Original Article

Surgically induced astigmatism and refractive outcomes following phacotrabeculectomy

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Purpose: To objectively evaluate surgically induced astigmatism (SIA) after phacotrabeculectomy using keratometry and topography and to compare the magnitude of SIA and the refractive outcomes of single-site and twin-site phacotrabeculectomies. **Methods:** Forty prospective subjects were enrolled in the study and were randomized into single-site and twin-site cohorts. SIA was objectively assessed using keratometry and Orbscan before and at three months after surgery. For both cohorts, the changes in SIA were assessed using power vector analysis compared at the third month after surgery. **Results:** Each cohort consisted of 20 eyes. The preoperative parameters and postoperative IOP were comparable and similar, respectively, in both the cohorts ($P = 0.1$). Majority of the patients in both the cohorts had preoperative against-the-rule (ATR) astigmatism. The median change in SIA at the three-month postoperative visit was similar in both the cohorts, with a small increase in ATR astigmatism. Although the SIA change measured by keratometry in the J0 component was similar in both the groups ($P = 0.54$), that of J45 was significantly different ($P = 0.01$). However, the median change in SIA was similar in both the groups for both the J0 ($P = 0.52$) and J45 components ($P = 0.94$) when measured by Orbscan. The SIA in both the groups measured with keratometry ($P = 0.62$) and topography ($P = 0.52$) were clinically and statistically similar. In both the groups, the refraction was similar at 1 month and 3 months. **Conclusion:** The SIA as measured with keratometry and topography was similar in the single-site and twin-site phacotrabeculectomy cohorts at the end of 3-months. The postoperative refraction was stabilized in 1-month in both the groups.

Key words: Combined surgery, phacotrabeculectomy, surgically induced astigmatism, single-site, twin-site

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Phacotrabeculectomy is the preferred technique in which combined cataract and glaucoma surgery are[1-3] performed either with single-site incision for both the procedures or separate incisions for each procedure.[4] Most studies have shown no difference in the intraocular pressure (IOP) control and the need for antiglaucoma medications with both the techniques.[1,5] Astigmatism induced after surgery [referred here as surgically induced astigmatism (SIA)] is an important factor because it influences the quality of vision and visual rehabilitation after surgery.[4] Trabeculectomy causes a steepening in the curvature of corneal radius along the vertical meridian, thus either inducing with-the-rule astigmatism or reducing any preoperative against-the-rule astigmatism.[6,7] Although similar SIA is expected with combined phacotrabeculectomy also, the available literature is limited,[6,8-10] with even fewer studies providing objective comparison of refractive outcomes with single-site and twin-site phacotrabeculectomies.[6] Astigmatism induced by single-site and twin-site procedures is likely to be different as the incision site for cataract removal can alter the corneal curvature,[11,12] independent of the incision for trabeculotomy. Earlier studies have shown lesser SIA and better IOP control in case of twin-site surgery.[6,10] Although Rosetti *et al.* recommended separate incisions for cataract and glaucoma surgery to decrease SIA,[6] these studies involved multiple surgeons and lacked the objective method of estimating astigmatism. The current study aims to objectively estimate SIA following combined phacotrabeculectomy and also to evaluate the impact of single versus twin incision on the SIA three months after surgery in the management of coexisting glaucoma and cataract.

Methods

SIA and the refractive outcomes of single-site and twin-site phacotrabeculectomies were compared in a randomized clinical trial, from June 2012 to March 2015. A single surgeon performed all the surgeries. The study was approved by the Institutional review board and was conducted in accordance with the Declaration of Helsinki. Written, informed consent was obtained from all the participants before enrollment.

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Patient enrollment and treatment assignment

To detect a 0.5-diopter (D) difference of SIA, with a power of 80% and a type-I error of 0.5, the required sample size was 20 eyes in each cohort. Forty adult subjects with either primary open-angle glaucoma (POAG) or primary angle-closure glaucoma (PACG) and requiring surgery for visually significant cataract were enrolled in the study. Exclusion criteria include previous incisional surgery in the same eye; preoperative astigmatism >3 D; indication of adjunctive antimetabolites (Mitomycin C) usage; and implantation of a nonfoldable intraocular lens. Patients with all types of secondary glaucomas were also excluded.

Enrolled patients were randomly assigned to two groups of 20 each and underwent either single-site (Group 1) or twin-site (Group 2) phacotrabeculectomy. Simple randomization with allocation concealment was used. Patients were free to withdraw from the study any time without affecting their clinical management. The postoperative outcome data of 3 months was analyzed.

