Original Article

# Comparing IOLM700 TK, Berdahl and Hardten astigmatism fix calculator and Barrett Rx formula in managing residual astigmatism due to toric intraocular lens misalignment

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**Purpose:** To compare the accuracy in astigmatism reduction by using IOLM 700 steep total keratometry (TK) axis, Berdahl and Hardten astigmatism fix, and Barrett Rx formula following misaligned toric intraocular lens (IOL). **Methods:** Ten patients with residual refractive astigmatism due to misalignment following toric IOL implantation were included in this retrospective study. They were analyzed at days 4, 7/8, and 10/11 following primary cataract surgery on the platform of Berdahl and Hardten astigmatism fix, Barrett Rx formula, and IOLM 700 to determine the optimum axis of repositioning, and underwent IOL realignment on the steep TK axis of IOLM 700 assisted by the Callisto eye. The final outcome parameters were subjective refraction and orientation of toric IOL assessed 22 ± 1 days following repositioning surgery. These parameters were fed in the Barrett Rx formula and its vector analysis graph was utilized to determine the predicted ideal axis with the least residual astigmatism and the estimated residual astigmatism if the toric IOL was realigned according to the axis suggested by Berdahl and Hardten astigmatism fix and Barrett Rx formula. **Results**: Realigning the toric IOL on IOLM 700 steep TK axis along with the Callisto eye reduces the residual refractive astigmatism significantly ($P$ = 0.003) from 2.00 ± 0.78 D to 0.18 ± 0.12 D (90.5 ± 7.6%) in comparison to the estimated 0.57 ± 0.31 D (68.4 ± 21.9%) by Berdahl and Hardten astigmatism fix and 0.61 ± 0.33 D (66.4 ± 23.5%) by Barrett Rx formula. **Conclusion**: Realigning the misaligned toric IOL on the IOLM 700 steep TK axis gives a better reduction in the residual refractive astigmatism in comparison to Berdahl and Hardten astigmatism fix and Barrett Rx formula.

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**Key words:** Barrett Rx formula, Berdahl and Hardten astigmatism fix calculator, IOLM 700 TK, misaligned toric IOL, repositioning, residual astigmatism

With several advances in cataract surgery and increased patient expectations, modern cataract surgery has become a refractive surgery. Significant corneal astigmatism is present in a large proportion of patients presenting for cataract surgery; in a large data set, more than 36% of the eyes had >1.0 D while an estimated 74% had >0.50 D of astigmatism.[1] One of the most effective ways to reduce astigmatism at the time of cataract surgery is by implanting a toric intraocular lens (IOL).[2]

Toric IOL is a revolutionary technology in cataract surgery to achieve excellent postoperative refractive results in patients with astigmatism to meet their ever-rising expectations of spectacle-free vision.

A misaligned toric IOL leads to residual refractive astigmatism due to inaccuracies in the IOL placement intraoperatively or due to IOL rotation.[3] For every degree that the orientation of a toric IOL differs from the ideal, there is a 3.3% decrease in its effectiveness at reducing astigmatism.[4]

Inadequacies in the intraoperative placement of toric IOL can be managed with the digital tracking system of the Callisto eye (Zeiss Meditec, Oberkochen, Germany). Raucau *et al*.[5] observed a mean difference of 4.7° between the manual horizontal axis marking on slit-lamp and automated horizontal axis of Callisto eye generated by conjunctival registration.

With a markerless integrated digital overlay, toric IOL can be precisely oriented at the intended axis with regard to a reference image acquired during the preoperative biometry with IOLM 700 (IOL Master 700) thus removing the errors of manual marking and achieving the desired orientation of IOL.[6]

Thus, with precise biometry and accurate intraoperative placement of the toric IOL, the lens rotation remains a major cause of toric IOL alignment errors. Toric IOLs had the greatest rotation in the early postoperative period usually within 1 h of cataract surgery and very little rotation after 1 week postoperatively.[7] The factors which may be associated with an increased likelihood of toric IOL rotation include a longer axial length, inaccurate capsulorhexis size and centration,

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incomplete removal of the ophthalmic viscosurgical devices, and changes in the intraocular pressure.[8-10]

Considerable misalignment can lead to unsatisfactory uncorrected visual acuity (UCVA) warranting realignment of the toric IOL. Multiple resources are available to help the surgeons evaluate patients with postoperative residual refractive astigmatism due to toric IOL misalignment.

Here we will compare the efficacy and accuracy of the realignment axis suggested by Berdahl and Hardten astigmatism fix calculator and Barrett Rx formula with the measured steep total keratometry (TK) axis of IOLM 700.

### Suggested terminology

Intended axis: Axis suggested by on-board Barrett Suite of IOLM 700 in the preoperative biometry analysis.

Predicted Ideal axis: Axis which gives the least possible residual astigmatism determined on the vector analysis graph of the Barrett Rx formula, obtained by using post-repositioning (day 22 ± 1 in this study) subjective refraction and IOL orientation confirmed on the Callisto eye.

