Original article

Comparison of Surgically Induced Astigmatism Between Superior Scleral Incision and Clear Corneal Temporal Incision in Phacoemulsification Surgery: A Prospective Comparative Study

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Abstract

Background: Careful placement of the cataract surgical incision on the steeper corneal meridian has been proposed as a simple means of reducing pre-existing astigmatism during phacoemulsification, without the additional cost or complexity of toric intraocular lenses or limbal relaxing incisions.

Objectives: To compare surgically induced astigmatism (SIA) between a superior scleral incision (for eyes with with-the-rule astigmatism) and a temporal clear corneal incision (for eyes with against-the-rule astigmatism) in phacoemulsification surgery.

Methods: This was a hospital-based, prospective, comparative study conducted in the Department of Ophthalmology of a tertiary care centre in India over a two-year period. One hundred eyes of 100 patients with uncomplicated senile cataract and preoperative astigmatism of 0.25-2 D were divided into two groups of 50 eyes each: Group 1 (with-the-rule astigmatism) underwent superior scleral incision phacoemulsification, and Group 2 (against-the-rule astigmatism) underwent temporal clear corneal incision phacoemulsification. Keratometry was performed preoperatively and at 1, 2, and 4 weeks postoperatively, and astigmatism was calculated by the simple subtraction method.

Results: Mean preoperative astigmatism was comparable between groups (Group 1: 1.105 ± 0.54 D; Group 2: 1.120 ± 0.49 D; p=0.8843). Postoperative astigmatism at 4 weeks reduced significantly in both groups (Group 1: 0.545 ± 0.51 D; Group 2: 0.59 ± 0.48 D; both p<0.0001 versus preoperative). Surgically induced astigmatism at 4 weeks was 0.56 ± 0.20 D in Group 1 and 0.54 ± 0.15 D in Group 2, a difference that was not statistically significant at 1, 2, or 4 weeks (p=0.7475, 0.7587, and 0.4818 respectively). A shift in astigmatism axis was observed in 4 (8%) patients in each group.

Conclusion: Placing the surgical incision on the steeper corneal meridian, whether via a superior scleral or temporal clear corneal route, produces a comparable and statistically significant reduction in pre-existing astigmatism following phacoemulsification, supporting incision-site selection based on preoperative keratometry as a simple, cost-free strategy for astigmatism management.

Keywords: Surgically induced astigmatism, phacoemulsification, superior scleral incision, temporal clear corneal incision, cataract surgery.

Introduction

Patients undergoing cataract surgery increasingly expect not only restoration of clarity of vision but also reduced dependence on spectacle correction postoperatively. Modern small-incision phacoemulsification with foldable intraocular lens implantation has allowed a large proportion of patients to achieve near-emmetropic outcomes, but pre-existing corneal astigmatism remains an important determinant of final uncorrected visual acuity.[9] Several strategies have been described to address pre-existing astigmatism at the time of cataract surgery, including toric intraocular lens implantation, limbal or corneal relaxing incisions, astigmatic keratotomy, and excimer laser ablation; each of these carries additional cost, technical complexity, or specific procedural drawbacks.

A simpler and more widely accessible approach is to place the primary phacoemulsification incision itself on the steeper corneal meridian, exploiting the well-recognised flattening effect that any corneal or limbal incision has on the meridian in which it is placed, with compensatory steepening 90 degrees away.[2,3] For eyes with with-the-rule astigmatism (steeper vertical meridian), a superior incision is therefore expected to flatten the vertical meridian and reduce astigmatism, whereas for eyes with against-the-rule astigmatism (steeper horizontal meridian), a temporal incision should similarly flatten the horizontal meridian.[3,4]

Since Kelman first introduced phacoemulsification, incision size, architecture, and location have all been shown to influence the magnitude and axis of surgically induced astigmatism (SIA), and multiple comparative studies have examined superior versus temporal incision placement with variable conclusions regarding the relative astigmatic advantage of each approach.[2,4,5,10] Given this ongoing debate, and the practical, low-cost nature of incision-site selection based on preoperative keratometry, further prospective comparative data remain valuable in guiding routine clinical practice, particularly in resource-limited settings where toric intraocular lenses and relaxing incision nomograms may not be readily accessible.

