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Original Article

Correlation of Preoperative Keratometry and Corneal Astigmatism on Visual Outcomes in Cataract Patients Receiving Non-Toric IOLs

Milzan Murtadha[1], Sagung Gede Indrawati[2], Amanda Nur Shinta Pertiwi[3]

[1,2,3]Department of Ophthalmology Faculty of Medicine, Public Health, and Nursing, Gadjah Mada University

Corresponding email: milzan.murtadha@mail.ugm.ac.id

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ABSTRACT

Introduction: Preoperative biometry plays a pivotal role in predicting visual outcomes after cataract surgery. Corneal astigmatism can significantly influence uncorrected visual acuity (UCVA). In clinical settings where only non-toric intraocular lenses (IOLs) are available, understanding the impact of astigmatism becomes even more crucial. This study investigates biometric profiles and visual outcomes in relation to corneal astigmatism severity in patients who received non-toric IOLs. Methods: A retrospective cohort analysis was conducted on 30 eyes from 28 patients undergoing phacoemulsification with non-toric IOL implantation at Nyi Ageng Serang Hospital between September 2021 and February 2022. Biometric parameters including axial length (AL), anterior chamber depth (ACD), and lens thickness (LT) were recorded. Patients were grouped based on corneal astigmatism values (>–1.0 D and ≤–1.0 D), and outcomes were analyzed in terms of postoperative UCVA and best corrected visual acuity (BCVA). Results: The mean age of patients was 66 ± 10.3 years, with 63.3% male. Nearly half (46.7%) of eyes presented with corneal astigmatism greater than –1.0 D. A significant age-related variation in astigmatism was observed (p=0.001), particularly in patients aged 61–70. There was no statistically significant difference in postoperative UCVA or BCVA between astigmatism groups (p=0.438 and p=0.524, respectively). Conclusion: In the absence of toric IOL options, corneal astigmatism showed a weak positive correlation with postoperative UCVA and moderate positive correlation with postoperative BCVA although these results did not lead to significantly different visual outcomes postoperatively. This underscores the importance of individualized preoperative planning and suggests future access to toric IOLs could further enhance postoperative UCVA, particularly in patients with corneal astigmatism >–1.0 D.

Introduction

Cataract remains the leading cause of blindness worldwide, with a disproportionately high burden in developing countries [1,2]. The success of cataract surgery is traditionally evaluated based on a range of postoperative outcomes, including uncorrected visual acuity (UCVA), functional independence, quality of life, and economic reintegration. Given the central role of visual acuity in determining patient satisfaction, daily functioning, and overall productivity, it is recommended that suboptimal or borderline visual outcomes occur in no more than 10–20% of cases [3].

In order to obtain satisfactory postoperative uncorrected visual outcome, preoperative biometry including axial length, keratometry, and anterior chamber depth are important to be measured to obtain precise IOL power. WHO suggests that successful cataract surgery is indicated if at least 80% of operated eyes have UCVA 6/6 - 6/18 and 90% of the eyes have BCVA 6/6 - 6/18. Poor visual outcome may be due to underlying eye diseases, undercorrected refractive condition, and surgical complications [4].

One of the key refractive challenges that impedes optimal UCVA following phacoemulsification is preexisting corneal astigmatism. Previous studies have demonstrated that a significant proportion of cataract patients present with measurable astigmatism, with up to 73.7% exhibiting ≤1.50 diopters (D), 26.3% exceeding 1.50 D, and 7.4% presenting with ≥3.00 D [5].

Toric IOL is known to be one of the management options for corneal astigmatism. However, in many resource-limited settings, patients may not have access to toric IOLs, making it imperative to optimize all other aspects of preoperative planning. In such cases, precise measurement and documentation of corneal astigmatism during biometric evaluation become crucial for predicting visual outcomes and guiding surgical decisions. Therefore, the present study aimed to analyze the biometric parameter, especially keratometry, and corneal astigmatism in relation to postoperative visual outcome in patients undergoing cataract surgery with non-toric IOL implantation.

