corneal mark at 3 o’clock (meridian 0°-180°) was performed at the slit-lamp. The previous clear-cornea incision at 12 o’clock was reopened by approximately 1.5 mm and a new side port incision of 1 mm was made at the corneal mark which was 15 degrees clockwise with respect to the temporal haptic of the pIOL. The lens was disengaged only from the temporal haptic and fixated again 15 degrees clockwise (Figure 1). The nasal haptic was not refixated and no suture was used after this second surgery.

Three months after rotation of the pIOL uncorrected VA values improved to 1.0 in OS with a manifest refraction of +0.50 –0.75 x 105°.

**DISCUSSION**

The present case report illustrates the impact of pIOL misalignment on refractive outcomes when correcting high levels of astigmatism. The advantages of IOLs design can be turned into disadvantages by decenteration, and in the case of toric IOLs, the importance of lens rotation is particularly high. The Artisan toric pIOL has shown good results, with 63% to 73% of eyes within 0.50 D of the predicted correction, and a best corrected visual acuity improvement in 65.7% to 70% of eyes. The Artiflex pIOL has been shown as effective and predictable for the correction of myopia, but to the authors’ knowledge there are no peer review reports on the toric design to date.

Refractive error is a vector, and may be therefore represented by its vectorial components. Refraction data in conventional clinical notation present a problem for analysis and comparison due to the variance in astigmatic power and axis and consequently needs to be transformed to be analyzed in dioptic power space for more accessible comparison. An interesting practical review on the manipulation of power vectors for the analysis of refractive outcomes has been published by Alpins and Goggin.

When pre- and post-surgery refraction values for the OS are changed to vectorial notation and then subtracted (pre-surgery minus post-surgery), the refractive effect caused by the pIOL may be observed, that is, the change induced. Had everything gone as initially planned, that change should have been equal to pre-surgery refraction, that is, the changed induced would be equal to the change attempted. If rotation occurs, the result would be the attempted values but rotated (around 15 degrees in the present case). When pre-operative and postoperative refractions in vectorial notation were subtracted and changed back into clinical notation the resulting refraction value was the same amount as attempted but rotated 15 degrees, agreeing with the observations made clinically. A different approach would be comparing the preoperative refraction and the preoperative refraction rotated 15 degrees.
may explain incorrect IOL alignment25, including: (1) desired angle. There are different sources of error that finally the limbus or the cornea are marked at the graduations is aligned to these primary marks, and vertical meridian, a secondary device with angular correction. Ophthalmologist using toric pIOLs (and toric IOLs in general) should be familiar with power vector analysis to better understand and improve patients’ outcomes.

Preventing lens misalignment, both decentration and rotation, is a fundamental requisite for effective refractive correction with toric pIOLs. Artiflex pIOL should provide excellent rotational stability due to the nature of fixation of the lens to the iris different from other pIOLs designs in which the lens is not physically attached to any ocular structure of the anterior segment of the eye. This could represent one of the main advantages of the iris-fixated pIOL design for the correction of high astigmatic defects. Different marking techniques have been published in order to achieve accurate toric lens alignment20,25. Those most commonly used involve a 3-step procedure in which the cornea or the limbus are marked at the horizontal or vertical meridian, a secondary device with angular graduations is aligned to these primary marks, and finally the limbus or the cornea are marked at the desired angle. There are different sources of error that may explain incorrect IOL alignment25, including: (1) the marks on the peripheral cornea are far from the outer margin of the IOL, and so the surgeon must interpolate these points intraoperatively to estimate the final correct axis of alignment; (2) the marks made with a dye or a surgical marking pen may smudge or disappear; (3) these techniques try to align the IOL axis with the anatomical cornea and not the visual axis, which may not be concentric with the anatomical cornea; (4) it is often not possible to keep the marking instrument, the IOL, and the limbus or corneal marks in focus simultaneously; (5) cyclotorsion can happen as a result of fixation of the patient when marking the horizontal or vertical meridian at the slit-lamp; (6), intraoperative iris movement (rotation and vertical or horizontal displacement) as a result of injecting viscoelastic materials or miotics may occur and could also explain disalignment in cases of iris-fixated toric pIOL.

In summary, we present a patient with bilateral implantation of toric Artiflex pIOLs that has shown excellent outcomes after detecting and correcting a significant amount of lens rotation in one eye, which in the case of a highly astigmatic prescription implied a significant refractive effect. Vectorial decomposition of refractive error proved to be a useful tool for confirming and quantifying the refractive impact of lens rotation, as well as to check the final result after correction. Ophthalmologist using toric pIOLs (and toric IOLs in general) should be familiar with power vector analysis to better understand and improve patients’ outcomes.

REFERENCES