This study was undertaken to compare surgically induced astigmatism between a superior scleral incision used for eyes with with-the-rule astigmatism and a temporal clear corneal incision used for eyes with against-the-rule astigmatism, in patients undergoing phacoemulsification for uncomplicated senile cataract.

Materials and Methods

Study Design and Setting

This was a hospital-based, prospective, comparative clinical study conducted in the Department of Ophthalmology at a tertiary care teaching centre in India, over the period November 2009 to November 2011.

Study Population and Sample Size

One hundred eyes of 100 patients attending the eye outpatient department were enrolled and divided into two groups of 50 eyes each according to their preoperative keratometric astigmatism: Group 1 comprised eyes with a steeper vertical meridian (with-the-rule astigmatism), and Group 2 comprised eyes with a steeper horizontal meridian (against-the-rule astigmatism).

Inclusion Criteria

All patients with uncomplicated senile cataract and preoperative astigmatism between 0.25 D and 2 D in the two principal meridians, as evident on keratometry, were included.

Exclusion Criteria

Patients with no pre-existing astigmatism, irregular astigmatism, astigmatism greater than 2 D, ocular pathologies including dry eye, pterygium, corneal or scleral pathology, or iridocyclitis, macular or retinal pathology (identified pre- or postoperatively), intraoperative or postoperative complications, previous ocular surgery, or those unwilling to participate were excluded.

Surgical Technique

All surgeries were performed by the same surgeon, and all preoperative and postoperative assessments, including keratometry, were performed by the same observer to minimise observer bias. Group 1 eyes underwent phacoemulsification via a 2 mm superior scleral incision placed 2 mm from the limbus, with a scleral tunnel fashioned using a 2.6 mm crescent blade and anterior chamber entry with a 2.8 mm keratome at the 12 o'clock position. Group 2 eyes underwent phacoemulsification via a temporal clear corneal incision, with anterior chamber entry using a 2.8 mm keratome at the 9 o'clock (right eye) or 3 o'clock (left eye) position. In

both groups, continuous curvilinear capsulorrhexis was performed after trypan blue staining where required, hydrodissection was performed with balanced salt solution, the nucleus was managed by a multiple chop technique, residual cortex was aspirated, and a foldable posterior chamber intraocular lens was implanted in the capsular bag through an incision enlarged to 3 mm. All surgery was performed under peribulbar anaesthesia.

Follow-up and Measurements

Uncorrected visual acuity was recorded preoperatively and at 1, 2, and 4 weeks postoperatively, and best corrected visual acuity was assessed at 4 weeks. Keratometry was performed preoperatively and at 1, 2, and 4 weeks postoperatively using the same keratometer for all patients, and astigmatism was calculated by the simple subtraction method (difference between the two principal keratometric readings). Surgically induced astigmatism (SIA) was calculated as the difference between preoperative and postoperative keratometric astigmatism at each follow-up point.

Statistical Analysis

Student's t-test was used to compare means between the two independent groups, and to compare preoperative and postoperative astigmatism within each group. A p-value less than 0.05 was considered statistically significant.

Results

The mean age was 60.64 ± 6.51 years in Group 1 and 61.60 ± 6.75 years in Group 2, a difference that was not statistically significant (p=0.4712). Group 1 comprised 26 (52%) male and 24 (48%) female patients, and Group 2 comprised 27 (54%) male and 23 (46%) female patients. The two groups were therefore comparable at baseline with respect to age and sex distribution (Table 1).

Table 1: Age and Gender-wise Distribution of Study Subjects (n = 100)

