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Surgically Induced Astigmatism after Superotemporal and Superonasal Clear Corneal Incisions in Phacoemulsification

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ABSTRACT

Introduction: Cataract surgery has undergone various advances since it was evolved from ancient couching to the modern phacoemulsification. A clear corneal incision has the benefit of being bloodless and having an easy approach but surgically induced astigmatism (SIA) remains one of the most common complications.

Objective: To determine and compare the SIA in clear corneal phacoemulsification by superotemporal (ST) approach in right eye and by superonasal (SN) approach in left eye.

Methodology: This was a hospital-based, interventional, analytical study conducted in the department of Ophthalmology at Nepal Medical College, from 2024 January to 2025 March after institutional ethical approval. Patients enrolled by consecutive sampling technique were divided into two groups. In Group A, patients with immature cataract in the right eye underwent ST corneal incision. In Group B, patients with immature cataract in the left eye underwent SN clear corneal incision. Group A had 31 eyes and Group B had 34 eyes. Astigmatism was measured by keratometry readings pre and post-operatively at first and sixth week. The SIA was calculated by the vector analysis at first and sixth week post-operatively.

Result: Mean SIA was lower in Group A (0.36 ± 0.32 D at the first week, reducing to 0.31 ± 0.29 D at sixth week) compared to Group B (0.37 ± 0.22 D at the first week and 0.35 ± 0.25 D at sixth week. The SIA of both groups decreased post-operatively at sixth week. No statistically significant difference was found in SIA at both first and sixth post-operative week between two groups ($p = 0.83$; $p = 0.55$).

Conclusion: The incisions, either ST or SN in phacoemulsification showed no statistically significant difference in SIA.

Key words: Corneal incision; phacoemulsification; surgically induced astigmatism.

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INTRODUCTION

Cataract is the leading treatable cause of blindness worldwide (Pascolini and Mariotti, 2012). Cataract surgery has undergone various advances since it was evolved from ancient couching to the modern phacoemulsification cataract surgery. The primary aim is good post-operative visual rehabilitation without correction with immediate mobilisation, but the main obstacle is surgically induced astigmatism (SIA). The SIA may originate from the changes of corneal curvature induced during corneal incision in cataract surgery (Hayashi et al., 2009), and remains as a leading cause of post-operative astigmatism, affecting post-operative visual outcome (Yoon et al., 2013; Solu et al., 2017). A clear corneal incision has the benefit of being bloodless and having an easy approach but SIA remains one of the most common complications. The SIA is defined as the flattening effect in that axis induced by an incision made on the cornea and influences the refractive outcomes of cataract surgery. Over time, various surgeons have developed different incisions to reduce the SIA. Post-operative SIA depends upon location, size, approach and architecture of the wound (Pakravan et al., 2009). Smaller incision is associated with less surgically induced change in corneal curvature. Peripheral incisions at limbus and sclera result in a less surgically induced change in corneal curvature than those involve the cornea (Zhang et al., 2013).

The purpose of this study was to determine the SIA in clear corneal phacoemulsification by superotemporal (ST) approach in right eye and by superonasal (SN) approach in left eye. Comparisons between corneal astigmatism of the two incisions were done using keratometric reading of preoperative and post-operative first and sixth week's status and SIA was calculated by vector analysis.

METHODOLOGY

This was a hospital-based, interventional, analytical study conducted in the department of Ophthalmology at Nepal Medical College, Attarkhel, Gokarneshwor, Kathmandu, Nepal from 2024 January to 2025 March after ethical approval. Ethical clearance was taken from the Institutional Review Committee of Nepal Medical College (NMC-IRC Reference number: 47-080/081). This study included total 65 eyes with immature cataract (nuclear sclerosis up to grade III). Cataract was graded according to Lens Opacification Classification System II. In Group A (31 eyes), ST incision for right eye and in Group B (34 eyes), SN incision for left eye were included.

The sampling technique used was consecutive. Not all cataract cases, but only those eligible patients with immature cataract who underwent phacoemulsification and met the inclusion criteria during the study period were included. The sample size was calculated using finite formula. The calculation has been elaborated below:

$$n = \frac{n_0}{1 + \frac{(n_0 - 1)}{N}}$$

$$= \frac{14000}{1 + \frac{(14000 - 1)}{60}}$$

$$= \frac{14000}{1 + \frac{(13999)}{60}}$$

$$= \frac{14000}{1+233}$$

$$= \frac{14000}{234}$$

$$= 59.8$$

Where, $n_0 = 14000$ = Total outpatient department (OPD) patients in the previous year; and N = 60 = number of phacoemulsifications done in the previous year. Hence, the sample size of 60 was taken.

