



Validity of Novel Microsoft Excel Software for Calculating Surgically Induced Astigmatism

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Authors' contributions

This work was carried out in collaboration between all authors. Author PSK designed the study, wrote the protocol and wrote the first draft of the manuscript. Author AKS managed the literature searches and editing of the article. Other authors reviewed the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Purpose: To investigate validity and predictability of a new software calculator for surgically induced astigmatism quantification.

Techniques and Methods: A new astigmatic calculator was designed, based on Pythagorean principle and trigonometric functions using Microsoft office excel 2007. Astigmatic magnitude was quantified in diopters and axis direction was depicted in degrees. Calculator was applied, investigated and analyzed on 30 pseudophakic eyes that underwent temporal scleral incision surgery with in the bag intraocular lens implantation. Pre and postoperative anterior corneal curvature was measured with Bausch and Lomb keratometer. Similarities and differences were compared with the existing version 1.1 and 2.1 calculators and statistical analysis was performed using Microsoft excel.

Results: Mean pre and postoperative astigmatic magnitude was calculated as 62.67 (+/- 2.40) and

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62.83 (+/- 2.29) diopters. Mean pre and postoperative astigmatic axis was 89.74 (+/- 1.37) and 89.51 (+/- 1.37) degrees. Pearson's coefficient (r) was calculated as 0.91 and 0.83; coefficient of determinations (R^2) was calculated as 0.82 and 0.68 for astigmatic magnitudes and axes respectively. Student chi-square test was used to calculate T values, which were 0.39 and 0.26 for astigmatic magnitude and axis respectively. P value less than 0.05 was considered as statistically significant (p 0.16). Validity was compared with existing surgically induced astigmatism calculators 1.1 and 2.1 versions and predictability was assessed by $y=2.83+0.95x$ for astigmatic magnitude and $y=15.28+0.83x$ equations for astigmatic axis.

Conclusion: Present Microsoft excel calculator application was valid as the values for astigmatic magnitude and axis were comparable with existing SIA calculators and can be used for astigmatic predictability.

Keywords: *Surgically Induced Astigmatism (SIA); Pythagorean principle; trigonometric and calculus formulae; astigmatic magnitude and direction.*

1. INTRODUCTION

Unexpected and post cataract surgical refractive astigmatic surprises are not uncommon in clinical practice. Understanding surgically induced astigmatism enlightens modifications in astigmatic control. Clinical prediction about pre and postoperative astigmatic magnitude and axis after cataract surgery improves acceptable modifications of surgeons' incision techniques that would provide least astigmatic correction to patients. Surgically induced astigmatism (SIA) determination uses subtraction method, vector analysis, vector decomposition, Cravy's vertical vector, Naeser's polar values and algebraic methods for calculations [1-2].

Recently, minimum standard format for reporting astigmatic outcomes and terminology to define astigmatism was formulated by astigmatic project group of the American national standard institute (ANSI) [3]. As astigmatism is manifested in magnitude and direction simultaneously, principles of vector Cartesian coordinate system calculations were adapted in the present study. Research rationale of this novel simple Microsoft (MS) excel 2007 software construction is to validate and correlate with existing SIA calculator 1.1 and 2.1 software. Furthermore, predictability of postoperative SIA vectors was evaluated by means of regression equations.

2. SUBJECTS AND METHODS

The experimental study was conducted primarily on patients recruited from an ongoing study on manual keratometric analysis of anterior corneal curvature following temporal scleral incision cataract surgery. Informed consent was taken from all patients. This project was approved by the institutional ethical committee and conducted

in accordance with the Declarations of Helsinki of 1975. A new, yet a simple MS excel software functions were employed to analyze SIA on the basis of Cartesian coordinate vector system. Thirty eyes of 30 cataract patients were included after three months of surgery as refractive status stabilizes by this time [4]. All patients underwent temporal scleral incision cataract surgery with in the bag intra ocular lens implantation. Eyes with intra operative complications were excluded. Pre and postoperative keratometric horizontal (Kh) and vertical meridians (Kv) were measured by Bausch and Lomb keratometer (Appasamy KMS 6). As Microsoft Excel is easily available and accessible, it can be used similarly on other versions also.