Surgical technique

Trabeculectomy was performed under peribulbar anesthesia with a superior fornix-based conjunctival flap. A 4 × 3 mm triangular scleral flap was made for all surgeries. In single-site surgery, phacoemulsification was performed by anterior chamber (AC) entry with a 2.8-mm keratome under the triangular scleral flap. In the twin-site procedure, phacoemulsification and intraocular lens (IOL) implantation were completed through a temporal 2.8-mm clear corneal incision and closed with a single 10-0 nylon suture. All eyes received a foldable in-the-bag IOL. A 2 × 2 mm deep block was excised and peripheral iridectomy was performed. The viscoelastic was thoroughly washed and the scleral flap was closed with one or two10’0 nylon sutures. The conjunctiva were closed with 8-0 polyglactin suture using a round-bodied needle with wing sutures.

Postoperative regime was topical antibiotic for 1-week, topical cycloplegic for 2–3 weeks, and topical prednisolone acetate 1% tapered over 6–8 weeks. All patients underwent 1-day, 1-week, 1-month, 3- month, and additional evaluations as needed.

Data collection

Preoperative data included demographics and clinical details of glaucoma. Comprehensive ocular examination was conducted preoperatively and at each postoperative visit. Data collection included subjective refraction, best-corrected Log MAR visual acuity (BCVA), manual keratometry (Bausch and Lomb manual keratometer), corneal topography (Bausch and Lomb OrbscanIIz), and IOP (Goldmann applanation tonometer). Use of antiglaucoma medications and complications if any were recorded. Two optometrists obtained keratometry and topography measurements preoperatively and after 1-and 3-months postoperatively.

Analysis of surgically induced astigmatism

Astigmatic refractive error is a vector with a magnitude and axis, and these may change independent of each other within and across groups.[13-16] Therefore, comparison of the magnitude of astigmatism pre- and postsurgery can be performed only after it is transformed to a common set of axes. The Power Vector analysis proposed by Thibos *et al.*[14] allows this to be done for two cross-cylinder axes, one oriented at 180 degrees (J0) and the other oriented at 45 degrees (J45). The third term, M, represents the spherical equivalent of refraction. Once transformed, astigmatism can be compared for absolute magnitude, with a larger number indicating greater magnitude. With-the-rule astigmatism (WTR) represents increased corneal curvature in the vertical meridian (positive value of J0) and against-the-rule astigmatism (ATR) represents decreased corneal curvature (negative value of J0). Similarly, a nonzero value of J45 indicates the presence of an oblique astigmatism, with a positive J45 value indicating that its axis is closer to 45° and a negative J45 value indicating that the axis is closer to 135°.[14,15] The corneas in the eyes of an individual display mirror symmetry; thus, an axis of 45° in the right eye has the same anatomic orientation with respect to the eyelids and other facial structures as an orientation of 135° in the left eye. Therefore, oblique astigmatism, J_x, was defined as $J_x = J_{45}$ in right eye and $J_x = -J_{45}$ in left eye. In our study, the cylindrical values of the refractive errors obtained after standard subjective refraction technique, using Keratometer and Orbscan, were converted into power vectors using published equation.[13,14] Since the aim was to compare the astigmatism outcomes in the two cohorts, the results were focused on the data of J0 and J45 power vector terms obtained in the study. The M-component of the Power vectors are not presented.

Outcome measures

The primary outcome of the study is the difference in SIA between the two groups at 3-months and the secondary outcome is the variation in postoperative refraction at 1-month and 3-months of both the single-site and twin-site groups.

Statistical analysis

The datasets were nonparametric and, hence, the results are presented as median and interquartile range (IQR). Categorical values between groups were compared with Chi-squared test. Data was analyzed with Mann Whitney ‘U’ test to determine the statistically significant difference between the groups in the induction of astigmatism at each time point. Differences between the two groups were compared using Student *t*-test and a *P* value <0.05 was considered as a statistically significant difference. All the calculations and charts were made using Microsoft Excel 2016. Statistical analysis was done using R Core Team (R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.2017).