Ideal residual cylinder: Residual cylinder obtained on the vector analysis graph of the Barrett Rx formula when the IOL is repositioned on the predicted ideal axis.

Predicted residual cylinder (post-repositioning): Residual cylinder on the vector analysis graph of the Barrett Rx formula when the IOL is repositioned on the axes suggested by the Berdahl Hardten Astigmatism fix or Barrett Rx formula.

## Methods

This is a retrospective study wherein patients with residual refractive astigmatism following implantation of toric IOL after cataract surgery from June 2018 to February 2020 with unsatisfactory unaided visual acuity and willing for reorientation were included. The study was done in accordance with the tenets of the Declaration of Helsinki and was approved by the institutional review board. Informed written consent was obtained from all patients. A total of 10 patients (six right eyes and for left eyes) with residual refractive astigmatism were evaluated on three postoperative visits at days 4, 7/8, and 10/11 following primary cataract surgery on the platform of IOL Master 700 TK, Berdahl and Hardten astigmatism fix calculator, and Barrett Rx formula to determine the most reliable and accurate axis of realignment to give the least residual refractive astigmatism.

### Primary cataract surgery

The Barrett suite (Barrett TK toric) of IOL Master 700 was utilized to calculate the IOL power and the intended axis of placement of toric IOL. A reference scleral image is automatically acquired by a camera integrated with IOLMaster 700 during routine preoperative biometry. This image along with biometry is transferred via a USB drive to the Callisto eye (Carl Zeiss Meditec part of Zeiss Cataract Suite). The toric IOL used were Tecnis toric IOL (Johnson and Johnson surgical vision, Inc., USA) with series ZCT150 (one eye), ZCT225 (2 eyes), ZCT300 (three eyes), and toric AT Torbi 709M (Carl Zeiss Meditec AG, Jena, Germany) with cylinder series 1.0 D (one eye), 1.5 D (two eyes) and 3.0 D (one eye).

### Pre-repositioning workup and assessment

UCVA, subjective refraction, lens orientation in the dilated pupils on slit-lamp after ensuring proper head alignment were recorded on three postoperative visits at days 4, 7/8, and 10/11 after the primary cataract surgery. The two variables, subjective refraction and lens orientation, were further analyzed.

These data were assessed and compared on the platform of the Berdahl and Hardten astigmatism fix calculator, Barrett Rx formula, and IOL Master 700 TK to calculate the axis for repositioning of the IOL. The patient data including subjective refraction, lens orientation, and the cylinder power of the implanted IOL are fed in the online back-calculation software Berdahl and Hardten astigmatism fix calculator and Barrett Rx formula to obtain the realignment axis with minimal residual astigmatism on days 4, 7/8, and 10/11. Also, a note is made of the steep TK axis on IOLM 700 on these three postoperative visits. The final realignment is done on the basis of day 10/11 steep TK axis of IOLM 700.

### Repositioning surgical procedure

All the patients underwent repositioning of the toric IOL on day 10/11 after the primary cataract surgery by the same experienced surgeon. The Callisto eye Z-align assistant function was prepared using the day 10/11 steep TK axis of IOLM 700 and the reference image from IOLM 700 was used for registration in real-time. Intraoperatively, the axis of placement shown by the Z-align was also manually marked which can be used as reference marks in case of loss of registration due to chemosis during the surgery. The capsular bag was irrigated using a balanced salt solution via the irrigating cannula through the old paracentesis wound. The cannula was used to lift the edge of the margin of capsulorhexis to free it from the anterior surface of toric IOL. The irrigating cannula was used to rotate the IOL freely to ensure that the haptics do not restrict the final axis of placement. The IOL is aligned according to the Z-align followed by minimal wound hydration as shown in Fig. 1. All cases received an intracameral injection of 0.5% w/v moxifloxacin at the end of the surgery followed by a standard topical antibiotic and steroid regimen.

### Post-repositioning assessment

The patients were evaluated on day 22 ± 1 following the repositioning procedure to record UCVA, subjective refraction, and dilated ophthalmic examination to record the final AOP (axis of placement) on the digital overlay of the Callisto eye. Pre- and post-repositioning UCVA was not used for the