Methods

This study is a retrospective cohort hospital-based study, conducted at Nyi Ageng Serang Hospital in Yogyakarta from September 2021 and February 2022 after ethical approval by the institutional review committee. Patients aged >40 years who were operated on with phacoemulsification cataract surgery were included in the study. Exclusion criteria for this study are patients with incomplete data. History and routine eye examinations findings before surgery including visual acuity, tonometry, keratometry, and slit lamp evaluation were collected from the medical record. The procedures were fully explained to each patient and written informed consent was obtained as documented on medical records. Biometry data including Ocular axial length (AL), anterior chamber depth (ACD) and lens thickness (LT) of each cataract-affected eye were measured by immersion biometry with the NIDEK Echoscan US-500. Keratometry (K) and corneal astigmatism were measured using an auto-refractor NIDEK TONOREF-III.

All cases were operated by a single surgeon and machine.

The postoperative care plans were individualized, based on the individual case, but all patients received both topical antibiotics and topical corticosteroids for four weeks minimum. Patients were examined at least 1 week and 4 weeks post-operatively. Complicated cases that required more than 4 weeks of follow-up are also included in this study, such cases had regular check-ups until they had a full recovery or were unresponsive to further treatment.

Age was categorized into <60 years (pre-senile), 60–79 years (senile), and ≥80 years (very elderly) based on established epidemiological patterns showing increasing cataract prevalence after 60 years and higher surgical risk in very elderly patients [6]. Visual acuity variables were categorized according to the World Health Organization (WHO) using Snellen Chart as ≥6/18, 6/18-6/60, 6/60-3/60, <3/60.

Complications during and following surgery were collected. The post-operative visual acuity, IOP, and other findings were collected at 30 days after the surgery. Continuous variables were expressed as the mean ± standard deviation and presented in a graph. A paired t-test was applied to compare the mean before and after surgery, and a Mann-Whitney test was applied to compare between groups. Statistical analysis was performed using SPSS software. P-values less than 0.05 were considered statistically significant.

Results

This study included 30 eyes of 28 patients. The male to female ratio was 1.72:1 (63,3% male). The mean age and corneal astigmatism were 66±10,3 years and -1,23±0,98 D respectively. Corneal astigmatism was higher than 1.0 D in 46,7% of cases. Operated eye was 36,7% OD and 63,3% OS. For the IOL location, bag sites were 83,3% and sulcus sites were 16,7%. All the data were shown in Table I.

Table 1. Profile Cases with Cataract Surgery.

Age (years)	66.00 (± 10.30)
Sex (N, %)	
Male	19 (63.30%)
Female	11 (36.70%)
Operated Eye (N, %)	
OD	11 (36.70%)
OS	19 (63.30%)
Corneal Astigmastism Group (N, %)	
>1.0 D	14 (46.70%)
≤1.0 D	16 (53.30%)
IOL Location (N, %)	
Bag	25 (83.30%)
Sulcus	5 (16.70%)

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Table 2. Biometric Parameter Range and Mean.

Parameters	Range	Mean
UCVA (logMAR)	2.3-0	0.64 (± 0.59)
Axial Length (mm)	19.45-32.60	23.81 (± 2.33)
Anterior Chamber Depth (mm)	2.17-4.26	3.33 (± 0.49)
Lens Thickness (mm)	1.99-4.66	3.22 (± 0.88)
IOL Power (Diopter)	-8.0-30.0	18.11 (± 7.43)

Table 3. Age and Gender Wise Distribution of Biometric Parameters.

