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Original articles

Refractive and visual outcome of toric intraocular lens implantation following cataract surgery

Ale JB, Power J, Zohs K, Cunningham F
Peninsula Eye Hospital, Moreton Eye Group, Queensland, Australia

Abstract

Purpose: To evaluate the refractive and visual outcome of toric IOL implantation for correction of pre-existing corneal astigmatism following cataract surgery.

Materials and methods: In this retrospective study, 56 eyes of 30 patients who underwent implantation of toric IOL following regular phacoemulsification were divided into two groups based on the types of toric IOL implanted: group 1 patients received Acrysof toric (Alcon) and group 2 patients received AT-Torbi (Zeiss Meditech) IOLs. Pre-and post-operative corneal and refractive astigmatisms, and post-operative distance vision were investigated. Statistical analysis was carried out using the paired student t-test when necessary. Factors affecting the success of toric IOL implantation are discussed and recommendations are made to optimize the outcome.

Results: The mean age of all patients was 75.56 ± 9.87 years. No statistical difference was observed between pre-and post-operative corneal astigmatism ($p = 0.819$). Postoperative refractive astigmatism was significantly less in both groups (Group 1: $p = 0.0014$; Group 2: $p = <0.00001$). The best-corrected distance visual acuity was 6/12 or better in 95 % of group 1 and 100 % of group 2 patients.

Conclusion: Toric IOL implantation is a viable and highly predictable method of correcting the corneal astigmatism. It allows correction without compromising the integrity of the cornea. Careful selection of the patient, accurate keratometry and precise alignment of the cylindrical axes are some of the factors to be considered for a superior outcome.

Key-words: toric intra-ocular lens, cataract surgery

Introduction

Modern cataract surgery had evolved from a mere cataract removing procedure to a regular component of the refractive surgery. Refractive outcome following cataract surgery is not always as perfect as a surgeon or a patient would like to have. Existence of significant post-operative residual astigmatic error, even in patients who are implanted with a toric IOL, is not uncommon. Number of potential sources such as error in biometry (keratometry, measurement of ocular dimensions), size and direction of the incision, implant position and centration of the IOL and the formula used in calculating the IOL power have been identified to contribute in suboptimal refractive outcome (Norrby, 2008).

Among the preoperative cataract population, about 15 to 20 percent exhibit more than 1.5D (Hoffer, 1980) and about 50 % exhibit more than 1.0D (Vitale

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et al, 2008) corneal astigmatism. In a phakic eye, the corneal astigmatism is modified, either compensated or enhanced, by the internal lenticular astigmatism resulting in a difference between keratometry and refractive astigmatism. However, in a pseudophakic eye, well positioned monofocal IOL (or conventional IOL) hardly induces any internal astigmatism unless it is tilted to or decentred from the visual axis (Atchison, 1989). Therefore, keratometric astigmatism is likely to manifest as a total refractive astigmatism post operatively, and thus leading to a suboptimal visual outcome.

Lower-order aberrations, namely defocus and astigmatic errors, have a greater impact on visual acuity. Defocus is relatively easier to correct with spectacle; however, spectacle correction of the astigmatism creates meridional asymmetry of retinal images due to variable magnification especially if the astigmatism is of moderate to high magnitudes. Moreover, adaptation of such distorted image, particularly in elderly individuals, is challenging. Adaptation becomes easier when the astigmatism is corrected in the corneal plane (e.g. contact lens correction) or IOL plane (correction with toric IOL) as the meridional magnification is negligible (Novis, 2000).

This opto-physiological understanding has lead to innovation of different methods attempting to control the corneal astigmatism intra-operatively. Corneal (or limbal) relaxing incision (Troutman and Swinger, 1980), astigmatic keratotomy (e.g. excimer laser keratotomy), variation in incision site (Kaufmann et al, 2005) and implantation of toric IOL are the commonest techniques being used. Corneal incision methods are reported to correct zero to 1D astigmatism depending on size, site and number of relaxing incisions (Ben and Desatnik, 2005). However, amount of correctable astigmatism with these procedures is unpredictable. Toric IOL implantation method is the most preferred technique as it is highly predictable and can correct even an extreme form of astigmatism.