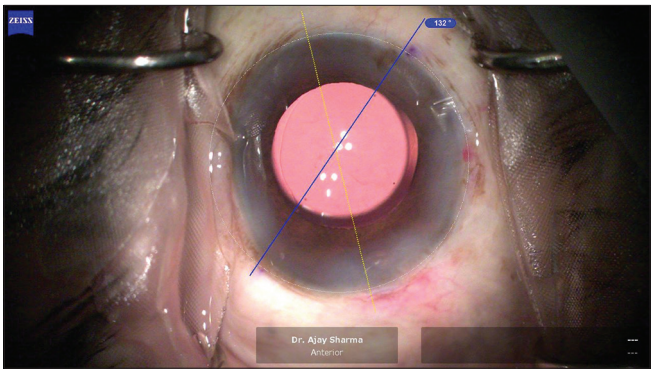


**Figure 1:** Final alignment of toric IOL assisted by the image-guided Callisto eye

analysis as the patients with targeted monovision were also included for repositioning. The final lens orientation and subjective refraction were entered in the online Barrett Rx formula to find the predicted ideal axis with the least possible residual astigmatism as shown in Fig. 2. Furthermore, the same vector analysis graph was utilized to calculate the predicted residual cylinder (post-repositioning) if the toric IOL was implanted on the axis suggested by the Berdahl and Hardten astigmatism fix calculator, Barrett Rx formula, and measured steep TK axis of IOLM 700 on three postoperative visits at days 4, 7/8, and 10/11 after the primary cataract surgery.

### Statistical analysis

Statistical analyses were performed using the statistical package SPSS (IBM SPSS Statistics for Windows, Version 24.0. IBM Corp). Descriptive was done for the continuous variables. Non-parametric tests were used for statistical analyses as data showed not normally distributed due to less sample size. The Wilcoxon test was done to compare two paired variables. The readings at the three visits were compared using the Friedman test. Intraclass correlation (ICC) was done to rule agreement between visits. The statistical significance was set at $P = 0.05$.

## Results

A total of 10 participants with a mean age of 69.5 ± 8.0 years who required IOL repositioning were included in the study. Table 1 summarizes the ocular parameters for the participants.

Fig. 3 depicts the postoperative changes in the lens orientation on days 4, 7/8, and 10/11 with respect to the intended axis for each participant. The average degree of misalignment from the intended axis and predicted ideal axis measured at day 10/11 after the primary cataract surgery was 55.4° ± 17.9° and 56.9° ± 18.1° including three clockwise and seven counter-clockwise rotations and were statistically similar to each other ($P = 0.55$).

The change in the axis measurements on the slit-lamp of misaligned toric IOL between days 4, 7/8, and 10/11 was 2.17° ± 1.55°. The change in the steep TK axis measurements on IOLM 700 between days 4, 7/8, and 10/11 was 2.5° ± 1.5° which was significantly small ($P = 0.59$) as compared to the variation in the realignment axis suggested by Berdahl and Hardten astigmatism fix calculator (8.8° ± 7.1°) and Barrett Rx formula (8.9° ± 7.4°) on the three postoperative visits.

The change in residual astigmatism measured at the corneal plane at days 4, 7/8, and 10/11 and the post-IOL repositioning with respect to the preoperative corneal astigmatism have been shown in Fig. 4. On day 10/11, the average astigmatism among the participants was 2.00 ± 0.78 D which after IOL repositioning reduced significantly to ≤0.25 D ($P = 0.005$).

Fig. 5 demonstrates the values of the AOP suggested by Berdahl and Hardten astigmatism fix calculator, Barrett Rx formula, and the measured steep TK axis of IOLM 700 at days 4,

**Table 1: Descriptives of the ocular parameters**

| Parameter | Mean±SD | Range |
|---|---|---|
| Axial length (mm) | 24.09±0.26 | 23.75-24.61 |
| Flat K readings (D) | 42.99±1.38 | 41.21-44.93 |
| Steep K readings (D) | 44.38±1.52 | 42.63-47.06 |
| ΔK (D) | 1.39±0.58 | 0.54-2.13 |
| Flat TK readings (D) | 43.06±1.37 | 41.30-45.01 |
| Steep TK readings (D) | 44.54±1.51 | 42.87-47.12 |
| ΔTK (D) | 1.49±0.47 | 0.81-2.11 |
| White to white diameter (mm) | 12.17±0.35 | 11.60-12.60 |
| Anterior chamber depth (mm) | 3.10±0.31 | 2.42-3.52 |
| IOL SE power (mm) | 19.45±2.48 | 15.00-22.00 |
| Amount of cylinder@ corneal plane (D) | 1.51±0.54 | 0.69-2.06 |

SD=standard deviation; K=keratometry; TK=total keratometry; D=diopters; IOL=intraocular lens; SE=spherical equivalent

