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COMPARISON OF POST-SURGICAL CORNEAL ASTIGMATISM WITH PHACOEMULSIFICATION AND SMALL INCISION CATARACT SURGERY

Original Research

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ABSTRACT

Background: Cataract, characterized by opacification of the crystalline lens, remains a leading cause of reversible blindness worldwide. Surgical intervention is the only effective treatment, with modern techniques shifting from large limbal incisions to smaller scleral approaches to improve wound healing and minimize surgically induced astigmatism. Comparative evaluation of incision size and position across surgical modalities is essential to optimize refractive outcomes and ensure faster visual rehabilitation.

Objective: To compare post-surgical corneal astigmatism following phacoemulsification and manual small incision cataract surgery (SICS), focusing on incision position and incision length.

Methods: A longitudinal study was conducted at LRBT Hospital, Lahore, between September 2022 and May 2023. A total of 140 patients aged 45–70 years were enrolled using non-probability convenience sampling. Participants were divided into two main groups: 70 underwent phacoemulsification and 70 underwent SICS. Each group was further subdivided into two subgroups of 35, based on incision position (superior or temporal) and incision length (1.75 mm or 2.75 mm). Visual acuity was assessed using a LogMAR chart, while corneal astigmatism was measured pre- and postoperatively using an autorefractometer and keratometer. Follow-up assessments were performed on Day 1, Week 1, and Week 6 post-surgery. Data were analyzed using Friedman's and Mann–Whitney U tests in SPSS version 24.

Results: Baseline mean visual acuity for the phacoemulsification group was 0.831±0.199 D, which improved to 0.467±0.218 D on Day 1, 0.353±0.184 D at Week 1, and 0.226±0.152 D at Week 6 (Friedman's test=177.138, p=0.00). For the SICS group, baseline vision was 0.884±0.178 D, improving to 0.544±0.260 D, 0.437±0.228 D, and 0.280±0.196 D respectively (Friedman's test=181.158, p=0.00). Mean cylindrical error in phacoemulsification decreased from 0.831±0.199 D at baseline to 0.182±0.914 D at Week 6 (p=0.00), while in SICS it decreased from 0.831±0.199 D to 0.136±0.962 D (p=0.000). Comparisons by incision length revealed no significant difference at 1.75 mm (p>0.05), whereas at 2.75 mm phacoemulsification showed a significantly lower cylindrical error (p=0.007).

Conclusion: Both phacoemulsification and SICS produced significant improvements in visual acuity and reductions in corneal astigmatism. Phacoemulsification offered faster rehabilitation and lower astigmatic error with larger incisions, while SICS demonstrated comparable outcomes at smaller incision sizes. Given its affordability and effectiveness, SICS remains a practical alternative in resource-limited settings.

Keywords: Astigmatism, Biometry, Cataract, Phacoemulsification, Refractive Errors, Slit Lamp, Visual Acuity.

INTRODUCTION

The human eye is a highly specialized organ responsible for detecting light and enabling access to visual information. Vision occurs when light reflected from objects enters the eye and forms images that can be interpreted by the brain. Structurally, the anterior portion of the eye consists of the transparent cornea, the pupil located centrally, the iris which regulates light entry, and the anterior chamber filled with aqueous humor. Eye movements are coordinated by six extraocular muscles, including four rectus and two oblique muscles, which collectively allow vertical, horizontal, and rotational movements (1,2). The crystalline lens, situated behind the iris, further refines incoming light and adjusts shape to accommodate visual focus. In adults, it measures approximately 10 mm in diameter and 4 mm in axial length, with shape dynamically altered during accommodation (3). With advancing age, the crystalline lens gradually loses its transparency, leading to cataract formation. Cataract is the leading global cause of partial or complete vision loss, accounting for nearly 50% of all blindness cases worldwide (4). An estimated 90% of affected individuals live in developing countries, where limited access to ophthalmic care and surgical services significantly contributes to the burden of disease. The condition disproportionately affects individuals over 50 years of age, a demographic representing 82% of the blind population globally (5,6). While cataract is surgically correctable, barriers such as cost, shortage of trained surgeons, and unequal healthcare access continue to exacerbate its impact. Nonetheless, global initiatives focusing on affordable cataract surgery, healthcare worker training, and innovative surgical techniques have markedly improved outcomes (7). Surgical management of cataract has undergone major advancements, shifting from extracapsular cataract extraction (ECCE) to manual small incision cataract surgery (MSICS) and phacoemulsification. Modern approaches are not only restorative but also refractive in nature, aiming to achieve postoperative emmetropia and improve visual-related quality of life (VRQOL) (8,9). Phacoemulsification, which utilizes an ultrasonic handpiece to emulsify and aspirate the cataractous lens, is particularly effective but demands costly equipment and extensive surgical expertise (10).