Performance of a toric IOL relies on various factors including accurate biometry data (Keratometry and axial length measurement), surgical procedure, IOL designs and post operative complications (Buckhurst et al, 2010). In this study, we retrospectively analysed the data of 56 eyes implanted with one of AT-Torbi or AcrySof toric IOL in Peninsula Eye Hospital Queensland, Australia. Outcome measures included pre and post operative keratometry and refraction, post operative uncorrected and best corrected distance vision. Postoperative corneal and refractive astigmatic changes were also investigated with a special interest to determine surgically induced astigmatism (SIA).

Materials and methods

Records of cataract patients implanted with two types of toric IOL (AT-Torbi and AcrySof) between July-December 2010 at Peninsula Eye Hospital, Redcliffe, Queensland, Australia were retrospectively analysed. Total 63 records were identified, out of which 56 eyes of 30 patients were included in the study. Remaining 7 eyes were excluded for insufficient data available.

Patients were categorized into two groups based on the type of toric IOL implanted. Group 1 and group 2 patients were implantation with AcrySof (Alcon, USA) and AT-Torbi (Carl Zeiss Meditec, Germany) toric IOLs respectively. There were 20 (35.7 %) eyes in group 1 and 36 (64.3 %) eyes in group 2. AT-Torbi is an acrylic bitoric plate haptic IOL with 6mm optic and 11 mm total diameter. It is available up to 12.0D cylinder in 0.50D steps. AcrySof is a single piece acrylic IOL with open loop L-shaped haptics. This IOL has 6.0 mm optics and the overall diameter is 13 mm. It is available with specification of T3 through T9 (1.50D to 6.0D cylinder in steps of 0.75D).

All eyes included in the study underwent uneventful phacoemulsification procedure through 2.7 mm wide clear corneal incision located at 120 degrees (for Group 1) or temporal incision (for Group 2; zero degrees in left eye and 180 degrees in right eye). The anterior chamber was maintained using a

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cohesive viscoelastic material throughout the procedure and during implantation of the IOL which was aspirated at the end of the procedure.

Variables collected for analysis included age, gender, pre and post-operative keratometry value, pre & post-operative subjective refraction and uncorrected & best corrected visual acuities. Surgically induced refractive change (SIRC) was calculated using the method described by Holladay et al (1992) for individual surgeon. Paired student t-test was employed for statistical significance when necessary.

Results

1. Demography

Mean age of all cases was 75.56 ± 9.87 years (range 51 – 91 years). Out of the total, 27 (48.21 %) were male and 29 (51.79 %) were female patients. Mean age of Group 2 and Group 1 patients were 79.3 ± 5.5 years (range 69-90 years) and 73.8 ± 11.6 years (range 51-91 years) respectively. Age group and gender of all the participating patients are illustrated in Figure 1.
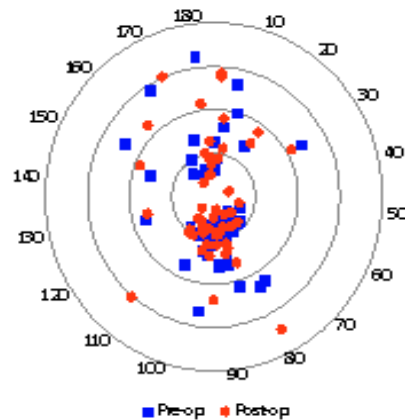
Figure 1: Age and gender distribution of subjects
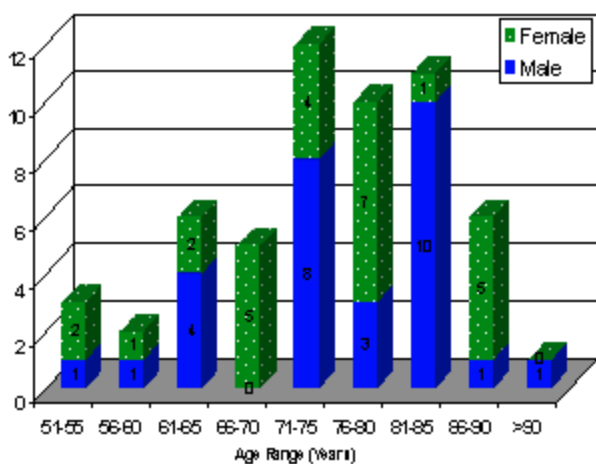
included in the study.

