ORIGINAL ARTICLE

The effect of incision sequence on surgically induced astigmatism in cataract surgery

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ABSTRACT

Purpose: To evaluate via Scheimpflug tomography the effect of incision sequence on surgically induced astigmatism (SIA) in 2.8 mm single step superior clear corneal incision cataract surgery.

Materials and Methods: We evaluated 86 patients who had undergone cataract surgery. All eyes were measured for both anterior and posterior corneal surfaces with the Scheimpflug tomography system preoperatively and one month after surgery. In Group 1, the surgery began with a side incision while in Group 2 the main incision was done first. Comparisons between groups were analyzed via student's t-test and Mann-Whitney U-test. Pearson's correlation was performed to analyze the relationship between preoperative astigmatism and SIA. P-values< 0.05 were considered statistically significant.

Results: Surgically induced anterior astigmatism (SIA-A) in Group 1 and Group 2 was 0.76 ± 0.43 D and 0.67 ± 0.38 D (p=0.274), surgically induced posterior astigmatism (SIA-P) was 0.27 ± 0.19 D and 0.22 ± 0.15 D (p=0.168), respectively. SIA-A of 1.0 D or greater was found in 24.4% of eyes in Group 1 and 15.6% of eyes in Group 2. SIA-P of 0.5 D or greater was found in 14.6% of eyes in Group 1 and 12.2% of eyes in Group 2. There was a statistically significant increase in anterior astigmatism (p=0.002 in Group 1, p=0.005 in Group 2) but not in posterior astigmatism (p=0.536 in Group 1, p= 0.219 in Group 2).

Conclusion: Making the main incision first caused less SIA on both anterior and posterior surfaces; however, the difference was not significant.

Keywords: Cataract surgery, Incision sequence, Surgery induced astigmatism, Corneal tomography.

INTRODUCTION

Cataract is the most common preventable cause of blindness and phacoemulsification is considered the gold-standard procedure for cataract treatment.[1,2] Clear corneal incision without suture is a standard cataract procedure; however, surgically induced astigmatism (SIA) and postoperative astigmatism are still a problem. In modern cataract surgery, reducing SIA is one of the main aims in order to improve patient satisfaction and increase uncorrected visual acuity. There are some potent procedures for reducing corneal astigmatism such as selecting the proper size and location of the incision, using limbal relaxing incision and employing toric intraocular lens implantation.[3-5]

The main incision is primarily responsible for SIA. Most surgeons prefer to start the surgery with a side incision, then fill the anterior chamber with an ophthalmic visco-surgical device (OVD) and make a main incision because this approach is more likely to avoid anterior capsule damage. The degree to which the anterior chamber is filled with an OVD can be affected by the normal anterior chamber depth, chamber volume, corneal shape and wound architecture. Under-filling or over-filling the anterior chamber may cause an upward or downward shift of the inner edge of the incision when the cornea returns to its normal architecture. This shift in the wound architecture may cause deviations from the linear structure of the incision, possibly causing SIA and postoperative astigmatism.

The aim of this study is to evaluate the effect of the incision sequence on anterior and posterior astigmatism

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and SIA in cataract surgery using Scheimpflug tomography measurements.

MATERIALS AND METHODS

This retrospective study included 86 eyes that underwent phacoemulsification. The procedure was performed by the same surgeon from October 2018 to March 2019. The study protocol was approved by the Institutional Review Board/Ethics Committee (Aksaray University, Human Research Ethics Committee, number 2020-08-33). The study adhered to the tenets of the Declaration of Helsinki.

All patients underwent a routine ophthalmic examination prior to operation. Fundoscopy was performed to evaluate retinal disease under a dilated pupil. The anterior corneal surface, steep meridian and posterior corneal surface were measured using the Scheimpflug analysis system (Pentacam HR, Oculus Optikgeräte GmbH, Wetzlar, Germany) before surgery and one month after surgery. Measurements were obtained by the Scheimpflug analysis system, which included the flat and steep central radii in the 3 mm zone on the anterior and posterior corneal surfaces and excluded all poor-quality Scheimpflug analysis scans. Astigmatism change (AC) was defined as the difference between preoperative and postoperative astigmatism measured by corneal tomography.

Patients who had cataracts with regular astigmatism less than 2.5 D and whose visual acuity was 3/10 or less on the Snellen chart were included in this study. Cataracts which is too dense to perform retinal examination were identified mature cataracts and weren't included the study. Patients with a history of intraocular surgery, refractive or pterygium surgery were excluded. Patients with severe dry eye (causing staining with fluoresceine on the corneal surface), any type of corneal ectasia or dystrophies, corneal opacity , corneal degeneration (except arcus senilis), and contact lens wear were excluded. Diabetes mellitus causing damage to the corneal surface and who has proliferative diabetic retinopathy were also excluded.

