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Frequency of Surgically Induced Astigmatism after Phacoemulsification

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ABSTRACT

Background: Cataract is the leading cause of avoidable blindness worldwide, and phacoemulsification is now the preferred surgical technique due to its superior visual and refractive outcomes compared to older methods. Despite these advantages, surgically induced astigmatism (SIA) remains a frequent concern, potentially limiting uncorrected visual acuity and patient satisfaction. **Objective:** To determine the frequency of surgically induced astigmatism following phacoemulsification at a tertiary eye hospital in Karachi. **Methods:** This descriptive study was conducted at the Cataract Clinic of Al-Ibrahim Eye Hospital, Karachi, from August 2024 to January 2025. A total of 373 patients aged 50–70 years undergoing phacoemulsification with foldable intraocular lens implantation were enrolled through non-probability consecutive sampling. Patients with pre-existing astigmatism ≥0.5 D, ocular comorbidities other than cataract, or loss to follow-up were excluded. Preoperative evaluation included visual acuity, slit lamp examination, keratometry, and fundus assessment. Postoperative assessments were performed at Day 1, Week 2, and Week 6. Surgically induced astigmatism was defined as ≥1.00 D at the final follow-up. Data were analyzed using SPSS v23, applying Chi-square or Fisher's exact test where appropriate, with $p \leq 0.05$ considered significant. **Results:** Of the 373 patients, the mean age was 61.4 ± 5.8 years, with 53.1% males and 46.9% females. At six weeks, uncorrected visual acuity of 6/12 or better was achieved in 84.2% of patients, while best corrected visual acuity of 6/9 or better was achieved in 90.3%. Surgically induced astigmatism ≥1.00 D was observed in 115 patients (30.8%), whereas 258 patients (69.2%) remained below this threshold. No significant association was found between SIA and age ($p = 0.67$) or gender ($p = 0.42$). However, higher preoperative keratometry values were significantly associated with the development of SIA ($p < 0.05$). **Conclusion:** Phacoemulsification is highly effective in restoring vision; however, nearly one-third of patients develop clinically significant surgically induced astigmatism. Preoperative corneal curvature emerged as a key determinant, while demographic factors such as age and gender were not associated with SIA. Optimizing incision technique and considering toric intraocular lenses may help reduce postoperative astigmatism and improve refractive outcomes.

INTRODUCTION

Cataract continues to be the leading cause of reversible blindness worldwide, responsible for nearly half of all cases of visual impairment, with an especially high burden in low- and middle-income countries [1]. According to global estimates, millions of individuals remain visually handicapped due to cataract despite the availability of surgical treatment, making cataract extraction the most frequently performed ophthalmic procedure across the globe [2]. In Pakistan, cataract accounts for approximately 50–60% of blindness, which underscores the urgency of improving surgical outcomes and reducing the burden of residual refractive errors following cataract extraction [3]. Over the past few decades, cataract surgery has undergone significant advances. Intracapsular cataract extraction (ICCE) and extracapsular cataract extraction (ECCE), once widely used, involved large corneal or limbal incisions and were associated with prolonged recovery, increased postoperative complications, and higher rates of surgically induced astigmatism (SIA) [4]. The development of phacoemulsification transformed cataract surgery into a more refined, minimally invasive procedure, using smaller corneal incisions, ultrasonic emulsification of the lens, and implantation of foldable intraocular lenses (IOLs) [5]. This technique not only improved surgical safety and reduced recovery time but also enhanced refractive predictability, making cataract extraction a refractive surgery rather than merely a rehabilitative one [6]. As patients increasingly expect not only restoration of vision but also independence from spectacles, precise control of postoperative astigmatism has become a key measure of surgical success [7]. Astigmatism is a refractive error

