Tomographic Analysis of Incision Sequence on Anterior and Posterior Surgically Induced Astigmatism in Cataract Surgery

Mehmet Adam ( drmehmetadam@gmail.com )
Aksaray University: Aksaray Universitesi  https://orcid.org/0000-0003-0552-5212

Osman Sayın
Konya EAH: Konya Meram Devlet Hastanesi

Okan Ağca
Konya Training and Research Hospital: Konya Meram Devlet Hastanesi

Hasan Altinkaynak
Konya Training and Research Hospital: Konya Meram Devlet Hastanesi

Research Article

Keywords: Cataract surgery, surgically induced astigmatism, incision sequence, anterior astigmatism, posterior astigmatism

DOI: https://doi.org/10.21203/rs.3.rs-682782/v1

License: ☕️ This work is licensed under a Creative Commons Attribution 4.0 International License. Read Full License
Abstract

**Purpose:** To evaluate the effect of incision sequence on anterior and posterior astigmatism and SIA at cataract surgery using Scheimpflug tomography measurements.

**Methods:** We evaluated 86 patients who had undergone cataract surgery between October 2018 to March 2019. All eyes were measured with a Scheimpflug tomography system preoperatively and at 1 month after surgery, which included anterior and posterior corneal surfaces. The surgery was begin with side incision in group 1, differently the main incision was done first in group 2. Student t test and Pearson's correlation were performed. P values < 0.05 were considered statistically significant.

**Result:** Surgically induced anterior astigmatism (SIA-A) 0.76±0.43, 0.67±0.38 and surgically induced posterior astigmatism(SIA-P) 0.27±0.19, 0.23±0.19 respectively in group 1 and group 2. 1D or greater SIA-A was found 24.4 % and 15.6% and 0.5 D or greater SIA-P was found 14.6% and 12.2% respectively in group 1 and group 2. There was a significant increase in anterior astigmatism (p=0.002, 0.005 respectively in group 1 and 2), but not in the posterior astigmatism (p=0.471 and 0.247 respectively in group 1 and 2). In the subgroup analysis, group 2 has lower SIA-A than group 1 except oblique subgroup and group 2 has lower SIA-P for all subgroups but it wasn't statistically significant.

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

Introduction

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

Main incision is primary responsible for surgery induced astigmatism. Most of surgeon prefer to make side incision firstly, then fill to anterior chamber with ophthalmic viscosurgical device (OVD) and make a main incision, because this approach might be safer to avoid to the anterior capsule damage. More or less filling of the anterior chamber with OVD can be effect normal anterior chamber depth, chamber volume corneal shape and wound architecture. Under or over filling of the anterior camera may cause upward or downward shift of the inner edge of the incision when the cornea returns to its normal architecture. This wound architectural shift situation may cause deviations from the linear structure of the incision, and this change may affect surgery-induced astigmatism and postoperative astigmatism.
The aim of this study to evaluate of effect incision sequence on anterior and posterior astigmatism and SIA at cataract surgery using Scheimpflug tomography measurements.

**Methods**

This study included 120 eyes who underwent phacoemulsification in the Konya Education and Research Hospital (new name Konya City Hospital). Surgery procedure was performed by the same surgeon between October 2018 to March 2019 The study protocol was approved by the Institutional Review Board/Ethics committee, and written informed consent was obtained from all participants. The study adhered to the tenets of the Declaration of Helsinki.

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

After the examination patient who have cataracts with regular astigmatism less than 2.5 D were included in this study. Preoperatively, patients were randomly divided into the groups. Patient who have previously ocular surgery history, pterygium, intraoperative surgical complications, severe dry eye or any corneal pathology were excluded.

120 eyes were included in the study but 34 eyes were excluded because of poor follow-up or insufficient topography quality data. Astigmatism was classified according to the steepest meridian. Horizontal (steepest meridian 0 to 29.9° or 150 to 180°), vertical (steepest meridian 60 to 119.9°), and oblique (steepest meridian 30 to 59° or 120 to 149.9°). We didn’t use the terms of classical astigmatism in accordance with the rule or against the rule because of negative dioptric power of the posterior cornea may cause confusion in nomenclature.