Astigmatism was classified according to the steepest meridian, categorized as either horizontal (steepest meridian 0 to 29.9° or 150 to 180°), vertical (steepest meridian 60 to 119.9°) or oblique (steepest meridian 30 to 59° or 120 to 149.9°). We did not use the traditional terms of with-the-rule or against-the-rule astigmatism because the negative dioptric power of the posterior cornea may cause confusion in nomenclature.

Surgical Technique

All procedures were performed same surgeon under topical anesthesia with proparacaine HCl 0.5% (Alcaine, Alcon Laboratories, Inc.). In group 1, a side incision was performed with a 20 gauge MVR blade(Alcon Laboratories, Inc.) on 150 degree and then the anterior chamber was filled with an OVD (Protectalon 2,0, VSY, Inc.). A second side incision (on 60 degree) and a 2.8 mm single-step clear corneal incision (on 90 degree) were performed on the cornea with a double bevel up blade (Alcon Laboratories, Inc.). In group 2, by contrast, a 2.8 mm single-step clear corneal incision was performed first, after that the anterior chamber was filled with the OVD. Side incisions were made with a 20 gauge MVR blade. All incisions were carried out on the same location (but in a different sequence) on the cornea in both groups. After standard cataract surgery by phacoemulsification, bimanual cortex aspiration was performed and acrylic single pieces of non-toric hydrophobic IOL (Acrysof SA60AT, Alcon Laboratories, Inc) were inserted in the capsular bag. The corneal incisions were left without suture. To standardize the study, only uneventful cataract surgeries with the main corneal incision made at 90 degrees were analyzed. After the operation, patients were treated with a combination of moxifloxacine and dexamethasone (Moxidexa, Abdi Ibrahim, Inc.) 8 times per day for the first week, then with 1 mg/mL dexamethasone (Maxidex, Alcon Laboratories, Inc.) eye drops 4 times per day for 3 weeks.

SIA Calculation

We used vector analysis software based on Alpin's method to calculate SIA.[6,7] The software was developed to calculate the dioptric power, axis, arithmetic mean and scalar mean of SIA. A graphical module was developed to present these specific results.

Statistical Analysis

Statistical Package for Social Sciences (SPSS) program (Worldwide Headquarters SPSS, Inc. 21.0 Windows package program) was used for the statistical analysis. Descriptive findings are displayed as mean ± standard deviation. Normal distribution of the data in both groups was assessed using the Shapiro- Wilk test. Comparisons between groups were analyzed via student's t-test and Mann-Whitney U-test. Chi-square test was used to compare categorical variables. Comparison of pre- and post-surgical measurements was made with paired t test and Wilcoxon Signed Rank test. Pearson's correlation was performed to analyze the relationship between preoperative astigmatism

and SIA. P-values < 0.05 were considered statistically significant.

Sample Size Calculation

The smallest astigmatic change that could be considered clinically relevant was defined to be 0.25 D and 0.125 D respectively for anterior and posterior corneal surface. Based on pilot data of 20 patients, the standard deviation of SIA was approximately 0.4 D and 0.2 D for anterior and posterior corneal surface, respectively. Setting alfa to 0.05 and power 0.8, the minimum sample size for each group was calculated to be 41 eyes.

RESULTS

86 eyes that underwent phacoemulsification surgery were evaluated in the study (41 eyes in group 1, 45 eyes in group 2) (Table 1). The mean ages of group 1 and group 2 were 67.48 ± 7.81 and 67.86 ± 8.03, respectively. The mean preoperative anterior astigmatism of group 1 and group 2 were 0.60 ± 0.37 D (range 0.1 to 1.4) and 0.67 ± 0.42 D (range 0.0 to 1.9), respectively. The mean preoperative posterior astigmatism of group 1 and group 2 were 0.30 ± 0.16 D (range 0.0 to 0.80) and 0.26 ± 0.15 D (range 0.0 to 0.70), respectively. Posterior corneal astigmatism was 0.30 D or less in 50.0% of measurements in group 1 and 0.25 D or less in 50.0% of measurements in group 2. Anterior corneal astigmatism was 0.50 D or less in 50.0% of measurements in group 1 and 0.60 D or less in 50.0% of measurements in group 2.