3. MS EXCEL SIA SOFTWARE-BASIC PRINCIPLES

Formulae were constructed accordingly, as astigmatism abides with power in diopters and axis direction in degrees by vector analysis system. Magnitude and axis of pre and postoperative SIA vectors was expressed in diopters and in degrees respectively. Generally in day-to-day practice, astigmatism involves correction of two principle meridians that are perpendicular to each other; hence resultant vector is the hypotenuse of Pythagorean right angle triangle that was used to calculate magnitude of SIA vector.

Pythagorean principle applies to right angle triangles composed of adjacent and opposite sides with hypotenuse. The formula is $\text{adjacent side}^2 + \text{opposite side}^2 = \text{hypotenuse}^2$, hence hypotenuse is equal to sum square root of adjacent and opposite sides that represents net astigmatic magnitude in diopters (Fig. 1). Pre and postoperative keratometric horizontal and vertical

values were substituted for opposite coordinate (a) and adjacent coordinate (b) respectively. Resultant displaced coordinate is the magnitude of SIA vector represented by hypotenuse value that was expressed in diopters of astigmatism.

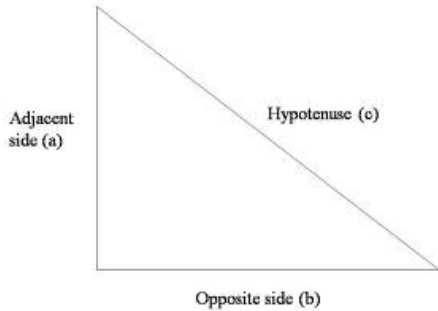


Figure 1 Calculation of SIA vector magnitude based on Pythagorean principle

Fig. 1. Calculation of magnitude of SIA vector-based on Pythagorean principle

For example 1

Pre operative cylinder -1.00 Dx90 degrees

Postoperative cylinder -2.00 Dx180 degrees

$$c^2 = a^2 + b^2 \text{ therefore } c = \sqrt{a^2 + b^2}$$

Therefore $c = \sqrt{1^2 + 2^2} = \sqrt{5} = 2.2$ D which is the resultant displaced magnitude of SIA vector.

To find out resultant pre and postoperative vector direction (angle) that is the astigmatic axis in degrees, trigonometric and calculus functions were applied. Here law of cosine was used for calculation of the angle theta for the resultant axis of SIA vector.

$$\text{Cosine } \theta = \frac{\text{Adjacent side}}{\text{Hypotenuse}}$$

$$\text{Sine } \theta = \frac{\text{Opposite side}}{\text{Hypotenuse}}$$

Therefore, adjacent side = hypotenuse cos θ and opposite side = hypotenuse sin θ . This formula is for understanding law of cosines to calculate vertical and horizontal components when hypotenuse is known and vice versa. However we want to find out the angle of hypotenuse that is the axis of SIA vector. Value for astigmatic angle is calculated from tangent formula as shown below:-

$$\text{Tan } \theta = \frac{\text{Opposite side (horizontal curvature)}}{\text{Adjacent side (vertical curvature)}} \text{ OR}$$

$\theta = \tan^{-1} \{Kh/Kv\}$ that is derived from referring to tables and Microsoft excel trigonometry functions. Since astigmatic axis doubles in direction, the formula was multiplied by 2. Then $\theta = 2 \tan^{-1} \{Kh/Kv\}$ which is the final formula for calculating pre and postoperative resultant axis of SIA vector in degrees.