By contrast, MSICS has gained wide adoption in high-volume settings due to its shorter learning curve, reduced costs, and comparable outcomes to phacoemulsification in terms of visual acuity and patient satisfaction (11). Both techniques have clear advantages over conventional ECCE, including smaller incision sizes, faster wound healing, fewer suture-related complications, reduced surgically induced astigmatism (SIA), and quicker rehabilitation (12). A key determinant of surgical outcomes is the degree of astigmatism induced by corneal incisions. The shape, size, and location of incisions strongly influence corneal curvature and postoperative refractive status (13). If left uncorrected, SIA can compromise visual clarity and patient satisfaction, even after technically successful surgery. Techniques such as limbal relaxing incisions (LRI), toric intraocular lenses, and optimized incision placement (temporal versus superior approaches) have been developed to address this complication and enhance postoperative visual outcomes (10,13). Advances in sutureless scleral tunnel incisions have further reduced astigmatism and improved wound stability, underscoring the importance of surgical precision in refractive outcomes (14). The evolution of cataract surgery demonstrates a paradigm shift: from merely restoring vision to meeting refractive expectations of patients who increasingly seek spectacle-free outcomes. As both spherical and cylindrical ametropias must be corrected, surgical innovation continues to refine incision design, IOL selection, and operative technique to minimize refractive error and maximize postoperative satisfaction (11,15). Given the global burden of cataract-related blindness and the increasing emphasis on refractive outcomes, this study is designed to evaluate the impact of different surgical approaches on surgically induced astigmatism and postoperative visual acuity. The objective is to rationalize how surgical techniques, incision placement, and corrective strategies can optimize refractive outcomes and improve overall quality of life for patients undergoing cataract surgery.

METHODS

The present study employed a longitudinal design and was conducted in the Department of Ophthalmology, LRBT Hospital, Lahore, from September 2022 to May 2023. Patients who underwent cataract surgery during this period were enrolled. A total of 140 patients were included, calculated using the standard sample size formula:

$$n = \frac{Z^2 P\,(1 - P)}{d^2}$$

where Z=1.96Z = 1.96 at a 95% confidence interval, P=0.10P = 0.10 as the prevalence value, and d=0.05d = 0.05 as the margin of error. The computed value of 138.3 was approximated to 140. Of these, 70 patients underwent phacoemulsification and 70 underwent manual small incision cataract surgery (MSICS). Non-probability convenience sampling was used to recruit participants. Eligible patients were between 45 and 70 years of age, of either gender, and diagnosed with uncomplicated bilateral immature senile cataract (grade 3 or less, with BCVA in either eye <0.50). Only patients with incision sizes between 1.75 mm and 2.75 mm and incision positions limited to superior or temporal locations were included. Patients with a history of extracapsular cataract extraction, incisions in other positions, mature, hypermature, complicated, congenital, or traumatic cataracts, or those associated with ocular comorbidities such as uveitis, pterygium, glaucoma, corneal infections, endophthalmitis, or retinal abnormalities were excluded. Patients outside the 45–70-year age range were also excluded.

Patients were allocated into two equal groups: 70 underwent phacoemulsification and 70 underwent MSICS. Each group was further subdivided into two subgroups of 35 each, based on incision position (superior or temporal) and incision length (minimum 1.75 mm, maximum 2.75 mm). All participants provided written informed consent prior to enrollment, and ethical approval was obtained from the Institutional Review Board of LRBT Hospital, Lahore. Clinical examinations were performed preoperatively and postoperatively at 1–3 weeks and 4–6 weeks. Visual acuity was assessed using a LogMAR chart, while anterior and posterior segment evaluation was conducted with a slit lamp biomicroscope (Digital camera system Pro-pix DC-200, Shin Nippon). Astigmatism was assessed using an auto-refractometer (Topcon) and keratometer (Nidek). Surgically induced astigmatism (SIA) was calculated by comparing pre- and postoperative keratometric values. All data were recorded in a pretested, self-structured proforma designed for the study. Data entry and statistical analysis were performed using IBM SPSS version 24. The normality of data was assessed using the Shapiro–Wilk test, which revealed a significance level of <0.05, indicating non-normal distribution. Consequently, non-parametric tests were applied. The Friedman's test was used for repeated measures within groups, and the Mann–Whitney U test was employed for intergroup comparisons. A p-value <0.05 was considered statistically significant.