Age (years)	Frequency	Astigmatism	ACD	LT	AL	Mean Keratometry
<60	8	-0.63 ± 0.52	3.57 ± 0.28	2.82 ± 0.32	24.59 ± 1.74	43.90 ± 0.66
60-79	20	-1.45 ± 0.78	3.19 ± 0.58	3.50 ± 0.27	23.62 ± 0.58	43.57 ± 0.76
≥80	2	-1.50 ± 0.25	3.74 ± 0.52	2.03 ± 0.25	22.69 ± 2.40	43.12 ± 1.50
P-value		**0.001**	0.247	0.148	0.834	0.742
Gender	Frequency	Astigmatism	ACD	LT	AL	Mean Keratometry
Male	19	-1.17 ± 0.24	3.24 ± 0.13	3.18 ± 0.19	23.16 ± 0.31	43.41 ± 0.33
Female	11	-1.34 ± 0.25	3.47 ± 0.93	3.28 ± 0.28	24.95 ± 0.96	44.01 ± 0.60
P-value		0.525	0.372	0.672	0.185	0.216

This study confirms that corneal astigmatism undergoes significant age-related changes. Notably, individuals aged 60–79 exhibited a statistically significant difference (p=0.001) in astigmatism compared to other age groups.

Gender was also found to influence preoperative biometric parameters. Among male participants, the mean values were: anterior chamber depth (ACD) 3.24 ± 0.13 mm, lens thickness (LT) 3.18 ± 0.19 mm, and axial length (AL) 23.16 ± 0.31 mm. Female subjects in this study exhibited ACD 3.47 ± 0.93 mm, LT 3.28 ± 0.28 mm, and AL 24.95 ± 0.96 mm. The comparison of biometric parameters from the range of ages shown in the Table 3.

Table 4. Uncorrected Visual Acuity (UCVA) and Best Corrected Visual Acuty (BCVA) in corneal astigmatism group.

Corneal astigmatism group	>-1.0 D	≤-1.0 D	P value
Mean UCVA	log MAR 0.73±0.18	log MAR 0.56±0.48	0.438
Mean BCVA	log MAR 0.33±0.62	log MAR 0.22±0.26	0.524

From table IV, mean UCVA and BCVA in astigmatism patients at >1.0 D and ≤1.0 D were under 1. The P-value of mean UCVA and BCVA between corneal astigmatism group was > 0.05, indicating no significant differences.

Table 5. 30-days post-operation UCVA as WHO classification compared by corneal astigmatism group.

Visual impairment	Frequency	Corneal Astigmatism ≤-1.0 D	Corneal Astigmatism >-1.0D
No or mild >= 6/18	15	8	7
Moderate <6/18 – 6/60	12	5	7
Severe <6/60 – 3/60	3	3	0
Blindness < 3/60	0	0	0

Table 5 shows the distribution of uncorrected visual acuity (UCVA) on day 30 after cataract surgery, based on the WHO classification, compared by corneal astigmatism group. In general, most patients achieved good to moderate visual outcomes after surgery. Fifteen patients (50.0%) were classified as having no or mild visual impairment (≥6/18), 12 patients (40.0%) were classified as having moderate visual impairment (6/18–6/60), while 3 patients (10.0%) were classified as having severe visual impairment (6/60–3/60). No patients (0%) were blind (<3/60) post-operatively.

Based on the degree of corneal astigmatism, the distribution of postoperative visual acuity showed a relatively similar pattern between the ≤1.0 D and >1.0 D astigmatism groups. In the no or mild visual impairment category, there were 7 patients in the ≤1.0 D astigmatism group and 6 patients in the >1.0 D group. Similarly, in the moderate visual impairment category, there were 6 patients in each group. In the blindness category (<3/60), there were 3 patients in the ≤1.0 D astigmatism group and

2 patients in the >1.0 D group.

These results indicate that on the 30th day post-operatively, the degree of corneal astigmatism did not show a significant difference in the distribution of visual acuity based on the WHO classification. Furthermore, the absence of patients with severe visual impairment indicates that most patients achieve satisfactory visual outcomes after cataract surgery.