Results

The preoperative characteristics of the single-site and the twin-site groups were similar. There were 20 eyes in each group. The median (interquartile range) preoperative IOP was similar in the two groups (single-site: 20.5 (18, 24) mm Hg; twin-site: 18 (15.5, 23) mm Hg, *P* = 0.29). The median number of preoperative antiglaucoma medications were similar in the two groups (single-site: 2 (1,3), twin-site: 2 (1.5, 2), *P* = 0.35). There were 8 eyes with POAG and 12 eyes with PACG in the single-site group and 11 eyes with POAG and 9 eyes with PACG in the twin-site group, (*P* = 0.34). The median age at surgery was 62 years (59, 68.5) in the single-site group and 66.5 years (60.5, 71) in the twin-site group, *P* = 0.20.

Postoperatively, the median (25th – 75th interquartile ranges) IOP at 3 months was 15 mmHg (12.5–17.5 mmHg) in the single-site and 13.5 mmHg (12–15.5 mmHg) in the twin-site group (P = 0.10). Three months after surgery, the number of glaucoma medications was similar for both groups (P = 0.52) with three eyes in single-site and two eyes in twin-site group needing one medication each.

The median (25th – 75th interquartile ranges) power vector values of the spherocylindrical refractive errors before (preoperative) and after surgery (3-months postoperative) in the two groups with Keratometer and Orbscan are in Table 1 and Fig. 1a, b. The data indicates changes in the power vector components before and after combined phacotrabeculotomy in both groups and the change was partly dependent on the technique used to measure astigmatism (i.e., Keratometer Vs. Orbscan). Astigmatism remained largely unchanged before and 3-months after surgery in the single-site group when measured using both Keratometry (P = 0.76) and Orbscan P = (P = 0.52) [Table 1]. However, astigmatism increased post surgery, relative to the preoperative values in the twin-site group measured using both techniques (P = 0.75 [Keratometry] and P = 0.32 [Orbscan]) [Table 1]. The J0 term remained stable before and after surgery in both the groups when measured using Keratometry; however, it increased post surgery when measured using Orbscan (Single-site P = 0.49 [Keratometry] and P = 0.40 [Orbscan]; Twin-site P = 0.59 [Keratometry] and P = 0.19 [Orbscan]) [Fig. 1a, b and Table 1]. The J45 terms were very close to 0D in both the groups before and after surgery, thus indicating minimal oblique astigmatism in this cohort (Single-site P = 0.01 [Keratometry] and P = 0.98 [Orbscan]; Twin-site P = 0.23 [Keratometry] and P = 0.70 [Orbscan]) [Fig. 1a, b and Table 1].

Table 2 and Fig. 1c, d show the change in J0 and J45 terms between preoperative and 3-months postoperative visits measured using Keratometer and Orbscan for both the groups. For keratometry, the data for single-site group showed minimal change in the J0 and J45 terms, [Fig. 1d]; while the twin-site data showed a small decrease in the J45 terms (~0.1D) three-months postsurgery, the J0 term did not show any significant change following surgery [Fig. 1d]. For Orbscan, the single-site cohort showed a small increase in the J0 term (~0.1D) 3-months postsurgery, while the J45 terms showed <0.1D change in the data pre- and postsurgery [Fig. 1c]. Postoperative Orbscan data of the twin-site cohort showed minimal change in both the J0 and J45 terms [Fig. 1d]. The 3-months postoperative change in astigmatism induced by both single-site and twin-site incisions were lesser than 0.5D when compared to preoperative values.

The results of J0 and J45 terms shown in Fig. 1 were small in both the groups, with relatively large intersubject variability in the data [Fig. 1]. This possibly reflects the preoperative variability in astigmatism of the enrolled subjects or the differential effect of the surgical procedure on postoperative astigmatism or an interaction between the two. To determine this, the correlation coefficients were calculated between the magnitude of preoperative astigmatism and the change in three-months postoperative astigmatism . For Orbscan, the correlation analysis was done for both J0 and J45 terms; but for the Keratometer, the correlation analysis was done only for J0 term [Table 3]. All correlation coefficients were positive, indicating greater reduction in the magnitude of postoperative astigmatism for those with larger magnitude of preoperative astigmatism. The values of the correlation coefficient were larger in the twin-site cohort compared to the single-site cohort suggesting that the twin-site surgery produced relatively greater reduction in preoperative astigmatism, given the similar magnitude of preoperative astigmatism [Table 1].

We also evaluated subjective refraction in both groups at 1- and 3- months postoperatively [Table 4]. There was no significant change in refraction in both the groups. The median change in J0 and J45 values were 0.00D in both single and twin-site groups.