Patients diagnosed as mature and hypermature cataract were not included in the present study. Written consent was taken prior to surgery and informed verbal consent was taken for participation in the study from each patient. All patients received detailed ophthalmological examination in addition to keratometry at the preoperative and post-operative first and sixth week. The keratometric readings in diopteric power was taken using Takagi keratometer. All phacoemulsification surgeries were done by a single right-handed surgeon under peribulbar anaesthesia. The machine used for phacoemulsification was Oertli and acrylic hydrophilic foldable Intra Ocular Lens (Fred Hollows foldable IOL) was implanted. The surgeon sat at 12 o'clock position and gave clear corneal biplanar self-sealing horizontal incision at superotemporal for the right eye (Group A) and at superonasal for the left eye (Group B) with 2.8 mm keratome about 0.5 mm inside the limbus. The keratome went parallel to the corneal surface for one-third of the corneal thickness, then dipped toward the anterior chamber. A side port was made at 90° to the main port with 15-degree knife. Anterior capsular staining was done with Trypan blue and anterior chamber formation was done with preloaded viscoelastic. Continuous Curvilinear Capsulorhexis was made followed by hydrodissection and hydrodelineation. The technique for nuclear fragmentation was direct chop, irrigation and aspiration of cortical lens matter and foldable IOL implantation through IOL insertion cartridge. All the incisions were closed by stromal hydration. A subconjunctival injection of antibiotics and steroid was given at the end of the surgery. Patients were started on topical antibiotic and steroid combination on day one and were followed up on first and sixth week post-operatively. The parameters like pre and post-operative best corrected visual acuity (BCVA), slit lamp examination, fundus examination, and keratometry preoperatively and post-operatively were recorded. The visual acuity of the patients recorded using Snellen's Chart were converted to Logarithm of minimum angle of resolution (LogMAR) units. In present study surgical SIA Calculator Version 2.1 vector analysis program developed by Sawhney and Aggarwal, https://www.insighteyeclinic.in/SIA_calculator.php (Sawhney and Aggarwal, 2019) was used to determine SIA. A 0-25° and 155°-180° was considered as against the rule (ATR) astigmatism and 65°-115° was with the rule (WTR) astigmatism. Data were statistically analysed using software, SPSS Statistics version 17.0 (SPSS Inc., Chicago, Ill., USA). Quantitative variables were reported as mean with standard deviation. Statistical tool like one way analysis of variance (ANOVA) and paired sample t test were used. The p-value <0.05 was considered as significant.

RESULT

Total 65 eyes were included in this study. The ST incision for right eye was done in 31

(47.7%) eyes (Group A) and 34 (52.3%) eyes had undergone SN incision (Group B) for left eye. In group A, (eight male and 23 female) and in group B (15 male and 19 female) were included. Out of 65 eyes the mean age was 65.03 ± 11.65 (range 37-87) years. Mean age was 67.48 ± 11.89 (range 42-87) years and 62.79 ± 11.14 (range 37-76) years in Group A and B respectively. In group A (10 Indo-aryan and 21 Tibeto-mongolian) and in group B (18 Indo-aryan and 16 Tibeto-mongolian) were noted. No statistical difference was found between two groups in terms of gender ($p = 0.12$), mean age ($p = 0.10$) and ethnicity ($p = 0.09$) (Table 1).

The preoperative astigmatism ranged from 0-1.75 D in both groups. Intragroup comparison showed significant decrease in astigmatism during post-operative sixth week when analysed by paired t-test in group A ($t = 3.22$, $p = 0.003$) whereas no significant decrease was seen in group B ($t = 1.93$, $p = 0.062$). The mean preoperative keratometric astigmatism in group A was (0.62 ± 0.44 D) which was more than in group B (0.57 ± 0.47D) but was not statistically significant ($p = 0.66$). In group A, the mean post-operative keratometric astigmatism at first and sixth week (0.45 ± 0.33 D and 0.41 ± 0.32 D) which were lesser in compare to group B (0.48 ± 0.40 D and 0.44 ± 0.34 D) respectively. However, there was no significant difference in mean post-operative keratometric astigmatism between two groups at first week and sixth week ($p = 0.75$ and $p = 0.76$) (Table 2).