**Surgical Technique**

All Operator procedures were performed under topical anesthesia with proparacaine HCl %0.5 (Alcaine, Alcon Laboratories Inc ). In grup 1, firstly side incision performed with 20 gauge mvr blade (Alcon Laboratories Inc) on 150 degree after the filling to anterior chamber with OVD (Protectalon 2,0 VSY inc) second side incision and 2,8mm single-step clear corneal incision were performed with double bevel up blade (Alcon Laboratories Inc). Main incision was performed on 90 degree and second side incision was performed on 60 degree away from main incision at cornea. In group 2, firstly 2,8mm single-step clear corneal incision was performed after that the anterior chamber was filled with OVD and side incision were made with 20 gauge mvr blade . After standard cataract surgery by phacoemulsification bimanual cortex...
aspiration was performed and acrylic single pieces non-toric hydrophobic IOL (Acrysof SA60AT; Alcon) was inserted in the capsular bag. All incision was carried out on same location on cornea in the both groups and corneal incision place were left without suture.

Patients were treated with a combination of moxifloxacine and dexamethasone (Moxidexa, Abdi Ibrahim Inc.) 8 times for first week then dexamethasone 1 mg/mL (Maxidex, Alcon Laboratories Inc) eyedrops 4 times a day for 3 weeks postoperatively.

**SIA Calculation**

We used vector analysis software based on Alpin’s method to calculate SIA[6,7].

**Statistical Analysis**

For statistical analysis, Statistical Package for Social Science (SPSS) program (Worldwide Headquarters SPSS Inc. 21.0 Windows package program) was used. Descriptive findings are displayed as mean ± standard deviation. Normal distribution of the data was according to assessed Kolmogorov-Smirnov test in both groups. Comparisons between groups were analyzed via student's t test. Chi-square test was used to compare categorical variables. Pearson's correlation was performed to analyze the relation preoperative astigmatism and the SIA. P values < 0.05 were considered statistically significant.

**Sample Size Calculation**

The smallest astigmatic change that might be clinically relevant was defined to be 0.25 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 to be 0.4 and 0.2 D respectively for anterior and posterior corneal surface. Setting a to 0.05 and power 0.8, the minimum sample size for each group was calculated to be 41 eyes.

**Result**

86 eyes that underwent phacoemulsification surgery were evaluated in this research (41 eyes in group 1 and 45 eyes in group 2). The average age was 67.48 ± 7.81 years and 67.86 ± 8.03 years, preoperative anterior astigmatism 0.60 ± 0.37 (range 0.1 to 1.4), 0.67 ± 0.42 (Range 0.0 to 1.9) and preoperative posterior astigmatism 0.30 ± 0.16 (range 0.0 to 0.80) 0.26 ± 0.15 (range 0.0 to 0.70) respectively in group 1 and group 2. Posterior corneal astigmatism was 0.30 D or less in 50.0% of measurements in group 1 and 0.25 D or less in group 2 and anterior corneal astigmatism was 0.50 D or less in 50.0% of measurements in group 1 and 0.60 D or less in group 2. Table 1 includes information about preoperative data.
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, 22 OS    | 0.117 |
| **Anterior cornea**     |                 |                 |       |
| 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 ± 0.42     | 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**    |                 |                 |       |
| 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               |       |

Abbreviations: CA: Corneal astigmatism,

Postoperative keratometric anterior astigmatism is 0.88 ± 0.51 (range 0.0 to 2.4D), 0.85 ± 0.48 (range 0.1 to 1.80D), postoperative posterior corneal astigmatism 0.30 ± 0.17 (range 0.0 to 0.8), 0.29 ± 0.18 (range 0.0 to 0.7) respectively in group 1 and group 2 (p = 0.861 and 0.923 for anterior and posterior astigmatism). Surgically induced anterior astigmatism (SIA-A) is 0.76 ± 0.43 (range 0.12 to 1.97), 0.67 ± 0.38 (range 0.06 to 1.62 ) and surgically induced posterior astigmatism(SIA-P) 0.27 ± 0.19 (range 0.0 to 0.82 ) 0.22 ± 0.15 (range 0.0 to 0.54) respectively in group 1 and group 2 (p = 0.274 and 0.149 for SIA-A
and SIA-P). 1D or greater SIA-A was found 24.4% and 15.6% and 0.5 D or greater SIA-P was found 14.6% and 12.2% respectively in group 1 and group 2. Table 2 shows information about postoperative data.