2. Corneal astigmatism

Pre-operative corneal astigmatism of the total patients was 2.60 ± 1.35D (range 1 – 5.75D). For Group 1 and 2, mean pre-operative corneal astig-

matism were 2.32 ± 1.10D (1 – 5.25D) and 3.11 ± 1.62D (1 – 4.75D), respectively. Post-operatively, mean corneal astigmatism of the total patients was 2.50 ± 1.49D (range 0.75 – 6.88D) which statistically did not differ from the pre-operative astigmatism (p = 0.711). Mean corneal astigmatism in Group 1 was 2.10 ± 1.12D (range 0.75 – 5.63D; p = 0.394) and in Group 2, it was 3.23 ± 1.81D (range 1.25 – 6.88D; p = 0.819). No statistical difference occurred between the groups (p = 0.064). Pre and post operative corneal astigmatism of the total patients and individual group can be seen in Figures 2 to 4.

Figure 2: Pre & post-operative corneal astigma-

tism of total patients (p = 0.711). Each concentric ring represents 2.0D astigmatic strength.

Figure 3: Pre & post-operative corneal astigmatism of Group 1 patients (p = 0.064). Each concentric ring represents 2.0D astigmatic strength.

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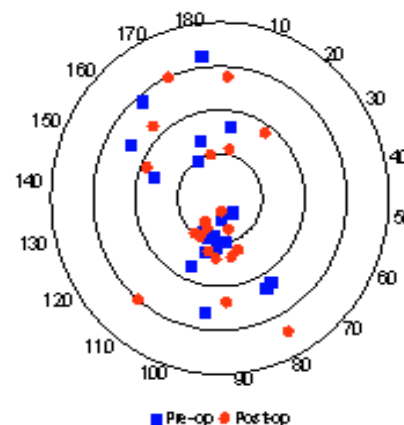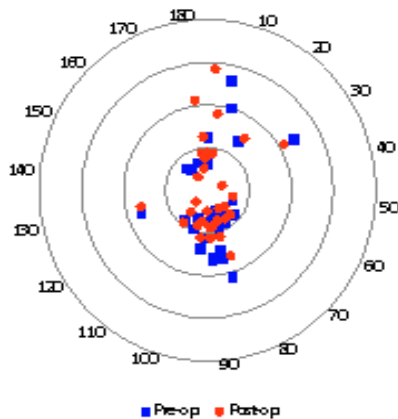*Visual outcome of toric IOL implantation*
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Figure 4: Pre & post-operative corneal astigmatism of Group 2 patients (p = 0.349). Each concentric ring represents 2.0D astigmatic strength.

3. Refractive astigmatism

Mean pre-operative refractive astigmatism of the total patients was 2.63 ± 1.66D (range $1 - 6.50$D). Group wise, it was 3.12 ± 2.13D for Group 1 and 2.36 ± 1.29D for Group 2 which did not differ statistically (p = 0.158). There was a significant drop in refractive astigmatism post operatively in total eyes and individual group. Of the total, mean post operative astigmatism reduced to 0.91 ± 0.78D (range $0 - 4.0$D; p = <0.00001). Group 1 patients had mean post-operative refractive astigmatism 1.33 ± 0.96D (range $0.5 - 4.0$D) which statistically differed from the pre-operative astigmatism (p = 0.0014). Group 2 patient had mean astigmatism of 0.681 ± 0.55D (range $0 - 3.00$D) which was significantly different from pre-operative astigmatism (p = <0.00001). A statistical difference was observed in mean post-operative refractive astigmatism between the two groups (p = 0.011). Pre and post operative refractive astigmatism for total patients and individual group can be seen in Figures 5 to 7.