Table 1: Preoperative demographic data.

Parameters	Group A	Group B	p-value
Male / Female (n)	8/23	15/19	0.12
Mean age	67.48 ± 11.89	62.79 ± 11.14	0.10
Indo-aryan / Tibeto-mongolian	10/21	18/16	0.09

Table 2: Mean preoperative and post-operative keratometric corneal astigmatism.

		Group A (Mean ± SD)	Group B (Mean ± SD)	p-value
Preoperative		0.62 ± 0.44	0.57 ± 0.47	0.66
Post-operative	First week	0.45 ± 0.33	0.48 ± 0.40	0.75
	Sixth week	0.41 ± 0.32	0.44 ± 0.34	0.76

Mean SIA calculated by vector analysis method was less in Group A (0.36 ± 0.32 D) at first week and (0.31 ± 0.29 D) at sixth week than those in Group B (0.37 ± 0.22 D) and (0.35 ± 0.25 D) at first and sixth week post-operatively. The SIA of both groups decreased post-operatively at sixth week. However, the mean difference was not statistically significant between the groups (p = 0.83, p = 0.55) (Table 3).

The mean preoperative keratometry horizontal (KH) and keratometry vertical (KV) in group A were 44.74 ± 2.02 and 44.74 ± 1.78 respectively whereas 43.66 ± 1.70 and 43.49 ± 1.89 in group B which showed significant difference in mean values between two groups (p = 0.023 and p = 0.008). On first week post-operative in group A and group B, KH and KV were 44.67 ± 1.85, 44.80 ± 1.64 and 43.67 ± 1.51, 43.52 ± 1.63 respectively which showed statistically significant difference (p = 0.020 and p = 0.003) between groups. In group A and B, at sixth week KH and KV were 44.85 ± 1.84, 44.83 ± 1.71 and 43.79 ± 1.55, 43.62 ± 1.70 respectively which showed statistically significant difference in mean keratometry values between two groups (Table 4).

Table 3: Mean surgically induced astigmatism by vector analysis in both groups.

Post-operative	Mean SIA (Diopter ± S.D) Group A	Mean SIA (Diopter ±S.D) Group B	p-value
First week	0.36 ± 0.32	0.37 ± 0.22	0.83
Sixth week	0.31 ± 0.29	0.35 ± 0.25	0.55

Table 4: Preoperative and post-operative mean keratometric readings between groups.

		Group A Mean ± S.D	Group B Mean ± S.D	p-value
Preoperative	Keratometry (KH)	44.74 ± 2.02	43.66 ± 1.70	0.023
	Keratometry (KV)	44.74 ± 1.78	43.49 ± 1.89	0.008
Post-operative first week	Keratometry (KH)	44.67 ± 1.85	43.67 ± 1.51	0.020
	Keratometry (KV)	44.80 ± 1.64	43.52 ± 1.63	0.003
Post-operative sixth week	Keratometry (KH)	44.85 ± 1.84	43.79 ± 1.55	0.015
	Keratometry (KV)	44.83 ± 1.71	43.62 ± 1.70	0.006

Preoperatively in group A, 15 (48.4%) had WTR, 14 (45.2%) had ATR and two (6.5%) were astigmatically neutral. Post-operative first week, in group A 17 (54.8%) had WTR, 10 (32.3%) had ATR and four (12.9%) had no astigmatism and at sixth week 12 (38.7%) had WTR, 13 (41.9%) had ATR and six (19.4%) had no astigmatism. Preoperatively in group B, 10 (29.4%) had WTR, 19 (55.9%) had ATR and five (14.7%) had no astigmatism. At first week of post-operative nine (26.5%) had WTR, 21 (61.8%) had ATR and four (11.8%) had no astigmatism. At sixth week 10 (29.4%) had WTR, 20 (58.8%) had ATR and four (11.8%) had no astigmatism. At sixth week, group B had more ATR astigmatism than group A. In present study, the type of astigmatism also did not differ between two groups significantly preoperative ($p = 0.88$) and post-operative first and sixth week ($p = 0.07$, and $p= 0.18$) respectively (Table 5).