RESULTS

A total of 140 participants met the eligibility criteria and were included. Group allocation was balanced: 70 underwent small incision cataract surgery (SICS) and 70 underwent phacoemulsification. Females comprised 58/140 (41.4%) and males 82/140 (58.6%); there were no missing responses. All participants were aged 45–70 years, distributed as 44 in 45–53 years, 53 in 54–62 years, and 43 in 63–70 years. Normality testing using Shapiro–Wilk indicated non-normal distributions for most outcomes (p<0.05), with visual acuity and cylindrical measures at several timepoints deviating from normality as per the reported normal probability plots. Within the phacoemulsification cohort, mean visual acuity improved from 0.831±0.199 D at baseline to 0.467±0.218 D on Day 1, 0.353±0.184 D at Week 1, and 0.226±0.152 D at Week 6. Repeated-measures analysis using Friedman's test yielded a test statistic of 177.138 with p=0.00, indicating a statistically significant change over time. Mean cylindrical error in the phacoemulsification cohort decreased from 0.831±0.199 D at baseline to 0.275±1.304 D on Day 1, 0.314±1.155 D at Week 1, and 0.182±0.914 D at Week 6, with Friedman's test=28.692; p=0.00. Within the SICS cohort, mean visual acuity improved from 0.884±0.178 D at baseline to 0.544±0.260 D on Day 1, 0.437±0.228 D at Week 1, and 0.280±0.196 D at Week 6, with Friedman's test=181.158; p=0.00. Mean cylindrical error for SICS was 0.831±0.199 D at baseline, 0.043±1.445 D on Day 1, 0.107±1.215 D at Week 1, and 0.136±0.962 D at Week 6, with Friedman's test=24.081; p=0.000. Between-group comparisons at 6 weeks stratified by incision length showed no significant difference in visual outcome for 1.75 mm incisions (Mann–Whitney U=515.5; p=0.238) and no significant difference in cylindrical error (U=497.0; p=0.172). For 2.75 mm incisions, there was no significant difference in visual outcome (U=585.5; p=0.743), while cylindrical error differed significantly between groups (U=841.0; p=0.007). Collectively, both surgical techniques demonstrated progressive improvement in visual acuity from baseline through Week 6 and reductions in cylindrical error by Week 6, with statistically significant within-group changes across follow-up timepoints.

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Table 1: Descriptive Statistics of Group undergoing Phacoemulsification (Visual Outcome)

	Phacoemulsification			
	Mean	±Standard Deviation	Friedman's Test Value	P-Value
Baseline Vision	0.831D	±0.199D	177.138	0.00
Postoperative vision (Day 1)	0.467D	±0.218D		
Postoperative vision (Week 1)	0.353D	±0.184D		
Postoperative vision (Week 6)	**0.226D**	**±0.152D**		

Table 2: Descriptive Statistics of Group undergoing Phacoemulsification (Cylindrical Error)

	Phacoemulsification			
	Mean	±Standard Deviation	Friedman's Test Value	P-Value
Baseline Cylindrical Error	0.831D	±0.199D	28.692	0.00
Postoperative Cylindrical Error (Day 1)	0.275D	±1.304D		
Postoperative Cylindrical Error (Week 1)	0.314D	±1.155D		
Postoperative Cylindrical Error (Week 6)	**0.182D**	**±0.914D**		

Table 3: Descriptive Statistics of Group undergoing SICS (Visual Outcome)

	SICS			
	Mean	±Standard Deviation	Friedman's Test Value	P-Value
Baseline Vision	0.884D	±0.178D	181.158	0.00
Postoperative vision (Day 1)	0.544D	±0.260D		
Postoperative vision (Week 1)	0.437D	±0.228D		
Postoperative vision (Week 6)	**0.280D**	**±0.196D**		

Table 4: Descriptive Statistics of Group undergoing SICS (Cylindrical Error)