Table 2  
Shows SIA, astigmatism class, mean magnitude of postoperative anterior and posterior corneal astigmatism 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 |
| **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     | 0.149 |
| CA                   | 0.30 ± 0.17     | 0.29 ± 0.18     | 0.923 |
| AC                   | -0.01 ± 0.22    | 0.04 ± 0.18     | 0.295 |
| Steep axis           | 93.43 ± 53.57   | 110.58 ± 58.85  | 0.160 |

**Abbreviations**: CA: Corneal astigmatism, AC: Astigmatism change, SIA: Surgery induced astigmatism

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, 0.005 respectively in group 1 and 2) but the difference between the magnitudes of the preoperative and postoperative posterior corneal astigmatism was
in insignificant (p = 0.471 and 0.247 respectively in group 1 and 2). The median posterior astigmatism change is -0.005 and -0.01 respectively in group 1 and 2.

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

|                      | n  | Preop CA (range), median | Postop CA (range),median | p          |
|----------------------|----|--------------------------|--------------------------|------------|
| **Anterior cornea**  |    |                          |                          |            |
| **Group 1**          |    |                          |                          |            |
| All                  | 41 | 0.60 ± 0.37 (0.0–1.4); 0.5 | 0.88 ± 0.51 (0.0–2.4); 0.9 | 0.002      |
| Vertical             | 17 | 0.69 ± 0.41 (0.1–1.4); 0.6 | 0.81 ± 0.33 (0.2–1.3); 0.85 | 0.276      |
| Horizontal           | 11 | 0.46 ± 0.41 (0.1–1.4); 0.4 | 1.06 ± 0.67 (0.2–2.4); 1.10 | 0.005      |
| Oblique              | 13 | 0.59 ± 0.28 (0.2–1.0); 0.6 | 0.80 ± 0.53 (0.0–1.9); 0.7 | 0.248      |
| **Group 2**          |    |                          |                          |            |
| All                  | 45 | 0.67 ± 0.42 (0.0–1.9); 0.6 | 0.85 ± 0.48 (0.0–1.7); 0.8 | 0.005      |
| Vertical             | 24 | 0.80 ± 0.45 (0.0–1.9); 0.7 | 0.84 ± 0.54 (0.1–1.7); 0.6 | 0.785      |
| Horizontal           | 10 | 0.44 ± 0.42 (0.1–1.3); 0.25 | 0.77 ± 0.41 (0.3–1.7); 0.8 | 0.017      |
| Oblique              | 11 | 0.63 ± 0.24 (0.3–1.2); 0.6 | 1.09 ± 0.40 (0.5–1.7); 1.15 | 0.015      |
| **Posterior Cornea** |    |                          |                          |            |
| **Group 1**          |    |                          |                          |            |
| All                  | 41 | 0.30 ± 0.17 (0.0–0.80); 0.3 | 0.29 ± 0.18 (0.0–0.80); 0.3 | 0.889      |
| Vertical             | 28 | 0.34 ± 0.16 (0.1–0.8); 0.3 | 0.28 ± 0.14 (0.1–0.6); 0.3 | 0.057      |
| Horizontal           | 6  | 0.18 ± 0.14 (0.0–0.4); 0.2 | 0.27 ± 0.25 (0.0–0.7); 0.2 | 0.465      |
| Oblique              | 7  | 0.22 ± 0.14 (0.1–0.5); 0.2 | 0.37 ± 0.21 (0.1–0.8); 0.3 | 0.216      |
| **Group 2**          |    |                          |                          |            |
| All                  | 45 | 0.26 ± 0.15 (0.0–0.7); 0.2 | 0.29 ± 0.18 (0.0–0.7); 0.2 | 0.247      |
| Vertical             | 30 | 0.30 ± 0.15 (0.1–0.7); 0.30 | 0.33 ± 0.19 (0.1–0.7); 0.3 | 0.516      |
| Horizontal           | 8  | 0.13 ± 0.09 (0.0–0.3); 0.1 | 0.18 ± 0.10 (0.0–0.3); 0.2 | 0.480      |
| Oblique              | 7  | 0.23 ± 0.15 (0.0–0.4); 0.20 | 0.29 ± 0.20 (0.1–0.6); 0.2 | 0.234      |

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

In the comparison of subgroups between groups, there was no significant difference in according to SIA-A, SIA-P, AC anterior and posterior, however SIA-A were lower in group 2 compared to the group 1 except oblique subgroup and groups 2 has less SIA-P for all subgroups. Table 4 shows SIA and AC between groups to compare subgroups for anterior and posterior corneal surface.