For example, Substituting our pre operative keratometric readings, when Kh is 42.74 diopters and Kv is 42.25 diopters in the formula we get, $\text{Tan } \theta = 42.74/42.25$ is equal to 0.99. Because $\theta = 2 \tan^{-1} \{0.99\}$ which is equal to 0.78 radians converted into 89.34 degrees automatically in the present software calculator. Therefore practically resultant axis of SIA vector becomes 90 degrees. Subtracting postoperative axis of SIA vector from pre operative axis of SIA vector, resultant axis of SIA vector was obtained.

4. RESULTS

Surgically induced astigmatism in 30 pseudophakic eyes of 30 patients was studied by applying newly formulated Microsoft Excel software calculator. Mean age was 60.3 (+/- 8.66) years with 14 males (46.66%) and 16 (53.34%) females. All cases operated from temporal side and in the bag intraocular lens placement were performed in 30 (100 %) eyes by same surgeon. Linear relationship and line of best fit for magnitude and axis of pre and postoperative magnitude and axis of SIA vectors is shown in Figs. 2 and 3.

Descriptive statistics of pre and postoperative magnitude with resultant magnitude of SIA vector in diopters is shown in Table 1. Descriptive statistics of pre and postoperative axis with resultant axis of SIA vectors in degrees is shown in Table 2. Student t test was performed to find out t values to know difference in the means. Statistical significant levels were set at 0.05 p value. Regression equation was employed to find out predictability of postoperative SIA vectors. This is calculated from the equation $y = a + bx$, where 'y' is dependant variable, 'a' is intercept and 'b' is slope for SIA vector (Table 3). Validity was tested by comparing with existing SIA calculator version 1.1 and 2.1. Tables 4 and 5 shows pre and postoperative keratometric data of study patients and summarizing similarities and differences between SIA calculator 1.1, SIA calculator 2.1 and new SIA calculators.

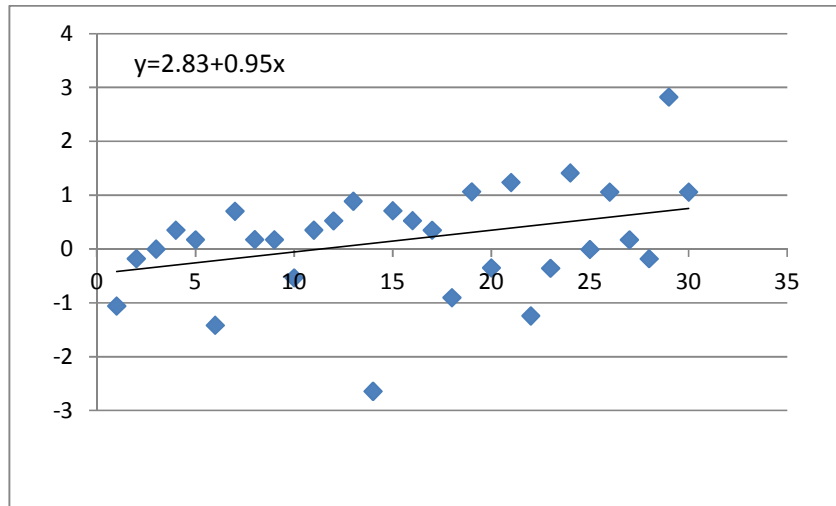


Fig. 2. Simple linear regression model of best line fit for resultant magnitude of SIA vector