resulting from irregular corneal curvature that prevents light from focusing evenly on the retina, leading to blurred or distorted vision. Even small amounts of astigmatism can significantly reduce uncorrected visual acuity, particularly in patients who have undergone cataract surgery with the expectation of spectacle-free vision [8]. Surgically induced astigmatism develops due to biomechanical changes in the cornea after cataract extraction, primarily as a result of corneal incisions and wound healing responses [9]. While phacoemulsification generally results in less postoperative astigmatism compared to older surgical methods, it is not entirely free from this complication [10]. The amount of astigmatism induced by phacoemulsification depends on a variety of factors, including the size, site, and configuration of the corneal incision, preoperative corneal curvature, axial length, type of intraocular lens implanted, and the surgeon's technique and expertise [11]. Studies have shown that smaller clear corneal incisions in the temporal region induce significantly less astigmatism compared to larger or superiorly placed incisions, which are more affected by eyelid pressure and corneal biomechanics [12]. Furthermore, the choice of suture placement or sutureless techniques, corneal thickness, and postoperative healing dynamics can alter the refractive outcome [13]. These factors highlight the importance of careful preoperative planning and standardization of surgical approaches to minimize astigmatism. The magnitude of surgically induced astigmatism varies across populations. International studies have reported postoperative astigmatism rates ranging between 30% and 45% following phacoemulsification [14]. While most cases are of low-grade astigmatism (<1.00 diopter), a significant number of patients experience clinically significant SIA that can impair visual function [15]. In regions where access to refractive correction is limited, even moderate astigmatism may translate into persistent functional disability [16]. In addition, with the growing emphasis on refractive cataract surgery, the expectation for spectacle independence has risen dramatically, making postoperative astigmatism a major determinant of patient satisfaction [17]. In the South Asian context, where cataract surgeries are performed on a very large scale, refractive outcomes assume even greater importance. In Pakistan, phacoemulsification has become increasingly common in tertiary eye care centers, replacing ECCE as the procedure of choice. However, variability in surgical training, incision site preferences, and postoperative follow-up practices means that outcomes can differ substantially between institutions [18]. Unfortunately, there is a scarcity of large-scale local data addressing the frequency and magnitude of surgically induced astigmatism after phacoemulsification. Most published work either involves small samples or focuses on specific incision types rather than assessing the overall frequency of induced astigmatism [19]. Without robust local data, it becomes difficult to benchmark outcomes, compare with international standards, or identify opportunities for improvement in surgical practice.

The importance of this issue extends beyond functional vision. Patients undergoing cataract surgery today often view the procedure not only as a treatment for blindness but also as a refractive procedure that should ideally correct preexisting ametropia and minimize the need for spectacles [20]. Even minor amounts of residual astigmatism may cause dissatisfaction in this group, undermining the perceived success of surgery despite technically sound outcomes. Furthermore, understanding the frequency of SIA has implications for surgical training, as incision planning and wound construction are technical skills that require precision and consistent evaluation [21]. Given the global emphasis on improving surgical outcomes and the increasing patient demand for refractive precision, determining the frequency of surgically induced astigmatism after phacoemulsification is of particular importance in developing countries such as Pakistan. A clearer understanding of the magnitude of this problem in local practice settings will enable ophthalmic surgeons to refine incision techniques, optimize surgical planning, and counsel patients more effectively regarding postoperative expectations. Therefore, this study was designed to determine the frequency of surgically induced astigmatism after phacoemulsification in patients undergoing cataract surgery at a tertiary eye care hospital in Karachi. By generating evidence from a representative cohort, the findings aim to contribute to improving local surgical outcomes, aligning them with global standards, and ultimately enhancing visual rehabilitation and quality of life for patients.

Objective

To determine the frequency of surgically induced astigmatism following phacoemulsification at a tertiary eye hospital in Karachi.

METHODOLOGY

This was a descriptive study conducted at the Cataract Clinic of Al-Ibrahim Eye Hospital, Karachi, from August 2024 to January 2025. A total of 373 patients scheduled for cataract surgery were enrolled using non-probability consecutive sampling. All surgeries were performed using phacoemulsification with foldable intraocular lens (IOL) implantation.

Inclusion Criteria

- Male and female patients aged 50–70 years.
- Newly registered cataract patients scheduled for phacoemulsification.
- Pre-existing corneal astigmatism less than 0.5 diopters (D).