| Group | Range; median | Group 2 | Range; median | P  |
|-------|---------------|---------|---------------|----|
| **Vertical** | | | | |
| SIA A | 0.76 ± 0.37 | (0.21-1.64);0.78 | 0.67 ± 0.43 | (0.13 - 1.62);0.67 | 0.389 |
| AC-A | 0.12 ± 0.44 | (-0.7-0.9), 0.2 | 0.04 ± 0.44 | (-0.90-0.9), 0.0 | 0.404 |
| SIA-P | 0.24 ± 0.14 | (0.10 - 0.54), 0.21 | 0.23 ± 0.15 | (0.10 - 0.54), 0.18 | 0.623 |
| AC-P | -0.05 ± 0.16 | (-0.3 - 0.40), -0.1 | 0.03 ± 0.19 | (-0.50 - 0.40), 0.10 | 0.099 |
| **Horizontal** | | | | |
| SIA A | 0.71 ± 0.47 | (0.10-1.4), 0.56 | 0.48 ± 0.24 | (0.06-0.8), 0.49 | 0.324 |
| AC-A | 0.60 ± 0.46 | (0.0-1.4), 0.50 | 0.33 ± 0.29 | (-0.1-0.7), 0.35 | 0.157 |
| SIA-P | 0.30 ± 0.28 | (0.0-0.82),0.25 | 0.20 ± 0.15 | (-0.42),0.16 | 0.604 |
| AC-P | 0.08 ± 0.26 | (-0.2 - 0.5), 0.0 | 0.04 ± 0.13 | (-0.10,0.3),0.0 | 0.947 |
| **Oblique** | | | | |
| SIA A | 0.79 ± 0.50 | (0.12-1.97), 0.61 | 0.82 ± 0.33 | (0.40-1.44), 0.85 | 0.524 |
| AC-A | 0.21 ± 0.57 | (-0.6 - 1.60), 0.2 | 0.46 ± 0.46 | (-0.1,-1,3), 0.40 | 0.245 |
| SIA-P | 0.38 ± 0.26 | (0.02 - 0.72), 0.43 | 0.20 ± 0.16 | (0.06 - 0.5), 0.14 | 0.224 |
| AC-P | 0.14 ± 0.28 | (-0.2 - 0.70), 0.1 | 0.08 ± 0.11 | (-0.1 - 0.2), 0.10 | 0.884 |

**Abbreviations:** SIA-A: Surgery induced astigmatism anterior, AC-A: Astigmatism change anterior SIA-P: Surgery induced astigmatism posterior, AC-P: Astigmatism change posterior

**Discussion**

Corneal incision causes tissue damage and healing process changes anterior and posterior corneal curvature. Consequently, these changes make as surgery-induced astigmatism therefore SIA should be
evaluated well but the classical spherocylinder format is not suitable for SIA thus different method was defined to manage this type of data, such as vector analysis technique or polar value analysis [6–8].

Many factors affects SIA such as the length, type, width and location of incision. For this purpose various incision location (like steep axis or temporal incision) or different type of incision (such as single plane, bi-plane corneal incision or scleral incision) were analyzed but the incision sequence was ignored [9,10].

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

Our mean SIA anterior is 0.76D, 0.67D respectively in group 1 and group 2 with 2.8 mm superior clear corneal incision. Performing the main incision first caused less SIA however there was no difference between the groups statistically. In a study comparing the temporal incision with the superior incision, average SIA was found 0.77 and 1.29 with 2.8 mm corneal incision respectively [11]. In another study showed that superior incision was cause 48.28 % more SIA than by the temporal incision [12]. Similarly, there is a publication stating that the superotemporal or superionasal incision is better options because it causes less SIA than the superior incision [13]. We prefer superior incision because of the manipulations are made more easy than the temporal position.

In our study, SIA posterior is 0.27 D and 0.23 D respectively in group1, group 2 and these rates are compatible with the literature. Although there was no statistically difference between the groups and subgroup analysis, group 2 has lower SIA-P than group 1 and subgroups of group 2 has less SIA-P than subgroups of group 1.