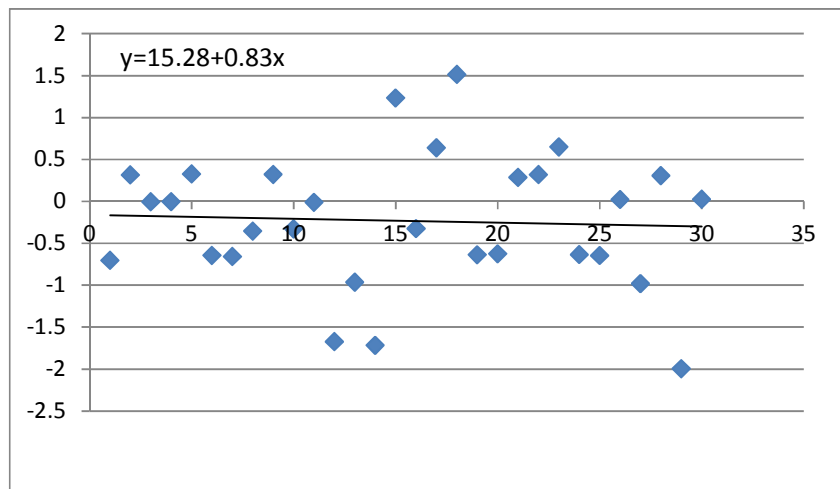


Fig. 3. Simple linear regression model of best line fit for resultant axis of SIA vector

Table 1. Descriptive statistics of pre and postoperative magnitude of SIA vectors in diopters (D)

n=30	Mean	Standard deviation	Standard error (SE)	Minimum	Maximum
Pre op magnitude	62.67 D	+/-2.40 D	1.03	56.93 D	67.20 D
Post op magnitude	62.83 D	+/- 2.29 D	0.47	57.11 D	67.20 D
Resultant magnitude of SIA vector	0.75 D	+/-0.68 D	0.19	0.00 D	2.83 D

Table 2. Descriptive statistics of pre and postoperative axis of SIA vector in degrees (d)

n=30	Mean	Standard deviation	Standard error (SE)	Minimum	Maximum
Pre operative axis	89.74 d	+/- 1.37 d	0.29	86.99 d	91.96 d
Post operative axis	89.51 d	+/- 1.37 d	0.28	86.99 d	92.25 d
Resultant axis of SIA vector	0.60 d	+/- 0.48 d	0.33	0.00 d	1.72 d

Table 3. Student t test results and regression equations for SIA vectors

	Resultant astigmatic magnitude	Resultant astigmatic axis
Pearson correlation (r)	0.91	0.83
Coefficient of determination (R ²)	0.82	0.68
Degree of freedom	29	29
T value	0.39	0.26
t critical one tail value	1.67	1.67
p value	0.59	0.11
Regression equation	y=2.83+0.95x	y=15.28+0.83x
Confident intervals	0.51 to 0.99	0.43 to 0.77

Table 4. Showing pre and postoperative keratometric data of patients with comparative analysis

S. no.	Pre operative data			Post operative data		SIA version 2.1	Present calculator
	Age	Kh	Kv	Kh	Kv	Resultant magnitude	Resultant magnitude
1	61	42.75	43.75	41.75	43.25	0.5	1.06
2	58	45.25	45	45.25	44.75	0.25	0.18
3	75	46.25	48.75	46.25	48.75	0	0
4	70	45	44.25	45.25	44.5	0	0.35
5	46	44	44.5	44.25	44.5	0.25	0.18
6	65	45.5	45.5	44.25	44.75	0.5	1.41
7	65	44.5	43.5	44.75	44.25	0.5	0.7
8	70	39.75	40.75	39.75	41	0.25	0.18
9	35	44.25	45.25	44.5	45.25	0.25	0.18
10	63	43.5	43	43	42.75	0.25	0.53
11	58	45	44	45.25	44.25	0	0.35
12	60	43.25	42.25	43	43.25	1.25	0.53
13	68	43	43.75	43.25	44.75	0.75	0.89
14	41	44	44.5	41.5	43.25	1.25	2.6
15	61	46	45.75	47	45.75	1.00	0.71
16	58	45.75	45	46	45.5	0.25	0.53
17	63	44.75	45.25	45.25	45.25	0.5	0.35
18	68	45.5	47.75	45.5	46.5	1.25	0.9
19	49	41	42.5	41.5	43.5	0.5	1.07
20	60	46	47.75	45.5	47.75	0.5	0.35
21	60	44.5	43	45.5	43.75	0.25	1.24
22	57	45.25	45.5	44.5	44.5	0.25	1.24
23	54	44	44.5	44	44	0.5	0.36
24	58	44.75	44.5	45.5	45.75	0.5	1.41
25	61	45	43.5	44.75	43.75	0.5	0
26	70	39.75	40.75	40.5	41.5	0	1.06
27	65	44.25	43.5	44	44	0.75	0.18
28	64	45.75	46.25	45.75	46	0.25	0.18
29	59	43	42	44.25	44.75	1.25	2.83
30	67	45	46.25	45.75	47	0	1.06