Discussion

This prospective study objectively compared surgically induced astigmatism following single-site and twin-site phacotrabeculectomy at three months after surgery. We used vector analysis and compared both the magnitude and direction of astigmatism before and after surgery within and across the groups. Postoperative astigmatism in both single-site and twin-site cohorts were similar and quite small (~0.5D), showing

Table 1: The preoperative and postoperative magnitude of astigmatism in the single-site and twin-site phacotrabeculectomy groups estimated by Keratometry and Orbscan

Parameter	Cohorts	Investigation	Preoperative astigmatism	3-months postoperative astigmatism	*P*
Astigmatism (D)	Single-site	Keratometry	-0.96 [-1.12, -0.52]	-0.88 [-1.06, -0.50]	0.76
		Orbscan	-0.95 [-1.55, -0.60]	-1.20 [-1.70, -0.90]	0.52
	Twin-site	Keratometry	-1.02 [-1.29, -0.58]	-0.88 [-1.56, -0.60]	0.75
		Orbscan	-0.75 [-1.20, -0.57]	-0.80 [-1.33, -0.50]	0.32
J0 (D)	Single-site	Keratometry	-0.30 [-0.55, -0.05]	-0.28 [-0.50, 0.06]	0.49
		Orbscan	-0.26 [-0.60, 0.11]	-0.40 [-0.61, -0.06]	0.40
	Twin-site	Keratometry	-0.22 [-0.53, 0.02]	-0.19 [-0.66, 0.14]	0.59
		Orbscan	-0.13 [-0.35, 0.09]	-0.22 [-0.56, 0.03]	0.19
J45(D)	Single-site	Keratometry	0.01 [0.00, 0.27]	0.00 [0.00, 0.00]	0.01
		Orbscan	0.17 [-0.03, 0.25]	0.12 [-0.05, 0.25]	0.98
	Twin-site	Keratometry	-0.09 [-0.20, 0.00]	0.00 [-0.00, 0.00]	0.23
		Orbscan	-0.07 [-0.27, 0.04]	-0.10 [-0.22, 0.06]	0.70