In group A, eight (25.8%) converted ATR to WTR, one (3.2%) WTR to ATR and 12 (38.7%) had no conversion. Similarly, in group B, 13 (38.2%) had conversion ATR to WTR, two (5.9%) had WTR to ATR and 11 (32.3%) had no conversion. There was no statistically significance difference in conversion between two groups ($p = 0.58$) (Table 6).

In group A, out of 31 eyes, post-operative SIA at sixth week was increased in six (19.4%), decreased in 17 (54.8%) and remained same in eight (25.8%) eyes. Similarly, in group B, 13 (38.2%) had increased, 15 (44.1%) had decreased and six (17.6%) had unchanged astigmatism at sixth week post-operative which showed no statistically significant difference between two groups ($p = 0.89$).

Mean BCVA (Log MAR) in Group A was 1.1 $\pm$ 0.41 pre-operatively and were 0.28 $\pm$ 0.21 and 0.09 $\pm$ 0.12 post-operative first and sixth week respectively. Similarly, in group B the mean preoperative BCVA was 1.1 $\pm$ 0.39 and post-operative were 0.27 $\pm$ 0.19 and 0.11 $\pm$ 0.12 at first and sixth week. BCVA was better in group A in compare to group B at sixth week post-operative but no statistical significance difference was found between two groups post-operative first and sixth week ($p = 0.83$, $p = 0.50$). When intragroup pre and post BCVA were compared, both groups showed statistically significant improvement in visual acuity ($t = 9.7$, $p = <0.001$ and $t = 14.11$, $p = <0.001$) post-operative first week and ($t = 5.6$, $p = <0.001$ and $t = 5.6$, $p = <0.001$) post-operative sixth week (Table 7).

Table 5: Distribution of keratometric corneal astigmatism according to type between groups.

		With the rule (N %)	Against the rule (N %)	No astigmatism (N %)	Total number	p-value
Preoperative	Group A	15 (48.4)	14 (45.2)	2 (6.5)	31	0.88
	Group B	10 (29.4)	19 (55.9)	5 (14.7)	34	
Post-operative first week	Group A	17 (54.8)	10 (32.3)	4 (12.9)	31	0.07
	Group B	9 (26.5)	21 (61.8)	4 (11.8)	34	
Post-operative sixth week	Group A	12 (38.7)	13 (41.9)	6 (19.4)	31	0.18
	Group B	10 (29.4)	20 (58.8)	4 (11.8)	34	

Table 6: Conversion of type of surgically induced astigmatism by vector analysis between two groups.

Conversion	Group A	Group B	p-value
ATR - WTR	8 (25.8)	13 (38.2)	0.58
WTR - ATR	1 (3.2)	2 (5.9)	
WTR - Nil	5 (16.1)	3 (8.8)	
ATR - Nil	3 (9.7)	1 (2.9)	
Nil - ATR	1 (3.2)	3 (8.8)	
Nil - WTR	1 (3.2)	1 (2.9)	
WTR - WTR	9 (29)	5 (14.7)	
ATR - ATR	3 (9.7)	5 (14.7)	
Nil - Nil	0	1 (2.9)	
Total	31	34	

Table 7: Comparison of mean BCVA Log MAR preoperative and post-operative between two groups.

BCVA		LogMAR mean ± SD Group A	LogMAR mean ± SD Group B	p-value
Preoperative		1.1 ± 0.41	1.1 ± 0.39	0.54
Postperative	First week	0.28 ± 0.21	0.27 ± 0.19	0.83
	Sixth week	0.09 ± 0.12	0.11 ± 0.12	0.50

DISCUSSION

Clear corneal incisions have revolutionised cataract surgery by reducing the surgical time and leading to faster post-operative recovery as compared to the scleral tunnel approach but SIA remains one of the common complications. Several studies have been conducted to compare the astigmatism with different types of corneal incisions in different locations like superior, superonasal, superotemporal, and temporal. In the present study, the SIA in clear corneal phacoemulsification by ST approach for right eye and SN approach for left eye were determined and compared. The advantage of oblique incisions is that they avoid injury to the superior conjunctiva in eyes which may later need glaucoma surgery.