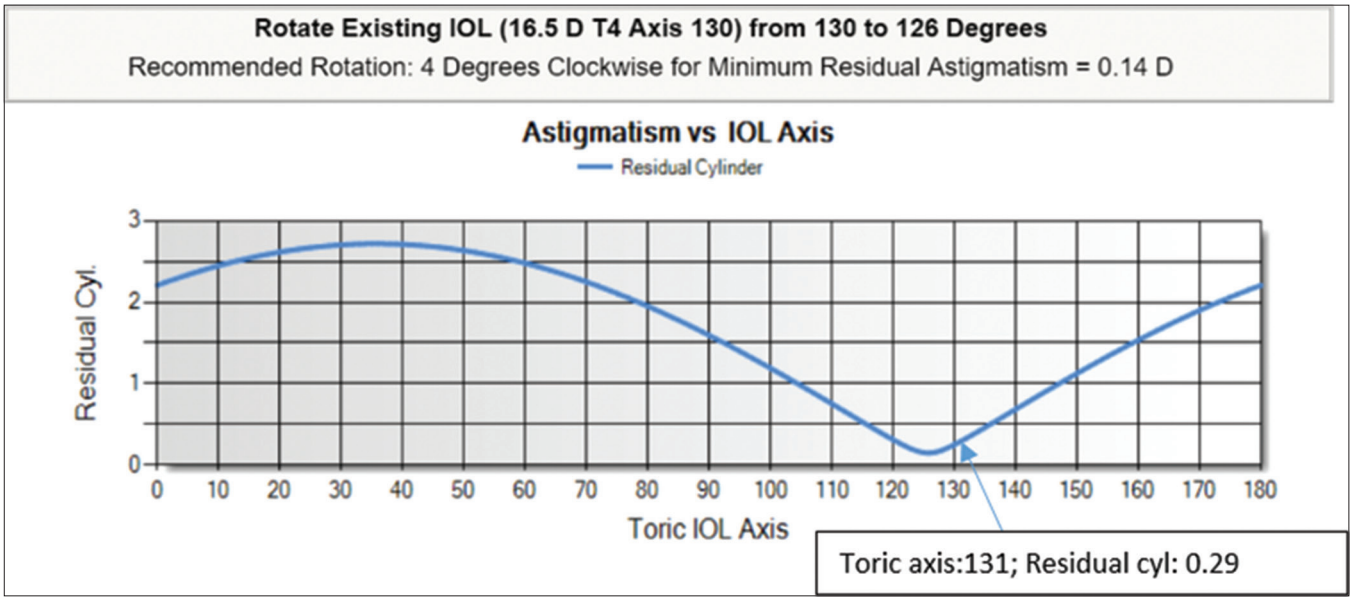


**Figure 2:** Final outcome parameters including subjective refraction and lens orientation after repositioning used in the vector analysis graph of the Barrett Rx formula to determine the predicted ideal axis with minimal residual refractive astigmatism, in the above patient the predicted ideal axis is 126° with residual astigmatism of 0.14 D. The blue arrow shows residual cylinder if toric IOL was repositioned on the axis suggested by the Berdahl and Hardten astigmatism fix calculator or Barrett Rx formula

7/8, and 10/11 after the primary cataract surgery and predicted residual cylinder (post-repositioning) if the toric IOL was repositioned on these suggested axes. The predicted residual cylinder was obtained from the vector analysis graph of the Barrett Rx formula with the final subjective refraction and lens orientation post 22 ± 1 days of repositioning as inputs. The amount of residual astigmatism predicted using the axis suggested by Berdahl and Hardten astigmatism fix calculator and Barrett Rx formula was significantly ($P < 0.001$) higher than with the steep TK axis measured by IOLM 700 at all three visits for the 10 participants.

Fig. 6 depicts that the repositioning of the toric IOL on the measured day 10/11 steep TK axis of IOLM 700 reduces the residual astigmatism from 2.00 ± 0.78 D to 0.18 ± 0.12 D. The residual astigmatism reduced significantly ($P = 0.003$) in comparison to the Berdahl and Hardten astigmatism fix calculator and Barrett Rx formula method, where the estimated residual astigmatism would have been 0.57 ± 0.31 D and 0.61 ± 0.33 D, respectively. The estimated reduction is calculated on the vector analysis graph of the Barrett Rx formula used to determine the predicted ideal axis 22 ± 1 days post-repositioning.

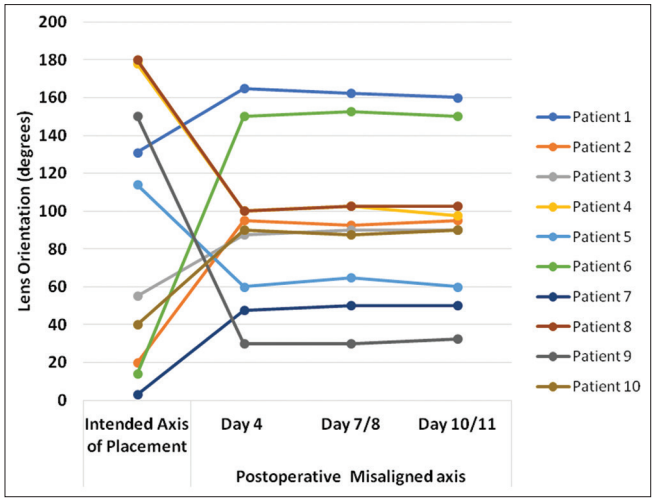


**Figure 3:** Changes in the lens orientation on postoperative day4, day7/8 and day10/11 with respect to the intended axis (different colored lines represent the various participants)

An average of 90.5 ± 7.6% reduction in the residual astigmatism was achieved on repositioning the toric IOL according to day 10/11 steep TK axis of IOLM 700. If the toric IOL was repositioned according to the axis suggested by Berdahl and Hardten astigmatism fix calculator and Barrett Rx formula on day 10/11, the estimated residual astigmatism reduction would have been 68.4 ± 21.9% and 66.4 ± 23.5%, respectively.