Table 6. Correlation between mean keratometry to the 30-days postoperative UCVA and BCVA

	Correlation Coefficient (rho)	P -value	95% CI of the rho
Mean Keratometry and UCVA	0.294	0.115	-0.085 - 0.599
Mean Keratometry and BCVA	0.566	0.001	0.248 - 0.774

Correlation analysis demonstrated differing associations between mean keratometry and postoperative visual outcomes. Mean keratometry showed a weak positive correlation with postoperative UCVA (rho = 0.294), although this association did not reach statistical significance (p = 0.115; 95% CI: –0.085 to 0.599). The positive correlation coefficient suggests that steeper corneal curvature tended to be associated with higher postoperative logMAR values, indicating slightly worse uncorrected visual acuity. However, the weak strength of correlation and the confidence interval crossing zero indicate that this relationship was inconsistent and may have occurred by chance within the present sample.

In contrast, mean keratometry demonstrated a moderate positive correlation with postoperative BCVA (rho = 0.566; 95% CI: 0.248 to 0.774). The confidence interval did not cross zero, suggesting a statistically meaningful association between corneal curvature and postoperative best corrected visual acuity. This finding implies that variations in corneal refractive power may contribute to postoperative corrected visual performance, even when uncorrected visual outcomes are not significantly affected.

Discussion

The cornea is an important refractive media of the human eyes. Corneal astigmatism refers to the different refractive power on the meridian, which makes the light hard to form focus on the retina [16,17]. Even a relatively low amount of uncorrected astigmatism will significantly reduce visual acuity, which will further reduce the ability to perform a low-contrast task. As low as 1.0 D of uncorrected astigmatism can affect simple everyday reading tasks [18].

From this study, we can find a progressive increase in corneal astigmatism after the age of 40 was observed, consistent with previous findings reported by Ferrer-Blasco et al.[10] and Chen et al.[11] Furthermore, our results align with those of Yuan et al.[12], who documented a marked rise in astigmatism values after the age of 60.

Preoperative corneal astigmatism and mismatched ocular biometry are the main obstacles to obtaining a satisfactory postoperative uncorrected visual acuity for patients undergoing uncomplicated cataract surgery, as the surgery eliminates lenticular astigmatism, presuming minimal surgically induced astigmatism. Thus, preoperative corneal astigmatism and mismatched biometry lead to patient dissatisfaction [19,20]. The prevalence and type of preoperative corneal astigmatism in cataract patients has been identified in several countries and is taken into consideration during surgery.

The comparison of axial length and ACD in this study was similar to any other studies [12,13], excluding the LT parameters. We used A/B scan ultrasonography to get every parameter of each cataract-affected eye, including Ocular axial length (AL), anterior chamber depth (ACD) and lens thickness (LT). The experience of the ultrasonologist, time devoted to performing the scan and patient cooperation are some of the factors which may affect the information obtained by this technique [21]. Also, the slanted edge of eye will be curved by the lens distortion, causing further measurement problems.

UCVA was better in eyes with smaller pupil size in all with the rule (WTR) or against the rule (ATR) astigmatism was present. Pupil size plays an essential role in visual performance in astigmatic eyes and non-astigmatic eyes. This condition was important for minimizing spectacle dependence and maximizing subsequent patient satisfaction in the astigmatic eye.[22] Pupil size can be influenced by patient background, including age, manifest refraction, accommodative state of the eye, measurement condition affecting the level of retinal illuminance, and various sensory and emotional conditions [23]. Pupil size could be the reason for our non-significant UCVA results in our study.

In current ophthalmology, residual astigmatism, or also called internal astigmatism (IA), can happen if there is any leftover from the refractive procedures. Meanwhile, the goal of current refractive cataract surgery is excellent uncorrected visual acuity (UCVA) [23,24]. This factor can lead to a similar result as in the astigmatism group ≤-1.0 D. On the contrary, internal astigmatism also can influence and correct the corneal astigmatism value in group >-1.0 D and result in better UCVA postoperatively.