	SICS			
	Mean	±Standard Deviation	Friedman's Test Value	P-Value
Baseline Cylindrical Error	0.831D	±0.199D	24.081	0.000
Postoperative Cylindrical Error (Day 1)	0.043D	±1.445D		
Postoperative Cylindrical Error (Week 1)	0.107D	±1.215D		
Postoperative Cylindrical Error (Week 6)	**0.136D**	**±0.962D**		

Table 5: Descriptive Statistics Postoperatively at 6th week with 1.75 Incision Length

	Mann-Whitney U Value	P-Value
Visual Outcome	515.5	0.238
Cylindrical Error	**497.0**	**0.172**

Table 6: Descriptive Statistics Postoperatively at 6th week with 2.75 Incision Length.

	Mann-Whitney U Value	P-Value
Visual Outcome	585.5	0.743
Cylindrical Error	**841.0**	**0.007**

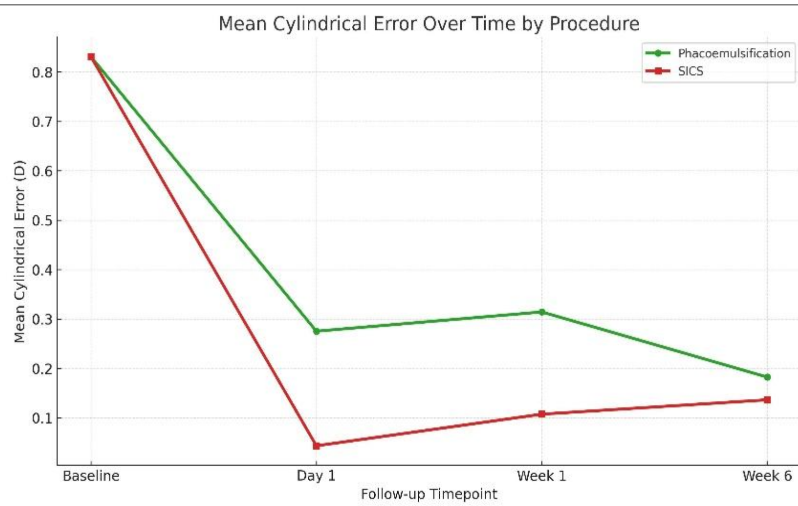


Figure 2 Mean Cylindrical Error Over Time by Procedure

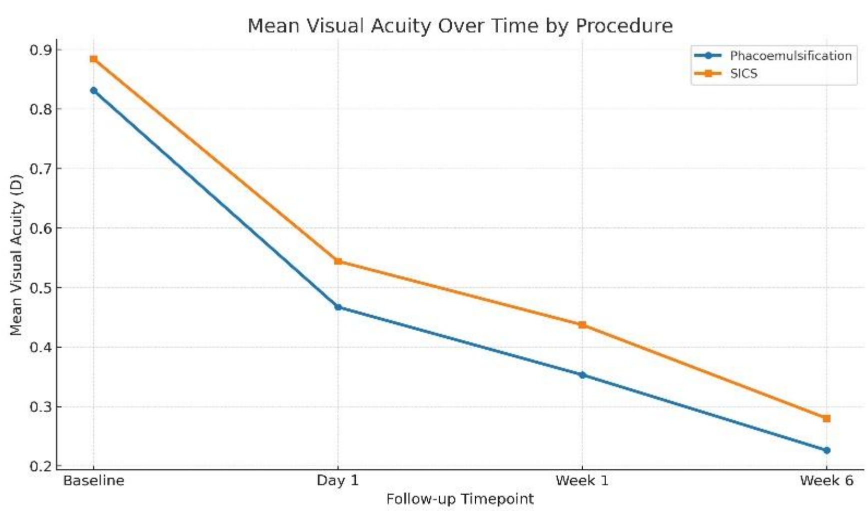
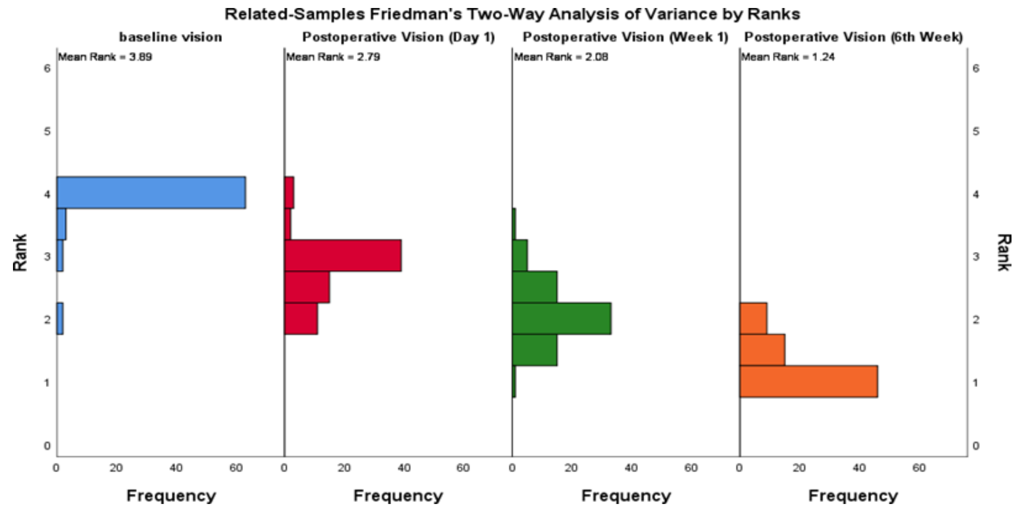
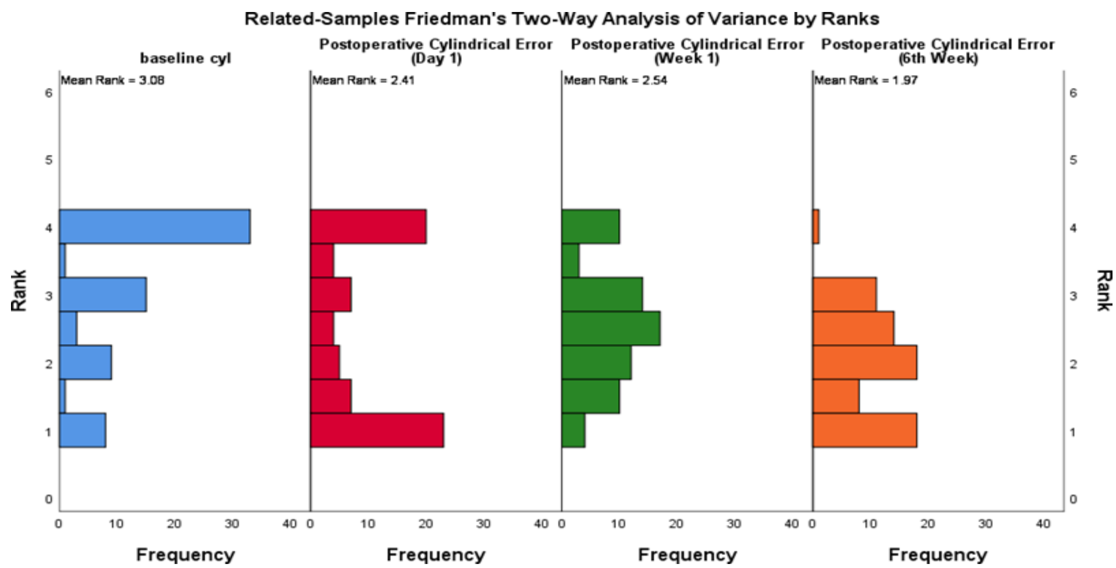
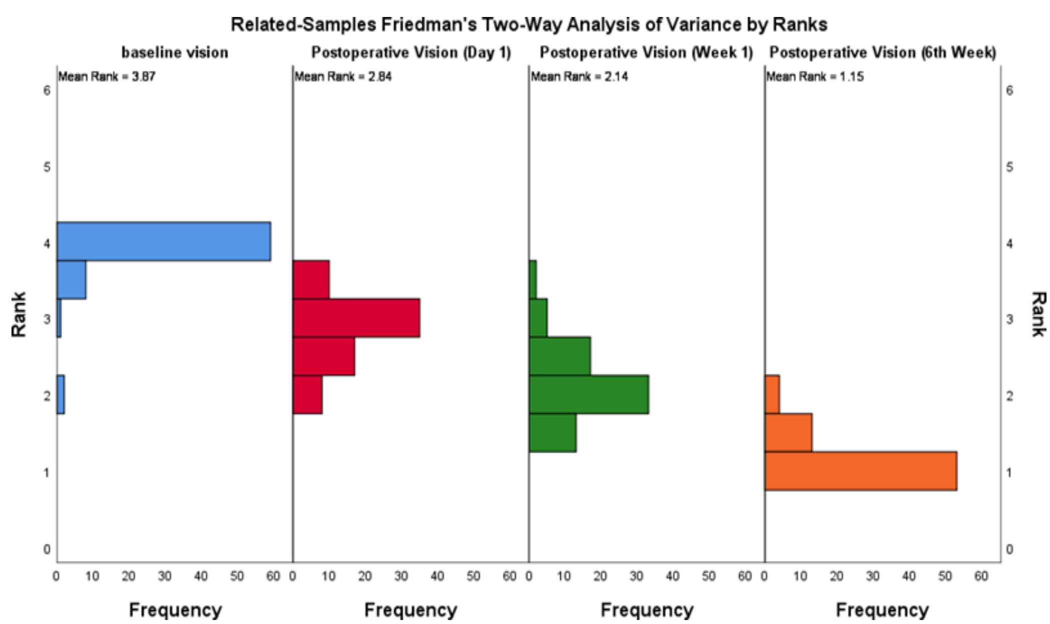