In the current study, posterior corneal astigmatism wasn't different from the preoperative in the both of groups. Similarly Kohnen et all. showed that posterior corneal astigmatism didn't change postoperative in one months period after 2.2 mm temporal clear corneal incisions in femtosecond laser–assisted cataract surgery [14]. In the another study with 2.75 mm temporal corneal incision, posterior astigmatic values didn't change after the operation [15]. Kim et al. found that the mean SIA of posterior cornea was 0.19D with a 2.2 mm temporal incision cataract surgery and stated that it did not make any changes in posterior astigmatism with regard to preoperative posterior cornea curvature [16].

There are also studies that have found a lower posterior SIA score. Hayashi et al. demonstrated mean SIA-P was 0,10D in short temporal CCI group but their study didn't compare postoperative posterior astigmatism with preoperative astigmatism [17]. In these studies concluded that changing posterior astigmatism after cataract surgery are clinically insignificant and negligible [14–17]. In our study, AC-P is almost zero. Additionally, a decrease in posterior astigmatism was observed in the ATR-P subgroup of group 1, but it was not significant.

Although cataract surgery does not seem to have a significant effect on posterior astigmatism in some studies in the literature, there are also publications reporting opposing opinions. Cheng et al. pointed out
that the posterior corneal astigmatism is a significant contributor to astigmatism after cataract surgery and demonstrated that posterior astigmatism is 0.5D or more in 24% of patients [18]. However, in this study, a single corneal suture was placed on main corneal incision and suture wasn't removed before measured by the Scheimpfug analysis system. In the study of Li et al. the mean SIA-p value was found to be 0.34 D but this study enrolled patient with regular corneal astigmatism ≥ 1.0 D and at the end of the study, a significant correlation was found between preoperative astigmatism value and SIA-P [19]. The mean preoperative astigmatism value was 1.58, and this may be the reason for the high SIA-P.

Nemeth at al. found that mean SIA-P was 0.31 D and it was 0.5 D or greater in 25% of eyes with 2.8 mm on axis manual corneal incision [20]. The mean SIA-P and 0.5 D or greater SIA-P were found is slightly higher than the our study. These rates were 14.6% and 12.2% respectively in group 1 and group 2 in the current study. The mean SIA-P and greater SIA-P than 0.5 D ratio were higher than our result whereas 2.8 mm corneal incision was used in both studies. However preoperative rate of posterior astigmatism more than 0.5 D was 11.36% in Nemeth et al.'s study whereas this ratio was just 2.4% in our study. A significant correlation was found between preoperative posterior astigmatic values of diopters and SIA-P in the study of Nemeth but in the current study although this correlation was present in both groups but it wasn't significant.

The limitations of our study are the short follow-up time and relatively small sample size. Since the data are obtained during a short follow-up period, long-term effect of incision order after surgery could not be analyzed in this study. Sample size has particularly limited the evaluation of subgroup analysis, so subgroup result should be treated carefully. Although SIA-A and SIA-P values were lower in group 2 especially in the horizontal subgroup, the results wasn't different, probably it 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 with 2.8 mm superior clear corneal incision cataract surgery. However, further prospective, clinical trials with larger numbers of patients are needed to investigate the long-term effects of the incision sequence on SIA and corneal astigmatism.

Declarations

Authors Contribution: All authors met the ICMJE authorship criteria. All authors made substantial contributions to conception, design, analysis and interpretation of data, contributed to writing the article, provided critical revision of the manuscript, and approved the final version.

Funding: The authors received no financial support for this study.

Data availability: Open request
**Conflict of interest:** No conflict of interest was declared by the authors

**Ethics approval:** The study protocol was approved by the Institutional Review Board/Ethics committee, and written informed consent was obtained from all participants.

**References**

1. Fong CS, Mitchell P, Rochtchina E, Teber ET, Hong T, Wang JJ. Correction of visual impairment by cataract surgery and improved survival in older persons: the Blue Mountains Eye Study cohort. Ophthalmology. 2013;120:1720-7. doi: 10.1016/j.ophtha.2013.02.009.

2. Murthy G, John N, Shamanna BR, Pant HB. Elimination of avoidable blindness due to cataract: where do we prioritize and how should we monitor this decade? Indian J Ophthalmol. 2012;60:438-45. doi: 10.4103/0301-4738.100545.

3. Nikose AS, Saha D, Laddha PM, Patil M. Surgically induced astigmatism after phacoemulsification by temporal clear corneal and superior clear corneal approach: a comparison. Clin Ophthalmol. 2018;12:65-70. doi: 10.2147/OPTH.S149709.