Fig. 7 and Table 2 compare the difference between the predicted ideal axis and the axis suggested by Berdahl and Hardten astigmatism fix calculator, Barrett Rx formula, and measured steep TK axis of IOLM 700 at days 4, 7/8, and 10/11 after the primary cataract surgery. The mean difference between the predicted ideal axis and IOLM TK axis at day 10/11 after the primary cataract surgery is 2.7° ± 2.7° which is significantly small ($P < 0.001$) in comparison to its difference with the axis suggested by the Berdahl and Hardten astigmatism fix calculator and Barrett Rx formula (12.2° ± 8.3° and 12.9° ± 8.8°), respectively.

Fig. 8 and Table 2 compares the difference between the ideal residual cylinder and predicted residual cylinder (post-repositioning) if the toric IOL is realigned at the axis suggested by the Berdahl and Hardten astigmatism

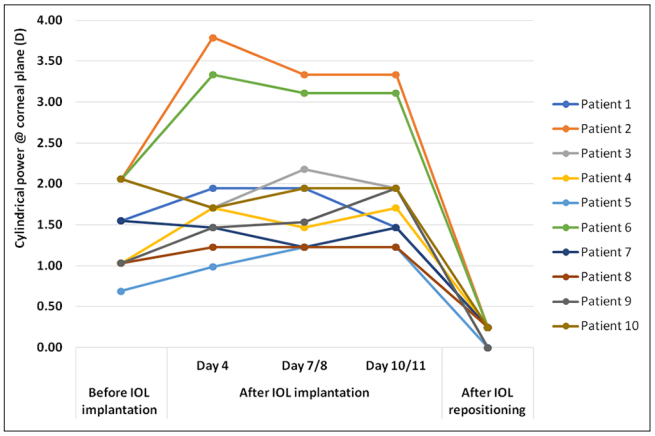


**Figure 4:** Change in residual refractive astigmatism measured at corneal plane at days 4, 7/8, and 10/11 postoperatively with respect to the preoperative and post-IOL repositioning values (different colored lines represent various participants)

**Table 2: Descriptives and comparison of difference between the predicted ideal axis and its residual cylinder with suggested axis and its predicted residual cylinder by the three methods at days 4, 7/8, and 10/11 10/11 after the primary cataract surgery**

| | Day 4 | | | | | Day 7/8 | | | | | Day 10/11 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | SD | 95% CI | | *P* | Mean | SD | 95% CI | | *P* | Mean | SD | 95% CI | | *P* |
| Difference between predicted ideal axis and suggested axis | | | | | | | | | | | | | | | |
| Berdahl and Hardten astigmatism fix | 16.00 | 11.51 | 8.87 | 23.13 | <0.001 | 16.30 | 9.23 | 10.58 | 22.02 | 0.00 | 12.20 | 8.31 | 7.05 | 17.35 | 0.00 |
| Barrett Rx formula | 18.00 | 11.10 | 11.12 | 24.88 | | 16.90 | 9.93 | 10.75 | 23.05 | | 12.90 | 8.84 | 7.42 | 18.38 | |
| IOLM TK | 3.00 | 2.00 | 1.76 | 4.24 | | 3.20 | 2.86 | 1.43 | 4.97 | | 2.70 | 2.75 | 1.00 | 4.40 | |
| Difference between ideal residual cylinder and predicted residual cylinder | | | | | | | | | | | | | | | |
| Berdahl and Hardten astigmatism fix | 0.72 | 0.46 | 0.43 | 1.01 | <0.001 | 0.61 | 0.30 | 0.42 | 0.80 | 0.00 | 0.47 | 0.33 | 0.27 | 0.67 | 0.00 |
| Barrett Rx formula | 0.78 | 0.47 | 0.49 | 1.07 | | 0.64 | 0.30 | 0.45 | 0.83 | | 0.51 | 0.35 | 0.29 | 0.73 | |
| IOLM TK | 0.11 | 0.13 | 0.03 | 0.19 | | 0.11 | 0.11 | 0.04 | 0.18 | | 0.08 | 0.09 | 0.02 | 0.14 | |