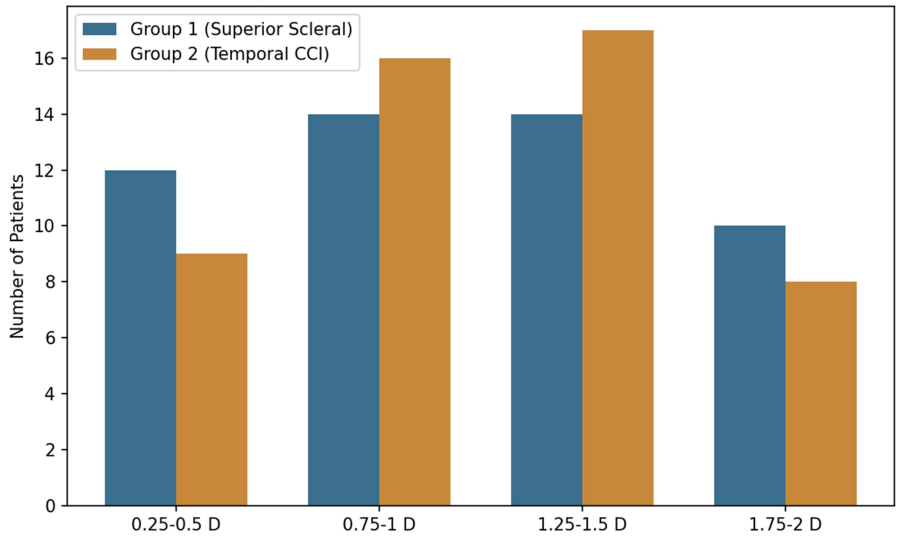
Characteristic	Category	Group 1 (Superior Scleral, n=50)	Group 2 (Temporal CCI, n=50)
Age (years)	51–60	24 (48%)	21 (42%)
	61–70	23 (46%)	24 (48%)
	>70	3 (6%)	5 (10%)
	Mean ± SD	60.64 ± 6.51	61.60 ± 6.75
Sex	Male	26 (52%)	27 (54%)
	Female	24 (48%)	23 (46%)

Mean preoperative astigmatism was 1.105 ± 0.54 D in Group 1 and 1.120 ± 0.49 D in Group 2, a difference that was not statistically significant (p=0.8843), confirming comparability of baseline astigmatism between groups (Table 2, Figure 1).

Table 2: Preoperative Astigmatism Distribution

Preoperative Astigmatism	Group 1, n (%)	Group 2, n (%)
0.25–0.5 D	12 (24%)	9 (18%)
0.75–1 D	14 (28%)	16 (32%)
1.25–1.5 D	14 (28%)	17 (34%)
1.75–2 D	10 (20%)	8 (16%)
Mean ± SD	1.105 ± 0.54 D	1.120 ± 0.49 D

Figure 1: Preoperative Astigmatism Distribution



Postoperative astigmatism decreased progressively in both groups over the follow-up period. At 4 weeks, 22 (44%) patients in Group 1 and 17 (34%) patients in Group 2 had residual astigmatism of 0-0.25 D, and no patient in either group had astigmatism of 2 D or more at any follow-up point (Table 3, Figure 2).

Table 3: Postoperative Astigmatism Distribution at 1, 2, and 4 Weeks

Postoperative Astigmatism	1 Week Group 1	1 Week Group 2	2 Weeks Group 1	2 Weeks Group 2	4 Weeks Group 1	4 Weeks Group 2
0–0.25 D	20 (40%)	16 (32%)	21 (42%)	17 (34%)	22 (44%)	17 (34%)
0.5–0.75 D	14 (28%)	17 (34%)	14 (28%)	17 (34%)	14 (28%)	18 (36%)
1–1.25 D	10 (20%)	12 (24%)	11 (22%)	13 (26%)	11 (22%)	13 (26%)
1.5–1.75 D	6 (12%)	5 (10%)	4 (8%)	3 (6%)	3 (6%)	2 (4%)
≥2 D	0	0	0	0	0	0
Mean ± SD (D)	0.615±0.54	0.640±0.53	0.580±0.52	0.605±0.50	0.545±0.51	0.59±0.48