4. Loncar VL, Vicković IP, Iveković R, Mandić Z. Limbal relaxing incision during cataract surgery. Acta Clin Croat. 2012;51:289-92. PMID: 23115958.

5. Mendicute J, Irigoyen C, Aramberri J, Ondarra A, Montés-Micó R. Foldable toric intraocular lens for astigmatism correction in cataract patients. J Cataract Refract Surg. 2008;34:601-7. doi: 10.1016/j.jcrs.2007.11.033.

6. Alpins N. Astigmatism analysis by the Alpins method. J Cataract Refract Surg. 2001;27:31-49. doi: 10.1016/s0886-3350(00)00798-7.

7. Egrilmez S, Dalkılıç G. Vector Analysis Software on Analyzing Astigmatism. Turk J Ophthalmol 2003;33:404-416.

8. Naeser K, Hjortdal J. Polar value analysis of refractive data. J Cataract Refract Surg. 2001;27:86-94. doi: 10.1016/s0886-3350(00)00799-9.

9. Rho CR, Joo CK. Effects of steep meridian incision on corneal astigmatism in phacoemulsification cataract surgery. J Cataract Refract Surg. 2012;38:666-71. doi: 10.1016/j.jcrs.2011.11.031.

10. Jauhari N, Chopra D, Chaurasia RK, Agarwal A. Comparison of surgically induced astigmatism in various incisions in manual small incision cataract surgery. Int J Ophthalmol. 2014;7:1001-4. doi: 10.3980/j.issn.2222-3959.2014.06.16.

11. Nikose AS, Saha D, Laddha PM, Patil M. Surgically induced astigmatism after phacoemulsification by temporal clear corneal and superior clear corneal approach: a comparison. Clin Ophthalmol. 2018;12:65-70. doi: 10.2147/OPTH.S149709.

12. Mallik VK, Kumar S, Kamboj R, Jain C, Jain K, Kumar S. Comparison of astigmatism following manual small incision cataract surgery: superior versus temporal approach. Nepal J Ophthalmol. 2012;4:54-8. doi: 10.3126/nepjoph.v4i1.5851. Erratum in: Nepal J Ophthalmol. 2012;4(2):343.
13. Pawar VS, Sindal DK. A comparative study on the superior, supero-temporal and the temporal incisions in small incision cataract surgeries for post operative astigmatism. J Clin Diagn Res 2012; 6:1229–1232.

14. Kohnen T, Löffler F, Herzog M, Petermann K, Böhm M. Tomographic analysis of anterior and posterior surgically induced astigmatism after 2.2 mm temporal clear corneal incisions in femtosecond laser-assisted cataract surgery. J Cataract Refract Surg. 2019;45:1602-1611. doi: 10.1016/j.jcrs.2019.06.010.

15. Schmitt AJ, Moreira ATR, Filho FAK, Schmitt FP. Corneal Posterior Curvature Changes After Phacoemulsification Cataract Surgery with 2.75 mm Corneal Incision. Med Hypothesis Discov Innov Ophthalmol. 2019;8:110-115.

16. Kim YJ, Knorz MC, Auffarth GU, Choi CY. Change in Anterior and Posterior Curvature After Cataract Surgery. J Refract Surg. 2016;32:754-759. doi: 10.3928/1081597X-20160816-01.

17. Hayashi K, Yoshida M, Hirata A, Yoshimura K. Changes in shape and astigmatism of total, anterior, and posterior cornea after long versus short clear corneal incision cataract surgery. J Cataract Refract Surg. 2018;44:39-49. doi: 10.1016/j.jcrs.2017.10.037.

18. Cheng LS, Tsai CY, Tsai RJ, Liou SW, Ho JD. Estimation accuracy of surgically induced astigmatism on the cornea when neglecting the posterior corneal surface measurement. Acta Ophthalmol. 2011;89:417-22. doi: 10.1111/j.1755-3768.2009.01732.x.

19. Li X, Chen X, He S, Xu W. Effect of 1.8-mm steep-axis clear corneal incision on the posterior corneal astigmatism in candidates for toric IOL implantation. BMC Ophthalmol. 2020;20:187. doi: 10.1186/s12886-020-01456-3.

20. Nemeth G, Berta A, Szalai E, Hassan Z, Modis L Jr. Analysis of surgically induced astigmatism on the posterior surface of the cornea. J Refract Surg. 2014;30:604-8. doi: 10.3928/1081597X-20140723-01.