AOP=Axis of placement; SD=standard deviation; CI=Confidence interval

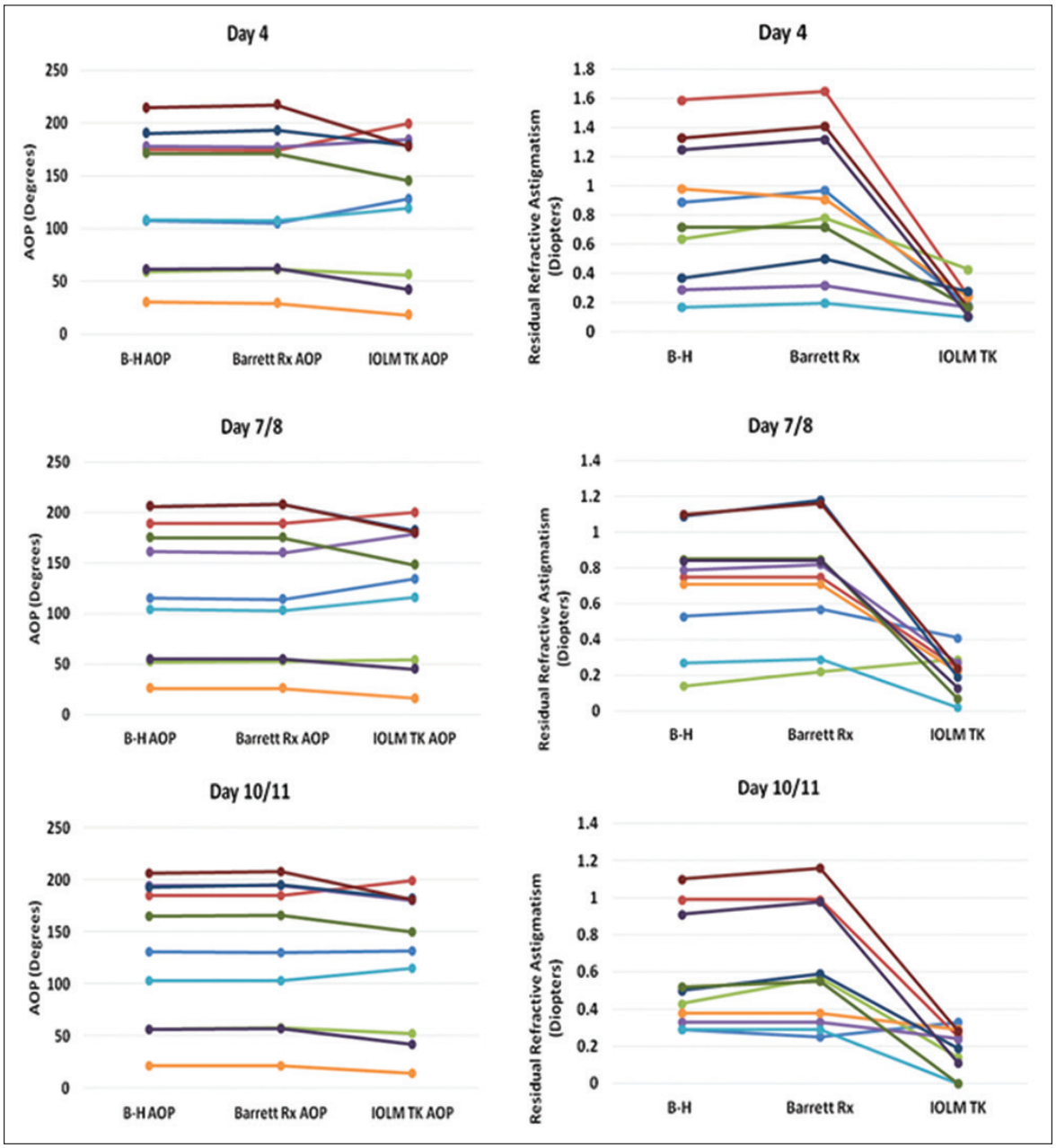


**Figure 5:** Axis of placement (AOP) suggested by three methods at days 4, 7/8, and 10/11 after primary surgery and its predicted residual cylinder derived from the vector analysis graph of the Barrett Rx formula (different colored lines represent the 10 participants). B-H = Berdahl and Hardten astigmatism fix calculator

fix calculator, Barrett Rx formula, and measured steep TK axis of IOLM 700 at days 4, 7/8, and 10/11 after primary cataract surgery. The mean difference between the ideal residual cylinder and predicted residual cylinder using the IOLM 700 TK axis at day 10/11 is 0.08 ± 0.09 D which was significantly small ($P$ = 0.003) as compared to its difference with the predicted residual cylinder using the axis suggested by the Berdahl and Hardten astigmatism fix calculator and Barrett Rx formula (0.47 ± 0.33 and 0.51 ± 0.35), respectively.

## Discussion

Reorientation planning of misaligned toric IOL to the desired axis is crucial in reducing residual astigmatism.