In group 1 and group 2 respectively, mean postoperative anterior astigmatism was 0.88 ± 0.51 D (range 0.0 to 2.4) and 0.85 ± 0.48 (range 0.1 to 1.80) (p=0.861), and mean postoperative posterior corneal astigmatism was 0.30 ± 0.17 D (range 0.0 to 0.8) and 0.30 ± 0.18 D (range 0.0 to 0.7) (p= 0.897). In group 1 and group 2 respectively, mean surgically induced anterior astigmatism (SIA-A) was 0.76 ± 0.43 D (range 0.12 to 1.97) and 0.67 ± 0.38 D (range 0.06 to 1.62)(p=0.274), and mean surgically induced posterior astigmatism (SIA-P) was 0.27 ± 0.19 D (range 0.0 to 0.82) and 0.22 ± 0.15 D (range 0.0 to 0.54) (p=0.168). In group 1, centroid SIA-A was 0.41 D at 22° and SIA-P was 0.10 D at 7°. In group 2, centroid SIA-A was 0.45 D at 20° and SIA-P was 0.04 at 21°. Figure 1 shows the double-angle plot of SIA for the anterior and posterior corneal surface.

Table 1: *Patient characteristics at baseline, distribution of astigmatism type and the mean magnitude of preoperative anterior and posterior corneal astigmatism.*

	Group 1 (n=41)	Group 2 (n=45)	*p*
Age	67.48±7.81	67.86±8.03	0.915*
Gender	22 Male, 19 female	23 Male, 23 female	0.725#
Sidedness	27 OD,14 OS	23 OD,22OS	0.117#
Anterior Cornea			*p*
K1	43.30±1.42	43.53±1.45	0.481*
K2	43.88±1.49	44.20±1.45	0.334*
CA	0.60 ±0.37	0.67±42	0.391*
Steep axis	83.80±50.8	84.95±45.31	0.913*
Vertical	17	24	0.542#
Oblique	13	11	
Horizontal	11	10	
Posterior Cornea			*p*
K1	-6.18 ±0.22	-6.24±0.24	0.254*
K2	-6.48±0.29	-6.49±0.24	0.831*
CA	0.30±0.16	0.26 ±0.15	0.254*
Steep axis	95.58±35.62	91.01±36.83	0.501*
Vertical	28	30	0.848#
Oblique	7	7	
Horizontal	6	8	

OD, oculus dexter; OS, oculus sinister; CA, corneal astigmatism.
* student's t-test; # Chi-square

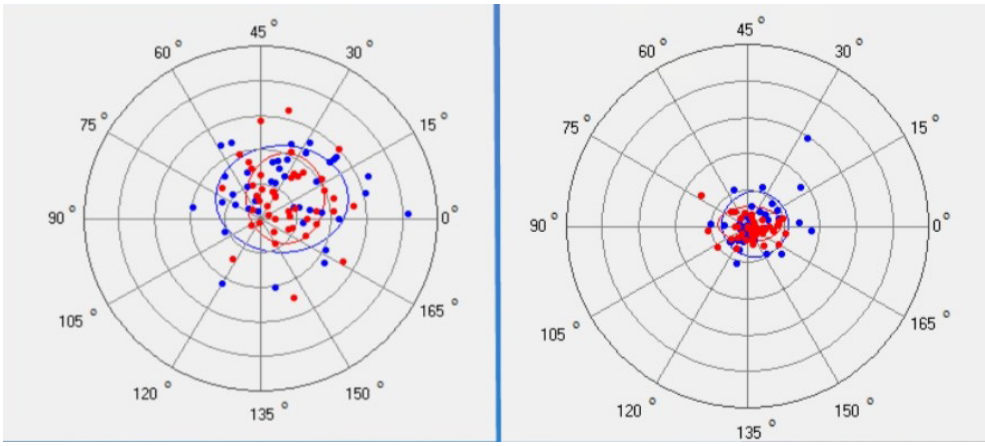

Figure 1: *Demonstrating the SIA distribution of every patient on double-angle plot graphic. Left side shows SIA-A and right side shows SIA-P*

SIA-A, surgically induced astigmatism anterior; SIA-P, surgically induced astigmatism posterior
† Every circle represents 0.5D, ‡ Blue dots demonstrated group 1, red dots demonstrated group 2

For group 1 and 2 respectively, SIA-A of 1 D or greater was found in 24.4% and 15.6% of eyes, and SIA-P of 0.5 D or greater was found in 14.6% and 12.2% of eyes. Table 2 shows information about postoperative data.