Table 5. Summarizing features showing SIA calculator version 2.1 and present calculator for astigmatic magnitude

	Principle	Equations	Z score	P value	Mean magnitude	Standard deviation
SIA version 2.1	Vector system	6 equations	-1.4119	0.16	0.46 D	+/- 0.38 D
New calculator	Vector system	2 equations	-1.4119	0.16	0.75 D	+/- 0.68 D

5. DISCUSSION

This study attempted to design a new SIA calculator using Microsoft office excel 2007 functions and applied on 30 pseudophakic eyes intended for the study on anterior corneal curvature analysis following temporal scleral incision cataract surgery.

Resultant magnitude of SIA vector was 0.48 with narrowed standard deviation and SEM compared to SIA calculator version 2.1 that showed resultant magnitudes of 0.75 that is close to the results of present new SIA calculator. Resultant astigmatic magnitude ranged from 0.00 diopters to 2.83 diopters in the present study (Table 1). Resultant axis of SIA vector was displaced in a range from 0.00 degrees to 1.72 degrees (Table 2). Pearson's correlation coefficient and coefficient of determination showed high interrelationship for magnitude and axis of SIA vector. However there was no statistical significant difference discerned either of magnitude or axis of SIA vectors. (p 0.59, p 0.11).

No significant difference was perceived on comparing means of magnitude and axis of SIA vectors as the t values calculated from student t test unveiled less than the t critical one tail values (Table 3). Analysis of resultant magnitude between SIA version 2.1 and present calculator was shown with pre and post operative keratometric data. T Values are the values calculated by one tailed and two tailed test to find out any comparative difference between the two means. If t value moves closure to zero then there would probably be not rejecting the null hypothesis on the other hand if it is moving towards greater value then the results more likely is against rejecting null hypothesis. In our study there is no difference between t values SIA calculators were compared and t value is closure to zero signifying that null hypothesis was not rejected means there was no difference between two methods of assessment of SIA (Table 4).

Linear regression analysis demonstrated data point's distribution close to trend line that suggested best fit model line. Predictability was assessed by substituting pre operative magnitude of SIA in place of independent variable 'x' in the regression equation $y=2.83+0.95x$ (Fig. 2). Similarly for axis of SIA vector, predictability was assessed by regression equation $y=15.28+0.83x$. Data point's distribution was not close to the trend line suggesting axis of

SIA vector discrepancy as majority of the data points was scattered widely and sparsely (Fig. 3).

Previous methods of surgically induced astigmatism were calculated from subtraction method, polar methods and vector method. Simple subtraction method involves subtracting the post operative average keratometric reading from preoperative reading that was insufficient to address overall change in anterior corneal curvature. Polar analysis of SIA is complicated and involves dioptric conversion in to plus cylinder form that involves laborious work up. Both polar method and vector analysis was followed for construction of SIA calculator version 1.1 and 2.1. Present calculator construction is only based on vector analysis. Vector analysis of SIA is reliable and acceptable method since it takes into account of astigmatic magnitude expressed in diopters and astigmatic axis direction expressed in degrees.

5.1 Similarities and Differences between Calculators

Existing SIA calculator version 1.1 and 2.1 are used to evaluate single case and multiple case analysis respectively however their theoretical aspects of analysis of SIA are similar. Simultaneous representation and measurement of astigmatic magnitude and axis add to the complexity of assessment that can be solved by applying principles of vector-based system. Both of these versions are based on astigmatic vector that assigned a position represented by x and y points.