D=Diopetrs

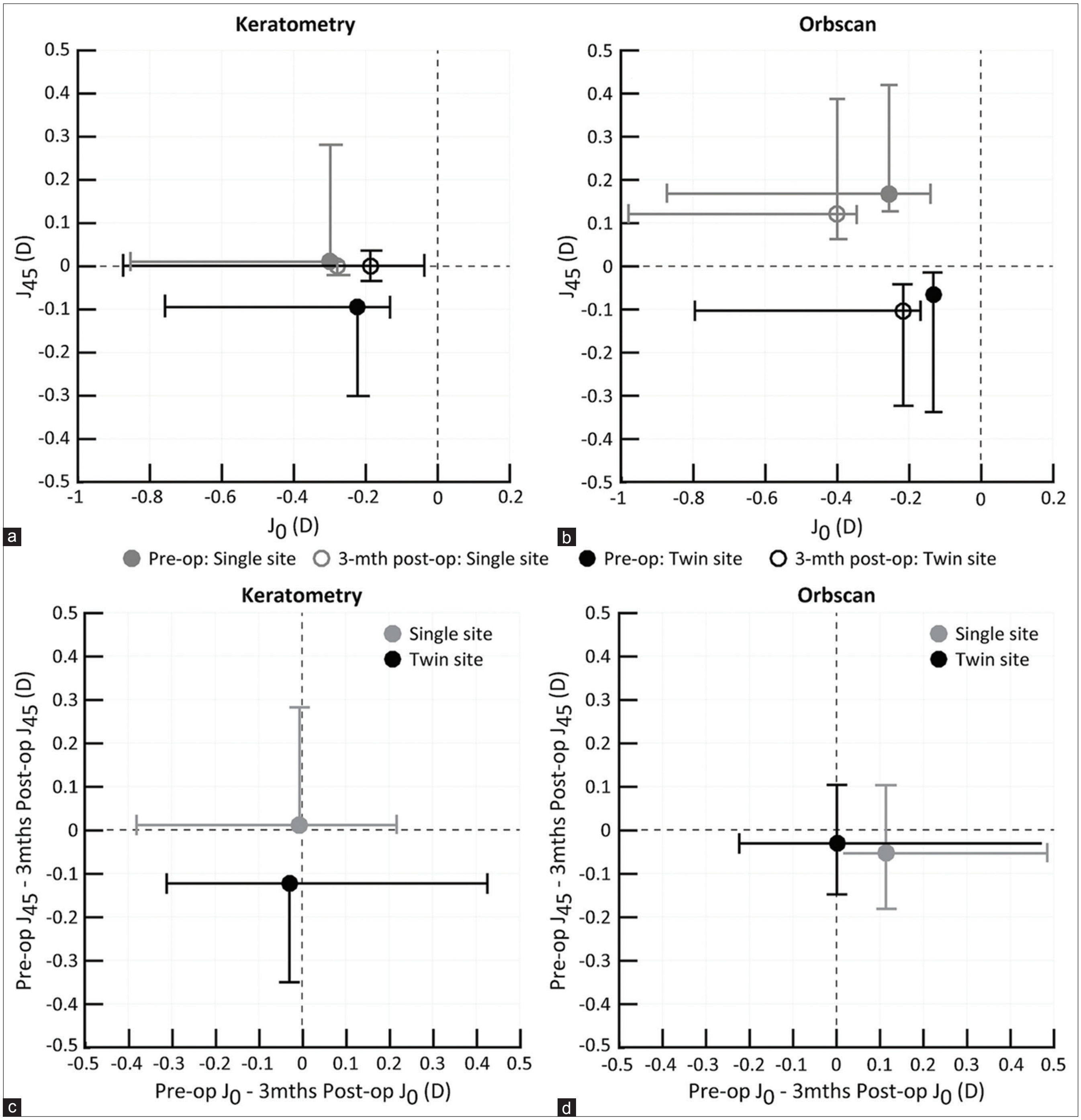

Figure 1: (a and b) Figure shows comparison of J0 and J45 components from preoperative to 3-months postoperative period in single-site and twin-site groups measured by Keratometry and Orbscan. (c and d) Figure shows postoperative change in SIA vectors by keratometry and Orbscan in single-site and twin-site groups

that both the surgical techniques are equally good in terms of surgically induced astigmatism.

We also noted that, in the presence of greater preoperative ATR astigmatism, astigmatic correction of preexisting cylinder was better in the twin-site cohort. SIA in trabeculectomy/combined surgery can be influenced by multiple preoperative, intraoperative, and postoperative factors. One important factor is the preexisting cylinder that was assessed and compared in this study. Greater the preoperative astigmatism, greater is its reduction after surgery. In this context, preoperative astigmatism was nearly the same in both the single-site and twin-site cohorts, but the correlations were stronger for the latter. Most of the preoperative astigmatism was ATR. In both single-site and twin-site cohorts, superior trabeculectomy induced WTR, thereby reducing the preexisting ATR. In addition, in the twin-site cohort, temporal corneal incision also helped to decrease ATR, possibly resulting in greater decrease in preoperative astigmatism.

Table 2: Postoperative median (Inter quartile range) change in SIA vectors by keratometry and Orbscan

	Single-site group	Twin-site group	P
Change in Keratometry J0 (D)	-0.01(-0.37,0.19)	-0.03 (-0.24, 0.41)	0.54
Change in Keratometry J45 (D)	0.01 (0,0.27)	-0.12 (-0.22, 0.00)	0.01
Change in Orbscan J0 (D)	0.11 (-0.09, 0.36)	0.00(-0.20, 0.37)	0.52
Change in Orbscan J45 (D)	-0.05 (-0.13, 0.14)	0.03 (-0.11, 0.13)	0.94

D=Diopters

Table 3: Correlation coefficients between the pre-operative and difference in the astigmatism at 3-months post-operative values of J0 and J45 components of astigmatism obtained using the Keratometer and Orbscan for the single-site and twin-site incision cohorts in this study

	Single-site group	P	Twin-site group	P
Keratometry				
J0	0.25	0.30	0.41	0.07
J45	N/A	-	N/A	-
Orbscan				
J0	0.43	0.06	0.65	0.002
J45	0.16	0.50	0.43	0.07

N/A=Not applicable

Table 4: Median (IQR) refraction in terms of spherical equivalent, J0 and J45components obtained at 1-month and 3-month postoperative period in the single-site and twin-site phacotrabeculectomy groups