Figure 2 Mean Visual Acuity Over Time by Procedure


Related-Samples Friedman's Two-Way Analysis of Variance by Ranks
baseline vision
Postoperative Vision (Day 1)
Postoperative Vision (Week 1)
Postoperative Vision (6th Week)
Mean Rank = 3.89
Mean Rank = 2.79
Mean Rank = 2.08
Mean Rank = 1.24
Rank
Frequency


Related-Samples Friedman's Two-Way Analysis of Variance by Ranks
baseline cyl
Postoperative Cylindrical Error (Day 1)
Postoperative Cylindrical Error (Week 1)
Postoperative Cylindrical Error (6th Week)
Mean Rank = 3.08
Mean Rank = 2.41
Mean Rank = 2.54
Mean Rank = 1.97
Rank
Frequency


Related-Samples Friedman's Two-Way Analysis of Variance by Ranks
baseline vision
Postoperative Vision (Day 1)
Postoperative Vision (Week 1)
Postoperative Vision (6th Week)
Mean Rank = 3.87
Mean Rank = 2.84
Mean Rank = 2.14
Mean Rank = 1.15
Rank
Frequency

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DISCUSSION

The findings of the present study confirm that both phacoemulsification and small-incision cataract surgery (SICS) yield statistically significant improvements in visual acuity over time, with concomitant reductions in cylindrical error by Week 6. These results align with the evolving paradigm that cataract surgery aims not only to restore clarity but also to optimize refractive outcomes. In interpreting these results, several dimensions merit discussion: comparison with previous literature, clinical implications, study strengths and limitations, and directions for future work. In terms of visual rehabilitation, the observed mean LogMAR declines from baseline to Week 6 (0.831 → 0.226 in the phaco group; 0.884 → 0.280 in the SICS group) affirm that both techniques lead to meaningful visual gains across the follow-up period. The slightly faster early recovery in the phaco group mirrors findings reported in earlier comparisons, wherein phaco often provides more rapid uncorrected acuity improvements than larger-incision techniques, though long-term outcomes converge (14,15). However, by six weeks, the margin between phaco and SICS in visual acuity narrowed, suggesting that SICS remains a viable alternative in resource-limited settings. This supports prior observations that, when skillfully performed, SICS can approach the refractive and visual outcomes of phaco in many contexts (16,17). Regarding cylindrical error and induced astigmatism, this study's data show greater early fluctuation and regression over time, culminating in lower mean cylindrical error at Week 6 than at Day 1 or Week 1. In the phacoemulsification arm, mean cylindrical error decreased from 0.275 D on Day 1 to 0.182 D at Week 6, and in the SICS arm from 0.043 D (Day 1) to 0.136 D. The initial spike or variation likely reflects transient corneal edema or wound remodeling, with gradual stabilization thereafter. This temporal pattern is consistent with prior reports that surgically induced astigmatism (SIA) is maximal in the early postoperative period and regresses somewhat over weeks to months (18,19).