In the present calculator, keratometric horizontal and vertical meridians were represented on opposite and adjacent coordinates of a right angle triangle to calculate resultant magnitude (hypotenuse) of SIA vector. In this calculator each component of vector was dealt separately for the ease of SIA calculations and understandings. The coordinates of right angle triangle was considered similar to keratometric horizontal and vertical meridians and assigned keratometric value to calculate hypotenuse that represents magnitude of SIA vector. Similarly axis was calculated from the equation $\theta=2 \tan^{-1} \{Kh/Kv\}$, here the value was multiplied by 2 as astigmatic axis repeats itself in 360 degrees. This new SIA calculator was applied for validating in pseudophakic eyes irrespective of incision dimensions.

All keratometric data was converted into plus cylinder format in SIA version 1.1 and 2.1 thus, following principles of polar method was used for calculations for SIA determination. Present calculator was constructed essentially on vector analysis for magnitude of SIA vector. Other similarity was both calculators adopted trigonometric and calculus function for calculating axis of SIA vector and similar results were obtained with our data when verified in SIA versions 1.1 and 2.1 (Table 5). Another similarity was resultant magnitude was calculated after subtracting pre operative values from post operative values.

5.2 Working of New SIA Software

Novel calculator consists of five excel spreadsheets named as pre op magnitude, post op magnitude, pre op axis, post op axis of SIA vector and lastly predictability equations. There are two equations in the new calculator for calculating resultant magnitude and axis of SIA vector while SIA version 2.1 constitutes 6 equations. Vector is shown as containing magnitude and directions in SIA version 2.1 where as the present calculator considers dealing magnitude and axis separately for SIA analysis. Although both calculators showed similar resultant axis while showing variations in resultant magnitude however, there was no statistically significant difference between the two calculators (Table 5).

By simply entering horizontal and vertical keratometric values; software automatically calculates magnitude and axis of SIA vectors. Subtracting pre operative from post operative magnitude or axis of SIA vectors values arrives at resultant magnitude or axis respectively. Predictability for post operative magnitude and axis of SIA vectors can be calculated in the last spreadsheet. Innumerable patients' data entry can be performed with the present new calculator. Proposed formula can be applied in all Microsoft office excel software as calculator was constructed on basic principles of vector analysis.

Other advantages of SIA version 2.1 calculator are that it may also be used to analyze SIA for foldable lenses through temporal approach and when calculating IOL power for toric IOL. A high value of coherence means that SIA value generated is truly representative of the whole data set that is not calculated with present calculator. Both calculators provided a detailed

analysis presented on the pages entitled for detailed report and could be used when publishing scientific studies. Both calculators derived similarly with respect to resultant astigmatic axis calculations. Another difference is predictability equation deduced from regression formula to find out predicated post operative SIA vector is provided with new calculator while predictability equations were not considered in SIA calculator 1.1 and 2.1 versions. Other limitations of present calculator are centroid and coherence facilities that are available in SIA version 1.1 and 2.1 and were not constructed.

5.3 Comparative Analysis of New SIA Calculator

Samar basak developed SIA calculator for single case (SIA soft version 1.1) and multiple case analysis (SIA soft version 2.1) based on vector analysis and reported 6.15 (+/-0.50) seconds to calculate SIA vector with software calculator method compared to 5.27 (+/-0.48) minutes by manual methods and recommended vector analysis is the gold standard for determining SIA. Mean astigmatic resultant magnitude of 0.48 diopters was calculated on present calculator and 0.75 diopters with SIA calculator version 2.1 (Table 5). However existing calculator did not show post operative predictability of magnitude and direction of astigmatic vector formulae for predication [1].

Mikael Dam-Johansen and Thomas Olsen calculated SIA in 197 eyes and reported 0.61 and 0.77 diopters of astigmatic magnitude for 4 mm and 6 mm scleral tunnel phacoemulsification four months after surgery by vector analysis that exhibited different outcomes from the present study results which was performed irrespective of incision dimensions [5]. Jauhari et al. [6] studied SIA on various incision sizes and reported a mean SIA vector of -0.88 (+/- 0.61) diopters at 90 degrees with inverted V incision that was statistically significant by SIA calculator version 2.1. Present study revealed 0.48 (+/- 0.38) diopters as resultant astigmatic magnitude irrespective of incision configuration.