More than 37 % of the total patients (n = 21) achieved post-operative astigmatism within 0.50D and 76.79 % (n = 43) achieved within 1.0D. 60 % of Group 1 and 86.10 % of Group 2 patients had refractive astigmatism within 1.0D post-operatively. Only 7.16 % of the total patient, 15 % of Group 1

and 2.78 % of Group 2 patient had post operative residual refractive astigmatism > 2.0D.

4. Surgically induced astigmatism (SIA)

Surgically induced corneal astigmatism may be defined as the combined changes in post operative corneal astigmatism from preoperative. Actual changes in corneal astigmatism were used in calculating the surgically induced astigmatism. Overall, the corneal astigmatism changed by 0.676 ± 0.616D @ $1.35 \pm 9°$ in Group 1 and 0.587 ± 0.52D @ $2.35 \pm 9°$ in Group 2 patients.
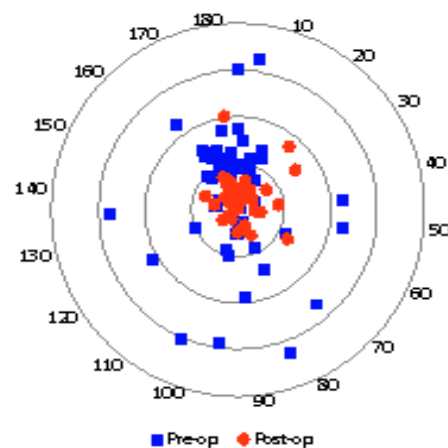

Figure 5: Pre & post-operative refractive astigmatism of total patients (p = <0.00001). Each concentric ring represents 2.0D astigmatic strength.
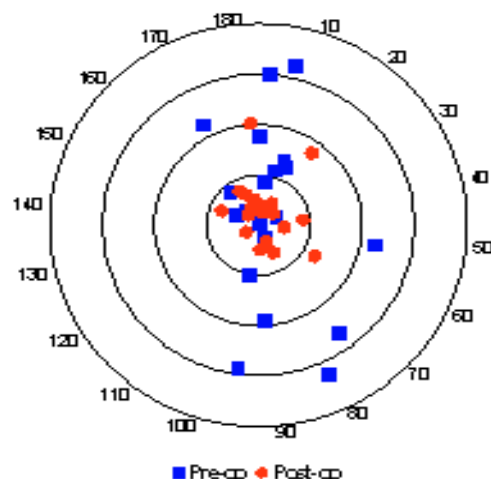

Figure 6: Pre & post-operative refractive astigmatism of Group 1 patient (p = 0.0014). Each concentric ring represents 2.0D astigmatic strength.
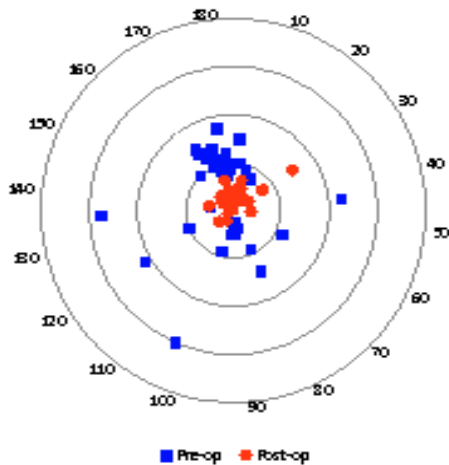
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Figure 7: Pre & pos-operative refractive astigmatism of Group 2 patient (p = <0.00001). Each concentric ring represents 2.0D astigmatic strength.