Exclusion Criteria

- Patients with visual impairment due to ocular pathologies other than cataract.
- Patients lost to follow-up during the study period.

Data Collection

After obtaining informed consent, patients underwent a detailed history and baseline ophthalmic evaluation. Preoperative assessment included visual acuity measurement with Snellen's chart, anterior segment examination with slit lamp biomicroscopy, cataract type classification, and dilated fundus examination using a 90D lens. Keratometry (K1 and K2), axial length, spherical equivalent, and IOL power calculations were also recorded. Following phacoemulsification, patients were

evaluated at three postoperative follow-ups: Day 1, Week 2, and Week 6. At each visit, visual acuity was assessed, slit lamp examination was performed to check IOL centration and anterior chamber status, and keratometry along with autorefractometry were carried out to measure astigmatism. Surgically induced astigmatism was defined as ≥1.00 D measured at the final follow-up (Week 6).

Statistical Analysis

All data were entered and analyzed using SPSS version 23. Continuous variables such as age, axial length, keratometry readings, and IOL power were tested for normality using the Shapiro–Wilk test and presented as mean ± standard deviation (SD) or median with interquartile range (IQR), depending on distribution. Categorical variables including gender, presence of surgically induced astigmatism, and types of refractive error were expressed as frequencies and percentages. Effect modifiers such as age and gender were controlled through stratification. Post-stratification comparisons were analyzed using Chi-square or Fisher's exact test where appropriate. A p-value ≤0.05 was considered statistically significant.

RESULTS

The study included 373 patients, with a nearly equal gender distribution (53.1% male vs. 46.9% female). The mean age of participants was 61.4 years, with most patients clustered in the 60–70 year age group (52.8%), followed by those aged 50–59 years (47.2%). No statistically significant difference in age distribution between males and females was observed (p = 0.58).

Table 1

Baseline Demographic Characteristics of Patients (N = 373)

Variable	Total (N = 373)	Male (n = 198)	Female (n = 175)	p-value
Age (years), Mean ± SD	61.4 ± 5.8	61.2 ± 6.0	61.6 ± 5.5	0.58
Age Groups, n (%)				
• 50–59	176 (47.2)	94 (47.5)	82 (46.9)	0.91
• 60–70	197 (52.8)	104 (52.5)	93 (53.1)	
Gender, n (%)	373 (100)	198 (53.1)	175 (46.9)	–

Preoperative ocular measurements showed an average axial length of 23.3 mm, with most values ranging between 22.5 and 24.1 mm. The mean intraocular lens power calculated for implantation was 20.7 D. Baseline keratometry readings revealed mean K1 and K2 values of 43.8 D and 44.2 D, respectively, indicating relatively regular corneal curvature prior to surgery. The average spherical equivalent was -0.75 D, suggesting that most patients had minimal refractive error before surgery.

Table 2

Preoperative Ocular Parameters (N = 373)

Variable	Mean ± SD	Median (IQR)	Range
Axial Length (mm)	23.3 ± 1.2	23.2 (22.5–24.1)	21.1–26.4
IOL Power (D)	20.7 ± 2.4	21.0 (19.0–22.0)	16.0–26.0
Pre-op K1 (D)	43.8 ± 1.5	43.7 (42.9–44.9)	40.1–47.2
Pre-op K2 (D)	44.2 ± 1.6	44.0 (43.1–45.4)	40.5–47.8
Spherical Equivalent (D)	-0.75 ± 1.8	-0.50 (-1.5–0.0)	-4.0–+2.0

Postoperative visual outcomes improved significantly over time. On Day 1, only 38.1% of patients achieved uncorrected visual acuity (UCVA) of 6/12 or better, but this improved to 68.1% at Week 2 and 84.2% by Week 6. Best corrected visual acuity (BCVA) followed a similar trend, improving from 45.3% on Day 1 to 90.3% at Week 6. Mean spherical equivalent also shifted closer to emmetropia over follow-up (from -0.90 D on Day 1 to -0.55 D at Week 6), with these changes being statistically significant (p < 0.001).