Figure 2: Postoperative Astigmatism Distribution at 4 Weeks

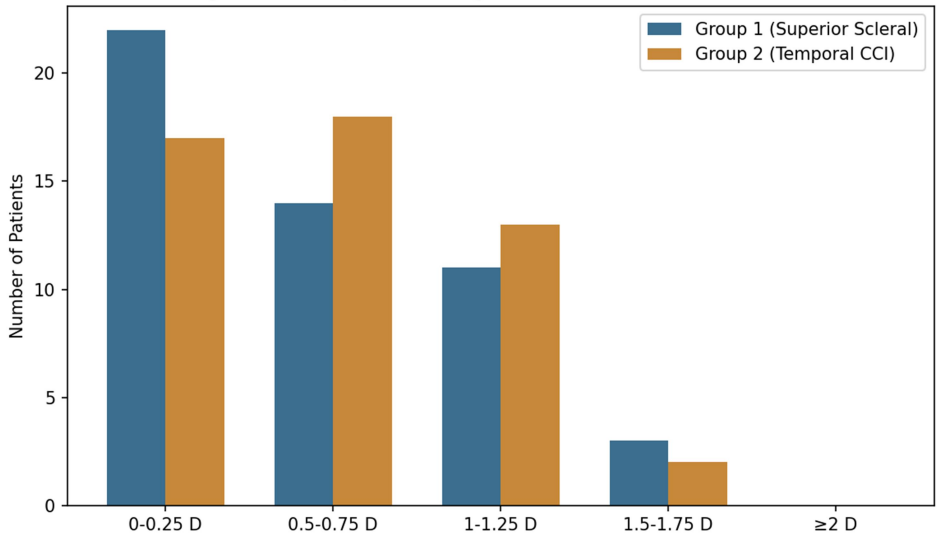
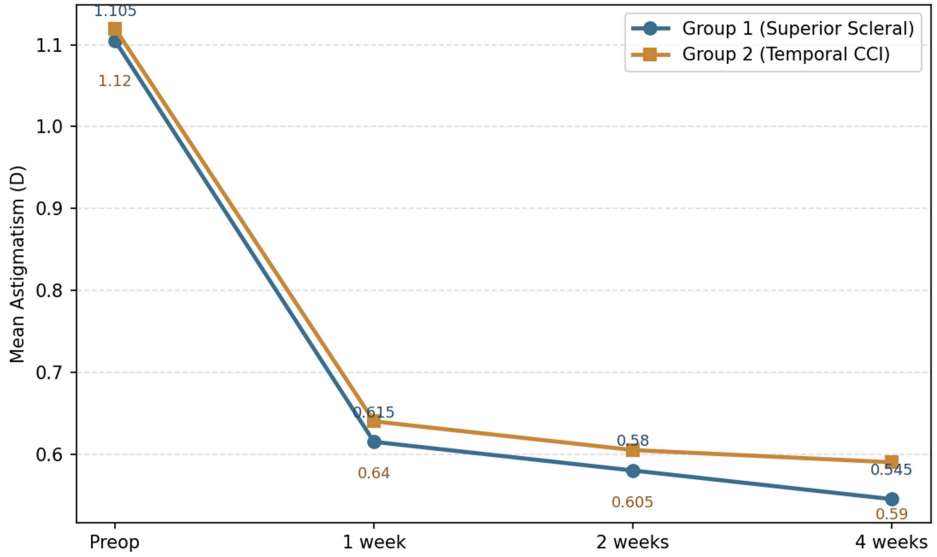


Figure 3: Trend of Mean Astigmatism from Preoperative to 4 Weeks Postoperative



In Group 1, mean astigmatism reduced from 1.105 ± 0.54 D preoperatively to 0.545 ± 0.51 D at 4 weeks ($p<0.0001$). In Group 2, mean astigmatism reduced from 1.120 ± 0.49 D preoperatively to 0.59 ± 0.48 D at 4 weeks ($p<0.0001$). Both reductions were highly statistically significant (Table 4).