5. Visual acuity

Practically, visual acuity is one of the most important parameters determining the success of cataract surgery. There was no difference in pre-operative visual acuities between the two groups post-operatively. Uncorrected visual acuity was 6/6 or better in 16.64 % and 6/12 or better in 69.64 % of the total eyes. Approximately 54 % achieved best corrected visual acuity 6/6 or better and 98.21 % achieved 6/12 or better. 95 % in Group 1 and 100 % in Group 2 eyes obtained 6/12 or better best corrected distance visual acuity post operatively (Table 1).

Table 1
Best corrected post-operative distance visual acuity

BCDVA	Total	Group 1	Group 2
≥ 6/6	30 (53.57 %)	10 (50.00 %)	20 (55.56 %)
< 6/6 – 6/12	25 (44.64 %)	9 (45.00 %)	16 (44.44 %)
< 6/12 – 6/18	1 (1.79 %)	1 (5.00 %)	0 (0.0 %)
< 6/18 – 6/60	0 (%)	0 (0.0 %)	0 (0.0 %)
< 6/60	0 (%)	0 (0.0 %)	0 (0.0 %)

Discussion

Several authors have reported refractive and visual outcomes following implantation of toric IOL. Jonathan et al (2002) reported within 1.0D post-operative refractive astigmatism in 75 % and within 0.50D in 48 % of the cases. Irene et al. (Irene,

Ursula et al 2000) reported post-operative refractive astigmatism within 1.0D in 78.4 % and within 0.5D in 48.6 %. Poll et al (2011) compared the efficacy of the corneal relaxing incision and implantation of toric IOL in correcting corneal astigmatism at the time of cataract surgery. The authors concluded that for corneal astigmatism more than approximately 2.0D, implantation of toric IOL is more effective than the corneal relaxing. In the present study more than 37 % of the total patients achieved post-operative astigmatism within 0.50D and 76.79 % achieved within 1.0D. 60 % of Group 1 and 86.10 % of Group 2 patients had refractive astigmatism within 1.0D post-operatively.

Irene et al (2000) found 6/6 or better best corrected distance vision in 54 % and 6/12 or better in 92 %. Uncorrected distance vision was 6/12 or better in 67.5 % of the total eyes. Tehrani et al (2003) found within 1.0D astigmatism in 95 % and UCVA equal or better than 6/9 in 85 % eyes. Chang (2003) found 6/12 BCVA in his 92 % of cases. Post operative distance visual acuities were 6/6 or better in 32 % and 20/40 or better in 96 % (Jonathan et al, 2002). Uncorrected distance visual acuity was 6/6 or better in 7 % and 6/12 or better in 66 % of the eyes. In the current study, uncorrected visual acuity was 6/6 or better in 16.64 % and 6/12 or better in 69.64 %. Approximately 54 % achieved best corrected visual acuity 6/6 or better and 98.21 % achieved 6/12 or better. 95 % in Group 1 and 100 % in Group 2 eyes obtained 6/12 or better best corrected distance visual acuity post operatively.

Poll et al (2011) reported within 5º rotation of axis in 62 % whereas 14 % had more than 15º rotation. Nearly 5 % required repositioning of the IOL. Patel et al. (1999), in one of their comparative study reported that the plate haptic is more stable than loop haptics in long term. Grabow (1997) found that the IOL rotates by >30º in 4.4 % of the cases. Irene et al (2000) reported about 5º rotation in 20 % of their subjects, whereas 2.7 % had >30º rotation. With a plate haptic toric IOL (10.8mm overall length), Chang (2003) found good stability. 72 %

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of his cases had within 5 degrees of intended axis and 98 % within 15 degrees.

Theoretically, a carefully calculated toric IOL should eliminate postoperative astigmatism; however in a practical sense, it is evidential that a toric IOL quite often fails to correct the corneal astigmatism fully. An important optical advantage of this method is that the IOL position is close to the nodal point which virtually results no variation in meridional magnification. Major factors affecting the outcome of a toric IOL implantation and strategies to of optimization may be summarized as following.