Table 3

Postoperative Visual Outcomes

Variable	Day 1	Week 2	Week 6	p-value (trend)
UCVA ≥ 6/12, n (%)	142 (38.1)	254 (68.1)	314 (84.2)	<0.001
BCVA ≥ 6/9, n (%)	169 (45.3)	282 (75.6)	337 (90.3)	<0.001
Mean Spherical Equivalent (D)	-0.90 ± 1.5	-0.70 ± 1.4	-0.55 ± 1.3	0.02

The overall frequency of surgically induced astigmatism (SIA) after phacoemulsification was 30.8% (115 patients), defined as ≥1.00 D at the six-week follow-up. The remaining 69.2% of patients (258 individuals) had astigmatism less than 1.00 D and were considered not to have clinically significant SIA. This indicates that approximately one in three patients developed significant astigmatism following cataract surgery.

Table 4

Frequency of Surgically Induced Astigmatism (SIA) (N=373)

Surgically Induced Astigmatism	n (%)
<1.00 D	258 (69.2)
≥1.00 D (clinically significant)	115 (30.8)
Total	373 (100)

When stratified by age, SIA was slightly more frequent in patients aged 60–70 years (32.0%) compared to those aged 50–59 years (29.5%), but this difference was not statistically significant (p = 0.67). Similarly, females had a somewhat higher proportion of significant astigmatism (33.1%) compared to males (28.8%), though again, the difference was not statistically significant (p = 0.42). These results suggest that age and gender were not major determinants of surgically induced astigmatism in this cohort.

Table 5

Stratification of Surgically Induced Astigmatism by Age and Gender

Variable		<1.00 D (n = 258)	≥1.00 D (n = 115)	p-value
Age Group, n (%)	• 50–59 (n = 176)	124 (70.5)	52 (29.5)	0.67
	• 60–70 (n = 197)	134 (68.0)	63 (32.0)	
Gender, n (%)	• Male (n = 198)	141 (71.2)	57 (28.8)	0.42
	• Female (n = 175)	117 (66.9)	58 (33.1)	

Analysis of preoperative ocular parameters showed that patients who developed significant SIA had slightly steeper corneas preoperatively, with mean K1 and K2 values of 44.1 D and 44.6 D compared to 43.7 D and 44.0 D in those without significant SIA. These differences were statistically significant (p = 0.04 and p = 0.02, respectively). However, axial length and IOL power did not differ meaningfully between groups. This suggests that higher preoperative corneal curvature may predispose patients to developing greater surgically induced

astigmatism.

Table 6

Association of Preoperative Keratometry with Surgically Induced Astigmatism

Parameter	<1.00 D SIA (n = 258)	≥1.00 D SIA (n = 115)	p-value
Mean Pre-op K1 (D)	43.7 ± 1.4	44.1 ± 1.6	0.04*
Mean Pre-op K2 (D)	44.0 ± 1.5	44.6 ± 1.7	0.02*
Mean Axial Length (mm)	23.4 ± 1.1	23.1 ± 1.2	0.09
Mean IOL Power (D)	20.6 ± 2.4	20.9 ± 2.3	0.27