Various online toric back calculators like the Berdahl and Hardten astigmatism fix calculator and Barrett Rx formula are commonly used to calculate the realignment axis with the least possible residual astigmatism. These online calculators require the current refractive and lens orientation data along with the IOL cylinder power as inputs. Thus, although they are mathematical formulas, the accuracy of the new AOP predicted by these calculators is entirely dependent on the accuracy of the patient's subjective refraction and measurement of the lens orientation. The axis of the implanted toric IOL assessed at the slit-lamp with a rotating slit and rotational gauge has 5° steps on the measuring reticule which limits the accuracy of this method. The head tilt errors during the slit-lamp assessment of the IOL axis marks can compound calculation errors.

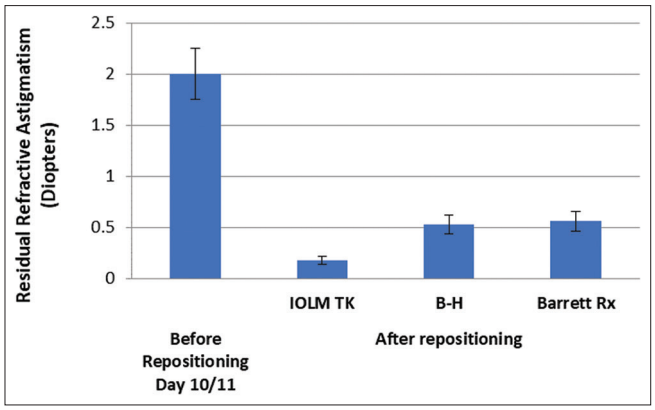


**Figure 6:** Comparison between the residual refractive astigmatism before repositioning on day 10/11 and with the three methods after repositioning

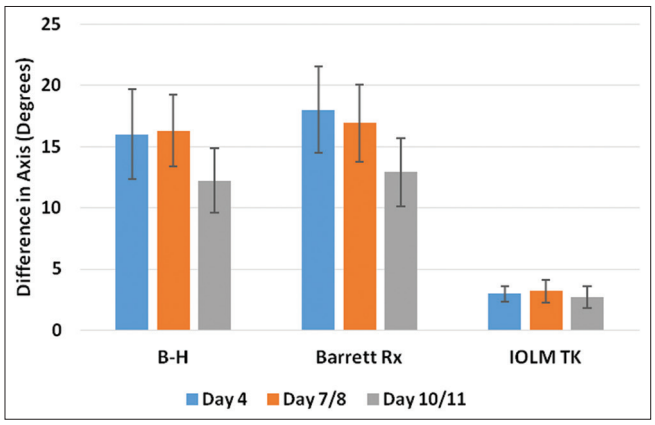


**Figure 7:** The difference between the predicted ideal axis and the axis suggested by the Berdahl and Hardten astigmatism fix calculator (B-H), Barrett Rx formula, and measured steep TK axis of IOLM 700 at days 4, 7/8, and 10/11after the primary cataract surgery

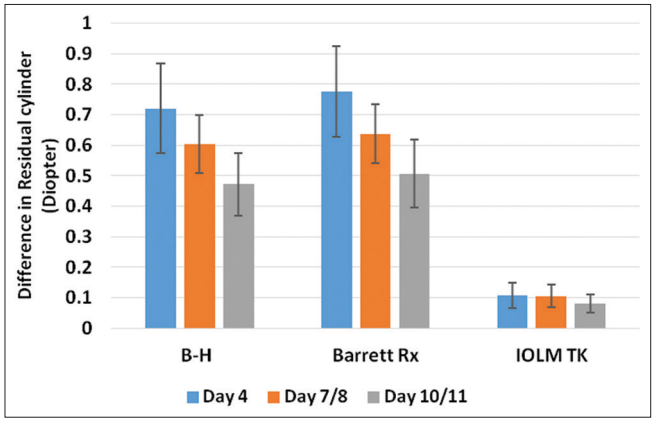


**Figure 8:** The difference between the ideal residual cylinder and predicted residual cylinder on repositioning the toric IOL on the axis suggested by the Berdahl and Hardten astigmatism fix calculator (B-H), Barrett Rx formula, and measured steep TK axis of IOLM 700 at days 4, 7/8, and 10/11 after primary cataract surgery

Our study reported a change of $2.17^0 \pm 1.55^0$ in misalignment axis measurements on slit-lamp between days 4, 7/8, and 10/11. The maximum lens rotation is expected between the initial 1st and 24 h after surgery.[7] Hence, small variations in the lens orientation after 24 h can be attributed to the errors in the measurement due to head tilt. Similar variations were found in the patient's subjective refraction between days 4, 7/8, and 10/11. The two variables put together have a compound effect on the new axis of repositioning predicted by the Berdahl and Hardten astigmatism fix calculator and Barrett Rx formula on days 4, 7/8, and 10/11.