In the current study, the mean SIA calculated by vector analysis method was lower in Group A (0.36 ± 0.32 D) at first week which reduced to (0.31 ± 0.29 D) at sixth week than those in Group B (0.37 ± 0.22 D) at first week and reduced to (0.35 ± 0.25 D) at sixth week post-operatively. The SIA of both groups decreased post-operatively at sixth week. However, no significant difference was found in mean SIA at both first and sixth post-operative week between two groups (p = 0.83, p = 0.55) which was similar to studies done by (Ermis et al., 2004; Susic et al., 2007; Paskvalin et al., 2007; Yoon et al, 2014; Garg et al 2015 and Solu et al., 2017) where SIA did not differ significantly between the ST and SN incision groups after surgery for a surgeon who sits at the 12 o'clock.

In contrast to this study, (Pakravan et al., 2009) found SIA of 0.26 D and 0.92 D six months after surgery for ST and SN incisions respectively. In study by (Kohnen et al., 2002), the mean SIA in the ST incision was 0.62 ±0.48 D at two week post-operatively and 0.47 ± 0.32 D at six months and in the SN incision, 1.55 ± 0.84 D and 1.05 ± 0.57 D, respectively. A study by (Yoon et al., 2014) found that the mean SIA in the ST group after one month was 0.81±0.64 D, whereas in the SN group it was 0.92±0.53 D. The mean SIA was calculated to be superior = 0.82D, superior-nasal = 0.50 D, superior-temporal = 0.63 D, temporal = 0.45 D, and nasal = 0.55 D. Superior incision induced the greatest SIA and temporal incision induced the smallest SIA in study done by (Park et al., 2011).

Significantly less SIA with the ST incision compared to the SN approach was reported (Pakravan et al., 2009; Ozkurt et al., 2008; Yaycioglu et al., 2007; Barequet et al., 2004; Kohnen et al., 2002) whose results differs from the present study.

In the current study, the mean preoperative keratometric astigmatism was (0.62 ± 0.44 D) in group A which was slightly higher than in group B (0.57 ± 0.47D) but was not statistically significant (p = 0.66). In group A, the mean post-operative keratometric astigmatism at one and sixth week (0.45 ± 0.33 D and 0.41 ± 0.32 D) which were lower in compared to group B (0.48 ± 0.40 D and 0.44 ± 0.34 D) respectively. However, there was no significant difference in mean post-operative keratometric astigmatism between two groups at first week and sixth week (p = 0.75 and p = 0.76). Similarly, in other studies also the mean preoperative astigmatism was slightly higher in ST (0.74 ± 0.45 D and 0.63±0.48 D) incision than in SN (0.69 ± 0.39 D and 0.38±0.39 D) incision (Ozkurt et al., 2008; Pakravan et al., 2009) respectively. In Pakravan et al., 2009 the mean keratometric astigmatism one week, four week, and six months post-operatively was 0.86 ± 0.47 D versus 1.95 ± 0.45 D ($p < 0.001$), 0.73 ± 0.46 D versus 1.79 ± 0.55 D ($p < 0.001$), and 0.63 ± 0.30 D versus 1.05 ± 0.56 D ($p = 0.053$) in the temporal versus nasal groups respectively. However, in those studies, the mean total astigmatism was lower in ST group at all post-operative examinations which was different from the result of this study.

In the present study, the type of astigmatism also did not differ between two groups significantly preoperatively and post-operatively. At the first week post-operative, group A had more WTR astigmatism and group B had more ATR astigmatism ($p = 0.07$). At the sixth post-operative week, both groups had more ATR astigmatism, group B had slightly more ATR than group A, however not statistically significant ($p = 0.18$). A study by (Yaycioglu et al., 2007) also found ATR was significantly larger in the SN group. At sixth week, 46% of eyes had ATR astigmatism and 35% had WTR astigmatism in (Ozkurt et al., 2008). Barequet et al., (2004) found shift towards WTR astigmatism six week and 12 months post-operatively. Similarly**,** Pakravan et al., (2009) found 75% of eyes had WTR astigmatism by sixth week. In group A, eight (25.8%) converted ATR to WTR, one (3.2%) WTR to ATR and 12 (38.7%) had no conversion. Likewise, in group B, 13 (38.2%) had conversion ATR to WTR, two (5.9%) had WTR to ATR and 11 (32.3%) had no conversion. There was no statistically significance difference in conversion between two groups ($p = 0.58$).

The limitations of the study could be its non-randomised design, small sample size, short follow-up period, and lack of corneal topography.

CONCLUSION

No significant difference in mean SIA and keratometric corneal astigmatism was found between two types of incision. Further randomised clinical studies with larger number of eyes and longer follow-up periods is recommended to determine and compare between ST and SN incisions.

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