DISCUSSION

This study evaluated the frequency of surgically induced astigmatism (SIA) after phacoemulsification in patients undergoing cataract surgery at a tertiary eye care hospital in Karachi. The results showed that nearly one-third of patients (30.8%) developed clinically significant astigmatism, defined as ≥1.00 D, at the six-week follow-up. The majority of patients (69.2%) had astigmatism below this threshold, reflecting favorable refractive stability. These findings highlight that while phacoemulsification generally provides excellent visual outcomes, SIA remains a common postoperative concern that can impact uncorrected visual acuity and overall patient satisfaction. The demographic distribution of patients demonstrated that phacoemulsification was most frequently performed in older individuals, with a mean age of 61.4 years. Age and gender, however, were not significantly associated with the development of SIA, as similar proportions of males and females developed astigmatism. A comparable observation has been reported in previous research, where neither age nor gender demonstrated a consistent association with postoperative astigmatism [22]. This reinforces the concept that the main determinants of SIA are more likely related to corneal biomechanics and surgical technique rather than demographic factors. Visual outcomes in this study improved progressively with each follow-up. By Week 6, 84.2% of patients achieved an uncorrected visual acuity of 6/12 or better, and 90.3% achieved best corrected visual acuity of 6/9 or better. These results reflect the effectiveness of phacoemulsification in restoring functional vision, even in cases where astigmatism developed. Similar visual improvements have been highlighted in previous research, which consistently describes phacoemulsification as superior to older techniques in terms of visual rehabilitation, patient comfort, and faster recovery times [23].

The frequency of SIA in this study (30.8%) falls within the range reported internationally, where previous research has shown postoperative astigmatism to affect 30–45% of patients undergoing phacoemulsification [24]. While the magnitude of induced astigmatism varies by population and surgical practices, the consistency of this frequency emphasizes that SIA remains a predictable and relatively common outcome despite technical advancements. This underscores the importance of recognizing SIA not as a rare complication but as a routine surgical outcome that requires proactive planning and management. An important observation from the present study was the association between preoperative corneal curvature and postoperative astigmatism. Patients with steeper preoperative keratometry readings (K1 and K2) were significantly more likely to develop SIA compared to those with flatter corneas. This relationship suggests that intrinsic corneal biomechanics may amplify the effect of surgical incisions, leading to greater curvature changes in eyes with steeper corneas. Previous research has similarly demonstrated that corneal curvature, incision size, and incision location are the most important predictors of SIA [25]. This supports the role of careful preoperative evaluation in identifying patients at higher risk and considering incision placement strategies such as temporal clear corneal incisions to minimize astigmatism. The clinical relevance of SIA lies not only in visual clarity but also in meeting patient expectations. Modern cataract surgery is increasingly considered a refractive procedure, and many patients expect spectacle independence after surgery. In this context, even mild astigmatism may reduce satisfaction. Previous research has highlighted that uncorrected astigmatism post-surgery significantly reduces patient-reported outcomes despite acceptable best corrected visual acuity [26]. The findings of this study support these concerns, as a notable proportion of patients experienced significant astigmatism despite excellent corrected vision.

The strengths of this study include its relatively large sample size and systematic follow-up at three key postoperative intervals. However, there are also limitations. The study did not stratify outcomes based on incision type or location, which could have provided further insight into modifiable surgical factors influencing SIA. Additionally, longer follow-up beyond six weeks could help assess the stability of corneal changes, as wound remodeling and corneal healing may continue beyond this period. Previous research has shown that SIA tends to stabilize after three months, suggesting that extended follow-up would strengthen the reliability of the findings [27]. Overall, the present study demonstrates that while phacoemulsification provides excellent visual outcomes, surgically induced astigmatism remains a significant issue in a considerable proportion of patients. The frequency observed here is comparable to previous research, and the significant association with preoperative keratometry highlights the need for tailored surgical planning [28]. Strategies such as smaller temporal incisions, the use of toric IOLs, and precise keratometric planning may help minimize postoperative astigmatism. By focusing on these aspects, ophthalmic surgeons can further improve refractive outcomes and enhance patient satisfaction following cataract surgery.

CONCLUSION

It is concluded that phacoemulsification provides excellent postoperative visual outcomes; however, surgically induced astigmatism remains a frequent occurrence, affecting nearly one-third of patients. The findings show that while age and gender were not significant determinants of astigmatism, steeper preoperative corneal curvature was associated with a higher likelihood of developing clinically significant SIA. These results emphasize the importance of careful preoperative assessment and surgical planning to minimize astigmatism

and improve refractive predictability. Adoption of optimized incision techniques, smaller temporal incisions, and consideration of advanced options such as toric intraocular lenses may help further reduce the burden of postoperative astigmatism and enhance patient satisfaction with cataract surgery.

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