As shown in Table 3, there is a significant change in anterior corneal astigmatism values in both groups compared to preoperative values (p=0.002 in group 1, p=0.005 in group 2). Nevertheless, the difference between the magnitudes

Table 2: *Surgically induced astigmatism, postoperative corneal parameters of anterior and posterior cornea at group 1 and 2.*

	Group 1	Group 2	*p*
Anterior Cornea			
K1	43.04±1.45	43.36±1.34	0.293*
K2	43.92±1.47	44.22±1.47	0.352*
SIA	0.76±0.43	0.67±0.38	0.274*
CA	0.88±0.51	0.85±0.48	0.861*
AC	0.27±0,51	0.20±0.44	0.501*
Steep axis	59.86±51.02	71.47±55.07	0.318*
Vertical	9	14	0.406#
Horizontal	18	21	
Oblique	14	10	
Posterior Cornea			
K1	-6.25±0.27	-6.30±0.28	0.451*
K2	-6.55±0.27	-6.59±0.33	0.521*
SIA	0.27±0.19	0.22±0.15	0.168*
CA	0.30±0.17	0.30±0.18	0.897*
AC	-0.01±0,22	0.04±0.18	0.295*
Steep axis	87.61±28.35	85.96±32.16	0.804*
Vertical	33	34	0.848#
Horizontal	4	5	
Oblique	4	6	

CA, corneal astigmatism; AC, astigmatism change; SIA, surgically induced astigmatism.
* student's t-test; # Chi-squar

of the preoperative and postoperative posterior corneal astigmatism was statistically insignificant (p=0.536 in group 1, p=0.219 in group 2). The median posterior astigmatism change was -0.005 D for group 1 and -0.01 D for group 2.

There was not a significant correlation between the magnitude of SIA-A and preoperative anterior corneal astigmatism (r=0.08 and p=0.639 in group 1; r=-0.07 and p=0.963 in group 2) or between SIA-P and posterior corneal astigmatism (r=0.249 and p=0.100 in group 1; r=0.139 and p=0.391 in group 2). In the subgroup analyses of the anterior corneal surface, anterior corneal astigmatism was significantly changed in the horizontal subgroup in group 1(p=0.005). In group 2, corneal astigmatism was significantly changed in the horizontal and oblique subgroups (p=0.017 and 0.015, respectively).

Comparing subgroups between groups, there was no statistically significant difference in SIA-A, SIA-P, AC-anterior and AC-posterior (Table 4). SIA-A was lower in group 2 compared to group 1, except in the oblique subgroup, and group 2 had less SIA-P for all subgroups.

DISCUSSION

Corneal incision causes tissue damage and the healing process changes the anterior and posterior corneal curvature, thus leading to SIA. While SIA must be evaluated, the classical sphero-cylinder format is not suitable. Different methods have been defined to manage this type of data, such as vector analysis technique and polar value analysis.[6-8]

Many factors affect SIA, such as the length, type, width and location of the incision. Various incision locations (like steep axis or temporal incision) and different types of incision (such as single plane, bi-plane corneal incision or scleral incision) have been analyzed, but the incision sequence has been ignored.[9,10]

Table 3: *Assessment of anterior and posterior corneal change in subgroups after cataract surgery*

	n	Preop CA	Postop CA	*p*
Anterior Cornea				
Group 1				
All	41	0.60 ±0.37	0.88±0.51	0.002*
Vertical	17	0.69±0.41	0.81±0.33	0.276#
Horizontal	11	0.46±0.41	1.06±0.67	0.005#
Oblique	13	0.59±0.28	0.80±0.53	0.248#
Group 2				
All	45	0.67±0.42	0.85±0.48	0.005*
Vertical	24	0.80±0.45	0.84±0.54	0.785#
Horizontal	10	0.44±0.42	0.77±0.41	0.017#
Oblique	11	0.63±0.24	1.09±0.40	0.015#
Posterior Cornea				
Group 1				
All	41	0.30±0.17	0.30±0.18	0.536#
Vertical	28	0.34±0.16	0.28±0.14	0.057#
Horizontal	6	0.18±0.14	0.27±0.25	0.465#
Oblique	7	0.22±0.14	0.37±0.21	0.216#
Group 2				
All	45	0.26 ±0.15	0.29±0.18	0.219#
Vertical	30	0.30±0.15	0.33±0.19	0.516#
Horizontal	8	0.13±0.09	0.18±0.10	0.480#
Oblique	7	0.23±0.15	0.29±0.20	0.234#

CA, corneal astigmatism.
* paired t-test; # Wilcoxon Signed Rank test

Table 4: *Subgroup analyses of surgically induced astigmatism and astigmatism change according to steep axis and astigmatism*