Table 4: Comparison of Preoperative and Postoperative Astigmatism at 4 Weeks

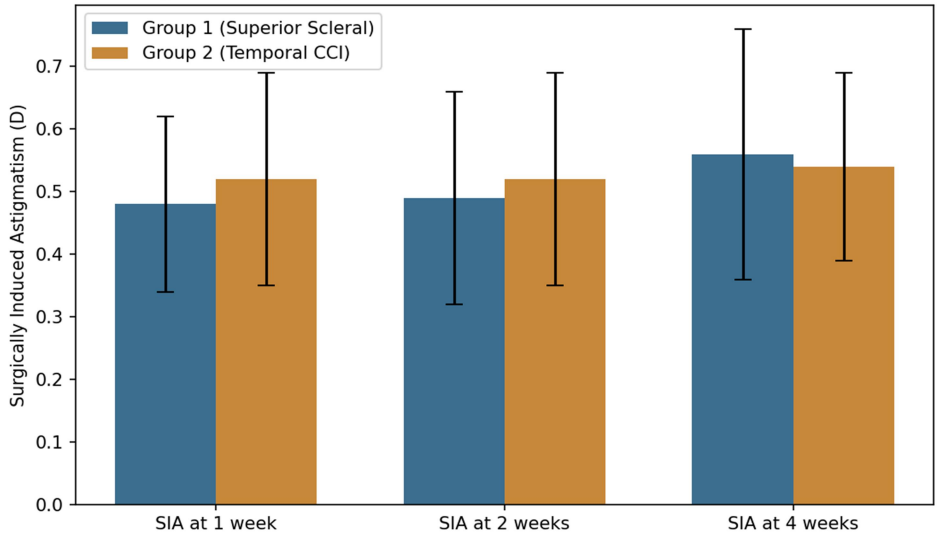
Group	Preoperative Astigmatism (D)	Postoperative Astigmatism at 4 Weeks (D)	P-value
Group 1 (Superior Scleral)	1.105 ± 0.54	0.545 ± 0.51	<0.0001
Group 2 (Temporal CCI)	1.120 ± 0.49	0.59 ± 0.48	<0.0001

Surgically induced astigmatism (SIA) in Group 1 was 0.48 ± 0.14 D at 1 week, 0.49 ± 0.17 D at 2 weeks, and 0.56 ± 0.20 D at 4 weeks. In Group 2, SIA was 0.52 ± 0.17 D at 1 week, 0.52 ± 0.17 D at 2 weeks, and 0.54 ± 0.15 D at 4 weeks. The difference between groups was not statistically significant at any follow-up point (Table 5, Figure 4).

Table 5: Surgically Induced Astigmatism (SIA) at 1, 2, and 4 Weeks

Group	SIA at 1 Week (D)	SIA at 2 Weeks (D)	SIA at 4 Weeks (D)
Group 1 (Superior Scleral)	0.48 ± 0.14	0.49 ± 0.17	0.56 ± 0.20
Group 2 (Temporal CCI)	0.52 ± 0.17	0.52 ± 0.17	0.54 ± 0.15
P-value	0.7475	0.7587	0.4818

Figure 4: Surgically Induced Astigmatism (SIA) at 1, 2, and 4 Weeks



A shift in the axis of astigmatism was observed in a minority of patients in each group: 4 (8%) patients in Group 1 shifted from preoperative with-the-rule to against-the-rule astigmatism, while 4 (8%) patients in Group 2 shifted from preoperative against-the-rule to with-the-rule astigmatism at 4 weeks (Table 6).

Table 6: Shift in Astigmatism Axis at 4 Weeks

Group	Preoperative Astigmatism Type	Shift Observed at 4 Weeks	Number of Patients, n (%)
Group 1	With-the-rule (WTR)	Shift to against-the-rule (ATR)	4 (8%)
Group 2	Against-the-rule (ATR)	Shift to with-the-rule (WTR)	4 (8%)

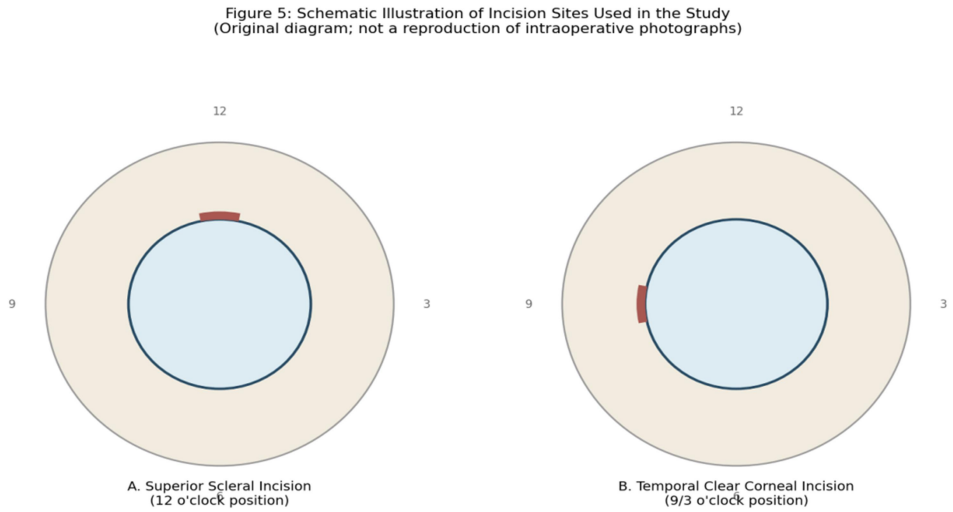


Figure 5: Schematic illustration of the superior scleral and temporal clear corneal incision sites used in this study.