In this study, the misaligned toric IOL was reoriented on the steep TK axis of the cornea measured on IOLM 700 guided by the digital overlay of the Callisto eye. The IOLM 700 includes TK which is a new measurement that combines telecentric keratometry and Swept Source- Optical Coherence Tomography(SS-OCT) technology for the assessment of the anterior and posterior corneal curvatures.[11] It is independent of the patient's current refractive and lens orientation data, the variable input in the Berdahl and Hardten astigmatism fix calculator and Barrett Rx formula, thus, improving precision by eliminating the possible errors in their measurements. The unique foveal fixation check of IOLM 700 ensures precise keratometry by detecting poor fixation, and thus, helps in determining the most accurate AOP.[12,13]

The head tilt errors during the measurement of the steep TK axis on IOLM 700 can lead to a corresponding change in the keratometric measurement of the steep meridian.[14] However, any head tilt errors during the IOLM 700 measurements resulting in the change of steep TK axis are compensated by the Callisto eye image-guided placement of the IOL which registers along subject-fixated coaxially-sighted corneal light reflex of Zeiss Lumera i microscope.

To the best of our knowledge, this is the first study comparing the efficacy of the Berdahl and Hardten astigmatism fix calculator, Barrett Rx formula, and steep TK axis of IOLM 700 to determine the optimum axis of repositioning.

Toric misalignment of small magnitude (<10°) has been known to change the postoperative refraction by an amount of ≤ 0.50 D and thus the patient is expected to have a satisfactory visual outcome. However, a large misalignment of up to 30° will result in the loss of most of the corrective effect of toric IOL, therefore, warranting a secondary procedure of repositioning.[4,15]

The realignment of toric IOL should ideally be done around 10–12 days, by which time the bag has shrunk, making the final position more likely stable.[8,16] If the reorientation of IOL is planned earlier than 1 week, then it may rotate again, however, if planned too late, then the bag may contract and scar, making the rotation more challenging.[17]

In our study, the repositioning procedure was done between 10 and 12 days after the primary cataract surgery.

The realignment axis in accordance with the steep TK axis measured on IOLM 700 is much more predictable as compared to the axis suggested by the Berdahl and Hardten astigmatism fix calculator and Barrett Rx formula. The difference between the predicted ideal axis and steep TK axis measured on IOLM 700 on day 10/11 is significantly small ($P < 0.001$) as compared to the difference between the predicted ideal axis and the axis suggested by the Berdahl and Hardten astigmatism fix calculator and Barrett Rx formula.

In a study done by Oshika T, Inamura M, Inoue Y, *et al.*,[18] the repositioning of toric IOL was planned according to the intended AOP during the primary surgery. They repositioned 42 eyes at an average of 9.9 ± 7.5 days where the misalignment reduced from 32.9° ± 15.7° to 8.8° ± 9.7°($P < 0.001$) and the refractive cylinder reduced from 2.4 ± 1.1 diopters (D) to 1.1 ± 0.8 D ($P < 0.001$).

Berdahl, Hardten *et al.*[19] retrospectively assessed 12,812 cases with a mean postoperative refractive astigmatism of 1.89 D who were repositioned according to the axis suggested by their calculator. The mean calculated percentage reduction in the residual cylinder after reorientation was 50% ± 31% (SD), with the magnitude of residual astigmatism after IOL reorientation expected to be 0.50 D or less in 37% of the eyes (4,835/12,812).

In our study, all the patients who underwent the repositioning procedure according to day 10/11 steep TK axis of IOLM 700 achieved a statistically significant reduction in the residual refractive astigmatism from 2.00 ± 0.78 D to 0.18 ± 0.12 D ($P = 0.003$). The average percentage reduction in the postoperative residual astigmatism was 90.5 ± 7.6%.

### Limitations

Bigger sample size is required to further validate our results. We do not have a control group where IOL repositioning is done according to the axis suggested by the Berdahl and Hardten astigmatism fix calculator and Barrett Rx formula for direct comparison. The predicted ideal axis determined on the vector analysis graph of the Barrett Rx formula is dependent on the accuracy of two variable inputs. The precision was increased by reconfirming the final lens orientation following realignment (22 ± 1 days) on the digital system of the Callisto eye. The variation in subjective refraction is fairly small as the magnitude of residual astigmatism post-repositioning was very little.

## Conclusion

In conclusion, IOLM 700 with its quick acquisition of data and accurate measurement of the anterior and posterior corneal toricity (TK), including any effect of surgically induced astigmatism (SIA) owing to primary cataract surgery, gives the precise AOP for repositioning of the toric IOL. It helps in determining the most favorable realignment axis to give the least possible residual refractive astigmatism independent of compounding variables like subjective refraction and lens orientation which can be a source of error, and hence, unsatisfactory refractive outcome. The precision further improves with the image-guided digital system of the Callisto eye which uses the same IOLM 700 image acquired to determine the steep TK axis of repositioning, thus, eliminating the head tilt errors during its acquisition.

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Nil.

### Conflicts of interest

There are no conflicts of interest.

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