	Group 1	Group 2	*p**
Vertical			
SIA-A	0.76 ±0.37	0.67±0.43	0.389
AC-A	0.12±0.44	0.04±0.44	0.404
SIA-P	0.24±0.14	0.23±0.15	0.623
AC-P	-0.05±0.16	0.03±0.19	0.099
Horizontal			
SIA-A	0.71±0.47	0.48±0.24	0.324
AC-A	0.60±0.46	0.33±0.29	0.157
SIA-P	0.30±0.28	0.20±0.15	0.604
AC-P	0.08±0.26	0.04±0.13	0.947
Oblique			
SIA-A	0.79±0.50	0.82±0.33	0.524
AC-A	0.21±0.57	0.46±0.46	0.245
SIA-P	0.38±0.26	0.20±0.16	0.224
AC-P	0.14±0.28	0.08±0.11	0.884

SIA-A, surgically induced astigmatism anterior; AC-A, astigmatism change anterior;
SIA-P, surgically induced astigmatism posterior; AC-P, astigmatism change posterior.
* Mann-Whitney U test

In the literature, no evidence was found about how the sequence of the incision affects anterior and posterior astigmatism and SIA, so we evaluated the effect of the sequence of 2.8 mm single plane clear corneal incision on SIA.

For a 2.8 mm superior clear corneal incision, our mean arithmetic anterior SIA was 0.76 D in group 1 and 0.67 D in group 2. Performing the main incision first caused less SIA; however, there was no statistically significant difference between the groups. This result is consistent with the studies performed with superior corneal incision in the literature. Popov et al. used a 2.75 mm superior corneal incision and found a mean SIA is 0.6 D, similar to our study. In addition, Popov et al. followed the patients throughout 3 months and found that the SIA value decreased to 0.4 D. They stated that the change between the 1st and 3rd month was more pronounced.[11] There are many studies in the literature on the effect of incision location on SIA. The generally accepted conclusion is that the temporal incision causes less SIA because the horizontal diameter of the cornea is bigger than superior corneal diameter.[12,13] However, there are also studies reporting different results. Laliwala et al. compared 2.8 mm superior and temporal incisions and found an average SIA of 0.5 D in the temporal group and 0.4 D in the superior incision at the end of 60 days and reported no difference between the groups.[14] The incision far from the optic axis is not always the best incision. It is also important to note in which quadrant the steep axis is located. Wendelstein et al. showed that SIA changes over time and astigmatisma magnitude showed a tendency to decrease for steep-meridian incisions and to increase in flat-meridian incisions.[15]

In the current study, posterior corneal astigmatism was not different from preoperative measurements in either group. Similarly, posterior corneal astigmatism did not change after 2.2 mm and 2.75 mm temporal corneal incision after the operation.[16,17] Kane et al. found the SIA-P to be 0.12 D and in more than 95% of patients the SIA P was below 0.25 D. Kane et al. did not find any correlation between posterior corneal SIA size and any preoperative measurement.[18] Some of the studies concluded that changes in posterior astigmatism after cataract surgery were clinically insignificant and negligible.[16-19] In our study, AC-Posterior was almost zero. Additionally, a decrease in posterior astigmatism was observed in the vertical subgroup of group 1, but it was not statistically significant.

Although cataract surgery does not seem to have a significant effect on posterior astigmatism in some studies in the literature, there are some publications reporting

the opposite. Liu et al. found a weak correlation between the amount of preoperative posterior astigmatism and the amount of SIA-P in cataract surgery with 2.2 mm and 120° scleral incision. Lui et al. analyzed the data of patients who underwent toric iol implantation. Therefore, both anterior and posterior surface astigmatism amounts are higher than our study. Liu et al. emphasize that SIA-P may have an important especially in patients with high preoperative anterior or posterior corneal astigmatism.[20]

Study Limitations

The limitations of our study are short follow-up time, only superior clear corneal main incision location and the relatively small sample size. Since the data were obtained during a short follow-up period, long-term effects of incision order after surgery could not be analyzed in this study. The sample size limited the subgroup analysis in particular. Although SIA-A and SIA-P values were lower in group 2, especially in the horizontal subgroup, the fact that the results were not different was likely caused by the small sample size.

CONCLUSION

Making the main incision first caused less SIA, especially on posterior surfaces; however, this difference was not significant, and phacoemulsification using manual 2.8 mm superior clear corneal incision did not affect posterior astigmatism in cataract surgery. However, further clinical trials with larger numbers of patients are needed to investigate the long-term effects of the incision sequence on SIA and corneal astigmatism, and to evaluate the effect on different locations, sizes, and steepest axis.

Ethics

Ethics Committee Approval: if necessary Aksaray University, Human Research Ethics Committee, number 2020-08-33.

Conflict of Interests: No conflict of interest was declared by the authors.

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