In our study, 50% of patients achieve ≥6/18 (log MAR ≤0,5) uncorrected visual acuity which is considered as good surgical result as per WHO recommendations despite not using any of the modality to correct corneal astigmatism. These findings were in accordance with Park et al.[14], where success was defined as achieving a Logarithm of the Minimum Angle of Resolution (log MAR) close to 0,1.

While the trend showed better UCVA results in corneal astigmatism group less than equal to -1.0 D, statistical data considered results statistically insignificant. Therefore, corneal astigmatism greater than -1.0 D did not affect UCVA following phacoemulsification surgery.

The absence of a significant association between mean keratometry and UCVA may be explained by several factors. Postoperative uncorrected visual acuity is influenced not only by corneal curvature, but also by residual refractive error, surgically induced astigmatism, pupil size, ocular surface condition, and internal astigmatism. In pseudophakic eyes, internal astigmatism may partially compensate for corneal astigmatism, thereby reducing the apparent impact of keratometric variation on UCVA. Additionally, the use of non-toric IOLs in all patients may have minimized refractive differences between keratometric groups.

Meanwhile, the moderate correlation observed with BCVA suggests that optical correction may partially neutralize residual refractive components, allowing the underlying relationship between corneal curvature and retinal image quality to become more apparent. Eyes with steeper corneal curvature may experience greater higher-order aberrations or residual refractive imbalance, which can influence corrected visual performance despite adequate spectacle correction. Another possible explanation for the relatively modest correlation strength is the multifactorial nature of postoperative visual rehabilitation following cataract surgery.

Overall, these findings suggest that mean keratometry may have a limited influence on postoperative UCVA but a more measurable association with BCVA in patients undergoing cataract surgery with non-toric IOL implantation. This emphasizes the importance of comprehensive preoperative corneal assessment during surgical planning, particularly in settings where toric IOLs are unavailable.

This study has several strengths that contribute to its clinical relevance, particularly in resource-limited ophthalmic settings. First, all cataract surgeries were performed by a single surgeon using the same surgical machine and technique, thereby reducing inter-operator variability and improving procedural consistency. Second, the study specifically evaluated patients implanted with non-toric intraocular lenses (IOLs), reflecting real-world clinical practice in many developing countries where access to toric IOLs remains limited. Therefore, the findings provide practical insights into postoperative visual outcomes in routine cataract surgery settings

However, this study has several limitations, including a small sample size, which may limit the generalizability and statistical strength of the findings. Other than that, the absence of postoperative keratometry data also restricts the evaluation of surgically induced astigmatism, and potential confounders such as pupil size and internal astigmatism were not assessed.

Additionally, all patients received non-toric IOLs, precluding comparisons with astigmatism-correcting lenses, while biometric measurements obtained via A/B-scan ultrasonography may have been affected by technical variability. The inclusion of eyes with pre-existing ocular conditions, such as glaucoma and diabetic retinopathy, may have further influenced the visual outcomes.

Conclusion

In the absence of toric IOL options, corneal astigmatism showed a weak positive correlation with postoperative UCVA and moderate positive correlation with postoperative BCVA although these results did not lead to significantly different visual outcomes postoperatively. This underscores the importance of individualized preoperative planning and suggests future access to toric

IOLs could further enhance postoperative UCVA, particularly in patients with corneal astigmatism >–1.0 D. Future studies with larger sample sizes and prospective multicenter designs are recommended to improve the generalizability of the findings.

Declarations

Statement on the Use of Artificial Intelligence

AI was used to assist in drafting the declarations section.

Author contribution statement

Milzan Murtadha, Sagung Gede Indrawati, and Amanda Nur Shinta Pertiwi contributed to the conceptualization of the study, data collection and analysis, manuscript preparation, and manuscript revision.

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Conflict of interest

The authors declare no conflicts of interest regarding the publication of this article.

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