Discussion

Both groups in this study were well matched at baseline for age, sex, and preoperative astigmatism, allowing meaningful comparison of the two incision strategies. The reduction in astigmatism achieved in this study, from a mean of approximately 1.1 D preoperatively to approximately 0.55-0.59 D at 4 weeks in both groups, falls within the range reported in earlier comparative literature, which has generally found that incision placement on the steeper meridian achieves clinically useful, though incomplete, correction of pre-existing astigmatism, usually in the order of 0.4-0.7 D.[2,3,7]

The absence of a statistically significant difference in SIA between the superior and temporal incision groups in this study is consistent with some, though not all, of the published comparative literature. Cillino and colleagues, comparing temporal and superior approach phacoemulsification, similarly reported comparable short-term postoperative astigmatism between the two approaches.[2] In contrast, other series, including that of Oshika and colleagues comparing superior and temporal scleral incisions, have reported differences favouring the temporal approach, reflecting its typically greater distance from the visual axis and reduced tendency to induce irregular astigmatism.[4] In the present study, Group 2 (temporal clear corneal incision) showed a numerically, though not statistically significantly, lower SIA than Group 1 (superior scleral incision) at 4 weeks (0.54 ± 0.15 D versus 0.56 ± 0.20 D), consistent with this general trend.

The pattern of axis shift observed in this study, with a minority of patients in each group shifting from their preoperative astigmatism type toward the opposite type postoperatively, is consistent with the well-recognised principle that any corneal or scleral incision flattens the meridian in which it is placed while inducing relative steepening 90 degrees away. This is consistent with the findings of Tejedor and Murube, who similarly demonstrated that superior incisions tend to induce a shift toward against-the-rule astigmatism, while temporal incisions tend to induce a shift toward with-the-rule astigmatism.[3]

The relatively rapid stabilisation of astigmatism observed in this study, with no significant difference in SIA between the 1-week and 4-week assessments in either group, supports the use of small-incision, sutureless phacoemulsification in achieving early refractive stability, consistent with the findings of Percival and Beare, who reported that clear corneal incisions achieve relatively stable astigmatic outcomes within the early

postoperative period.[1] This early stabilisation has practical clinical relevance, as it allows earlier and more reliable spectacle prescription following surgery.

Taken together, these findings support incision-site selection based on preoperative keratometric astigmatism axis as a simple, cost-free, and effective strategy for reducing pre-existing corneal astigmatism at the time of routine phacoemulsification, without requiring the additional expense or technical complexity associated with toric intraocular lenses, limbal relaxing incisions, or excimer laser-based astigmatism correction.[6,8]

Strengths and Limitations

This study's strengths include its prospective design, use of a single surgeon and single observer to minimise procedural and measurement bias, and well-matched comparison groups at baseline. Limitations include the relatively short follow-up period of 4 weeks, which may not capture longer-term astigmatic stability or decay, as some incision types have been shown to demonstrate astigmatic changes continuing beyond this period; the use of keratometric simple subtraction rather than vector analysis for astigmatism calculation, which does not account for changes in axis in as much detail as vector methods; and the single-centre design, which may limit generalisability to other surgical settings and surgeon experience levels.

Conclusion

Both superior scleral incision and temporal clear corneal incision, when placed on the steeper preoperative corneal meridian, achieve a comparable and statistically significant reduction in pre-existing astigmatism following phacoemulsification, with no significant difference in surgically induced astigmatism between the two approaches at 1, 2, or 4 weeks. These findings support careful preoperative keratometric assessment and incision-site planning as a simple and effective strategy for astigmatism management during routine cataract surgery.

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