Keratometry is an important component of the ocular biometry. Accurate measurement of the corneal astigmatism (strength and axis) is extremely important as an error may give rise to improper determination of the toric IOL strength thereby inducing unwanted residual astigmatism. Studies have demonstrated that various available methods are of keratometry including automated, topographical and manual methods are equally reliable for the purpose of IOL calculations (Tennan et al, 1995; Huynh, 2006; Elbaz et al, 2007; Shirayama et al, 2009; Symes, 2011). To minimize the error, keratometry should be performed prior to any other procedure such as applanation tonometry and gonioscopy. There are two obvious reasons for this; firstly, the topical anaesthetic agent may cause the tear film instability leading to an error in keratometry reading. Instable tear film has been shown to create errors larger than 0.60D (Erdelyi et al, 2006). Secondly, mechanical pressure exerted by the procedures may alter the topography of the cornea that may mask the true keratometry readings. Verification of Keratometry is highly recommended using different instrument especially when a cornea exhibit significant astigmatism (>3.0D).

Astigmatic correction with a toric IOL is also critically dependent on alignment of cylindrical axis with the axis of the corneal astigmatism. Magnitude (and so the percentage) of astigmatic correction or equivalently the residual astigmatism due to misalignment of the axis is sinusoidal in nature (Buckhurst et al, 2010). When the axis is misaligned by 30º, the induced astigmatism is equal to the original astigmatism with shift in resultant axis by 90º. The residual astigmatism doubles (200 %) when the axis is misaligned by 90º from the intended axis. An accurate alignment becomes more critical for a stronger cylinder. Therefore, a routine must be followed that reference markers in the opposite sides of the pupil must be established preoperatively to demarcate the correct axis of corneal astigmatism and IOL orientation. Marking must be done in upright (sitting) position because the rotation occurs in a supine position (Chernyak, 2004).

Surgically induced astigmatism (SIA) is one of the factors inherent to a cataract surgery. Therefore, adjusting a SIA is essential while implanting a toric IOL. Though IOL manufacturers (e.g. Alcon, Zeiss) provide a handy formula to calculate sphero-cylindrical power of a toric IOL with an average SIA (typically 0.5), it is strongly recommended to optimize the value for individual surgeon.

Postoperative IOL rotation is one of the most frequently reported complications. Several bio-physio-mechanical factors play a role in the long term stability of a toric IOL. Postoperative capsular fibrosis and shrinkage of the bag may lead to a significant rotation of the axis. In case, IOL repositioning (axis realignment) is required, it should be done within 2 weeks from the implantation. After two weeks haptics are usually well captured within the equator hence the realignment becomes extremely difficult with increased risk of capsule rupture. Refraction and observation of axis alignment must be checked on first day and two weeks post-operative. Vigorous capsule polishing reduces the epithelial cell migration and formation of PCO thereby ensuring better stabilization of the IOL. Similarly, complete aspiration of visco-elastic material is critical for a long term stabilization of the IOL. Pre-existing ocular and systemic pathology such as retinitis pigmentosa, glaucoma and diabetes predispose the capsular fibrosis postoperatively which increase the risk of IOL rotation.

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Design of toric IOL, especially the haptics design, is another important determinant for its stability. Plate haptics has demonstrated an excellent stability compared to open loop haptics (Patel et al, 1999). However, any design may offer reasonably stable position provided there exist a maximum friction between the haptics and the capsular bag which is partly determined by the overall size the IOL (Chang, 2003).

Conclusion

Implantation of a toric IOL can effectively correct corneal astigmatism thereby enhancing the postoperative visual outcome. It is a viable and highly predictable method and allows correction without compromising integrity of the cornea. Real time intraoperative refraction would be an ideal method for an accurate IOL placement, but before this technique is readily available, certain careful measures in selecting patients, measuring corneal curvature and aligning cylinder axis may further optimize the outcome.

This is an in-house study with no commercial interest. No specific research grant has been used in conducting this study.

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