	Single-site	Twin-site	P
1-month post-op			
SE (D)	-0.63 (-0.91-0.22)	-0.75 (-1.38-0.00)	0.56
J0 (D)	-0.50 (-0.66-0.09)	-0.36 (-0.50-0.08)	0.48
J45 (D)	0.00 (0.00-0.00)	0.00 (0.00-0.00)	0.45
3-month post-op			
SE (D)	-0.31 (-0.81-0.00)	-1.00 (-1.31-0.25)	0.14
J0 (D)	-0.44 (-0.62-0.00)	-0.37 (-0.75-0.06)	0.73
J45 (D)	0.00 (0.00-0.00)	0.00 (0.00-0.00)	0.85
Change in refraction			
SE (D)	0.00 (-0.09,0.13)	0.00 (-0.25,0.72)	0.58
J0 (D)	0.00 (-0.15,0.01)	0.00 (-0.12,0.25)	0.67
J45 (D)	0.00 (0.00-0.00)	0.00 (0.00-0.00)	0.85

SE=Spherical equivalent

Apart from the preexisting cylinder, several intraoperative factors including surgical techniques influence SIA magnitude.[8,17-19] In our series, using a single surgeon and the same technique could have contributed to similar results in the two groups. Although there was better correction of preoperative astigmatism in the twin-site group, SIA of both the groups were similar. The magnitude of astigmatism induced by combined cataract and glaucoma surgery in this study is not significantly different from those reported previously.[2,6,9,20,21] The magnitude of SIA was greater in a study by Hong *et al.*; however, extracapsular cataract extraction with trabeculectomy and MMC use could have contributed to this.[22] A retrospective study comparing single- and twin-site phacotrabeculectomies (without MMC) in nanophthalmic eyes, reported a higher postoperative refractive error and astigmatism in the twin-site cohort, 0.75D vs 1.75D. However, the article does not clearly state whether the difference noted was with spherical equivalent or SIA. In their study, the temporal clear corneal incision for phacoemulsification was left unsutured except in 3/14 eyes that had wound leak. This could have contributed to the higher refractive error in their twin-site cohort.

MMC, an antimetabolite, which decreases scarring by modulating wound healing, was not used in our study as it delays wound healing and takes longer time for refraction stabilization. It is known to induce less with-the-rule astigmatism and continues to increase against-the-rule astigmatism to a variable degree and takes longer stabilization time.[8,17,23] We included eyes with no MMC to understand the role of the technique and to overcome the influence of antimetabolite on SIA. This could be a limitation as most combined surgeries use MMC and the data cannot be extrapolated directly to eyes with MMC phacotrabeculectomy. However, the component contributed by MMC is likely to be the same in both the techniques and our results could then be generalized.

The absolute magnitude of astigmatism and its change with surgery depends to some extent on the technique used to measure the astigmatism—keratometry vs. Orbscan in this case. This was expected given the differences in the methods and techniques used, and their relative sensitivity to measure small changes in astigmatism. Thus, any analysis of postoperative astigmatism should note the technique used to measure the astigmatism. A review article on ocular biometry changes after trabeculectomy,[24] reported variable magnitude of astigmatism ranging from 0.38-1.4 D WTR, using either objective or subjective methods of estimation. Some made an objective estimation with keratometry;[8] however, there was no uniformity in the surgical technique employed. Some have included trabeculectomy and have combined cataract and glaucoma surgeries with or without antimetabolite use. None used topography to estimate the postoperative changes in astigmatism with combined surgery.

Stabilization of refraction after trabeculectomy occurs as early as 1 month and as late as 1 year.[24] Studies have shown minimal change in refraction after 1 month,[25,26] and this was evident in the current study also with topography and keratometry. The change in induced astigmatism was minimal after 1 month, and was not significantly different three months after surgery. Hence, the prescription for refractive correction is recommended after one month.

Both the techniques appear equal in terms of the IOP control. While it can be argued that minimal conjunctival tissue is handled in twin-site surgery and better long-term results are possible by separating the cataract and trabeculectomy wound, no such difference was found in the present study. Our data was comparable with the results of previous studies comparing single-site and twin-site phacotrabeculectomies.[2,3,21,27,28]

Conclusion

In conclusion, both the two commonly used techniques of combined cataract and glaucoma surgery proved to be efficacious without any difference in the refractive outcomes. Final refractive correction can be done at the one month postoperative visit. There was no difference in IOP reduction between one-site and two-site techniques. No added advantage is gained by separating the two incision sites and the surgeon can choose either technique according to one's "skill and comfort" level.

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Conflicts of interest

There are no conflicts of interest.

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