Mallik et al. studied 110 eyes in superior and temporal incision manual cataract surgery cases and reported a mean magnitude of SIA vector of 1.45 (+/- 0.74) diopters in superior group and 0.75 (+/-0.41) diopters in temporal incision category by SIA version 1.1 calculator with Z score of 5.71 with statistically significant

difference. Similar values obtained from the new calculator for temporal incision cataract surgery, revealed 0.48 (+/- 0.38) diopters as magnitude of SIA calculator. However statistical significant difference was not found in the current study either for magnitude or axis of SIA vector [7-8].

Marek et al. [9] reported 0.63 (+/-0.28) diopters of astigmatic magnitude for temporal phacoemulsification with 2.8 mm corneal incision with statistical significant difference comparable to the present study. Naeser et al. [10] demonstrated univariate and bivariate polar analysis method for SIA calculations and reported astigmatic magnitude of 1.02 diopters for 9 mm incision, 0.71 diopters for 5.5 mm and 0.64 diopters for 4 mm corneal incisions. Polar methods were not analyzed in the present study. Ernest et al. study of SIA following squared posterior limbal and clear corneal incisions during phacoemulsification revealed average 0.25 (+/- 0.14) diopters for 2.2 mm incision size. There was no statistical significant difference between two types of incision sites similar to results of present study and SIA calculated from statsoft Inc 'statistica' software [11-12].

Ofir et al. [13] studied SIA by vector analysis for 2.4 mm corneal incision in 70 eyes and compared between three corneal measuring devices (Lenstar LS900, Haag-Streit, Koeniz, Switzerland; IOLMaster 500, Carl Zeiss Meditec, Dublin, CA; and Atlas topographer, Carl Zeiss Meditec) with similar results. Bausch and Lomb keratometry was used to assess SIA in the present study. Hala Ali and Sumith Perera reported a mean SIA vector or 0.5-0.7 diopters following small incision cataract surgery and recommended inclusion of measurements variation of biometric devices when interpreting the results, while calculating SIA using the doctor-hill.com online SIA calculator [14].

Derya et al. [15] reported lower SIA values for superior limbal incision group on the basis of vector analysis although the difference was not statistically significant. Yoon et al. [16] reported a mean SIA of 0.81 and 0.92 diopters respectively for temporal and nasal 3.0 mm clear corneal incision in bilateral phacoemulsification with equivocal astigmatic change at three months follow-up.

Kawahara et al. [17] study calculated astigmatism using the Alpins method that showed no statistical difference in mean SIA score between one handed and two handed phacoemulsification techniques however results

indicated corneal side port in two handed cataract surgery had a torque effect on astigmatic axis. Denoyer et al. [18] recommended consideration of biomechanical features of cornea such as corneal hysteresis and corneal resistance factor for better predictability of refractive outcomes of cataract surgery.

6. LIMITATIONS OF STUDY

SIA magnitude and axis quantified irrespective of incision dimensions and configuration was one of the limitations. Small sample size was chosen for new calculator application as a pilot study to corroborate validity and predictability. Strength of new calculator is in determining accurate axis and post operative predictability of magnitude and axis of SIA vector.

7. CONCLUSION

In conclusion, new SIA calculator provided comparable results with existing calculators in addition to predictability judgment on astigmatic quantification and axis direction. Added value of present new SIA calculator is magnitude and axis separately dealt for ease of understanding and knowledge on predictability on post operative SIA vector was highlighted. Ophthalmic surgeons with fair knowledge concerning Microsoft office excel software 2007 are sufficient to enter their patients pre and post operative keratometric readings for appraising surgically induced astigmatic quantifications and provide maximum post operative visual rehabilitation with prescription of minimum amount of induced astigmatic error.

DISCLAIMER

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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