Comparisons between techniques in the current study revealed that for 1.75 mm incision length, there was no statistically significant difference in visual outcome (p=0.238) or cylindrical error (p=0.172). For 2.75 mm incisions, visual outcome still did not differ significantly (p=0.743), but the cylindrical error comparison was statistically significant (p=0.007), indicating that the larger incision size may exacerbate astigmatic differences between techniques. This nuance underscores that incision size and geometry remain critical modulators of refractive outcome. Studies comparing phaco clear corneal incisions located temporally versus superiorly have demonstrated lower SIA with temporal incisions, especially when the incision is farther from the visual axis and shorter in length (20,21). In MSICS literature, modifications in incision location (temporal vs superior) have also shown variable SIA results—for example, a study reported lower SIA in temporal scleral incisions vs superior (1.09 ± 0.42 D vs. 1.38 ± 0.62 D) in SICS (22). The clinical implications of these findings are salient. First, in settings where phacoemulsification is not affordable or available, high-quality SICS offers a cost-effective alternative with respectable refractive performance. Surgeons should judiciously choose incision position and length to mitigate induced astigmatism. In cases with preexisting astigmatism, aligning incisions along the steep meridian or combining with adjunct techniques (e.g., limbal relaxing incisions or toric IOLs) might further limit residual cylinder. Moreover, the data suggest that marginal differences in astigmatism may emerge only with larger incisions, reinforcing the rationale for minimizing incision size when possible.

Several strengths bolster the credibility of this study. The longitudinal design with repeated measures allowed within-subject tracking of refractive evolution. The balanced sample size between techniques and subdivision by incision parameters improved internal comparability. Use of standardized instrumentation (auto-refractometer, keratometer, LogMAR) and nonparametric statistical methods appropriate for non-normal data distribution enhanced methodological rigor. By assessing outcomes at multiple postoperative timepoints (Day 1, Week 1, Week 6), the temporal trend of healing and astigmatic regression was captured. Nevertheless, the study had limitations. The non-probability convenience sampling limits generalizability and introduces potential selection bias. Subgrouping by incision position and length, though logical, may have reduced statistical power within subgroups and increased the risk of Type II error. The absence of vector analysis of SIA (e.g., Alpins method) and lack of reporting confidence intervals or effect sizes restrains deeper interpretation. The follow-up period of six weeks is relatively short—longer monitoring (e.g., six or twelve months) would better characterize astigmatic stabilization. Additionally, baseline cylindrical error values seemed identical across groups in the original data, which may suggest transcription or measurement consistency issues that require verification. Finally, surgeon learning curve, intraoperative manipulation, and wound architecture (frown vs straight) were not explicitly controlled or reported, but these factors may affect astigmatic outcomes. Looking ahead, future research should adopt vector analysis methods to more precisely quantify SIA magnitude and axis change, and should follow subjects for extended durations to ascertain long-term stability. Studies may also explore incision geometry (frown, chevron, S-shaped) and their impact in both phaco and SICS contexts. Randomized allocation rather than convenience sampling would strengthen validity. Further work could also evaluate patient-reported visual quality and spectacle independence, linking refractive metrics to functional outcomes (23). In summary, this study demonstrated that both phacoemulsification and SICS lead to meaningful improvements in visual acuity and reductions in astigmatic error over six weeks, with minimal differences in refractive outcomes when optimized incision parameters are used. While phaco may offer earlier stabilization and slightly lower induced astigmatism, well-executed SICS remains a robust option, especially in resource-constrained settings. The findings reinforce the importance of incision planning and advocate for longer-term, vector-based studies to guide surgical refinement.

CONCLUSION

In conclusion, the study highlights that both phacoemulsification and manual small incision cataract surgery are effective in restoring vision and improving postoperative outcomes. While phacoemulsification offers the benefit of quicker visual rehabilitation due to its minimally invasive approach, the simplicity, affordability, and reliability of SICS make it an equally valuable technique, particularly in high-volume and resource-limited settings. These findings emphasize that the choice of surgical method should be guided by patient needs, surgeon expertise, and healthcare resources, ensuring that safe and effective cataract care remains accessible to diverse populations.

AUTHOR CONTRIBUTION

Author	Contribution
Afrish Maqbool	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Abdul Sattar	Substantial Contribution to study design, acquisition and interpretation of Data Critical Review and Manuscript Writing Has given Final Approval of the version to be published
Saima Ghufran*	Substantial Contribution to acquisition and interpretation of Data Has given Final Approval of the version to be published

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