

Original Research Article

Validity of Novel Microsoft excel Software for Calculating Surgically Induced Astigmatism

Abstract

Purpose: Present study investigated validity and predictability of new software calculator for surgically induced astigmatism.

Techniques and methods: This experimental study investigated astigmatic calculator that was designed based on Pythagorean principle, trigonometric functions using Microsoft office excel 2007. Astigmatic magnitude quantified in diopters and axis direction scaled in degrees. Calculator applicability investigated and analyzed on 23 cataractous eyes that underwent temporal scleral incision surgery in the bag/ciliary sulcus intraocular lens implantation. Pre and post operative anterior corneal curvature measured with Bausch and lamb keratometer. Similar and difference on statistical significance with existing calculators considered as primary and secondary outcomes respectively. Statistical analyses performed by Microsoft excel.

Results: Population mean age was 59.35 (+/- 9.47) years with 13 males (56.52%) and 10 (43.48%) females. Mean pre and post operative astigmatic magnitude of 62.87 (+/- 2.31) and 62.80 (+/- 2.27) diopters calculated. Resultant and adjusted astigmatic magnitude was 0.07 (+/- 0.92) and 0.70 (+/- 0.58) diopters. Mean pre and post operative astigmatic axis was 89.48 (+/- 1.37) and 89.16 (+/- 1.34) degrees. Resultant and adjusted astigmatic axis was 0.32 (+/- 1.57) and 1.24 (+/- 0.97) degrees. Mann-Whitney U test revealed z values of 0.11 and 0.71 for astigmatic vector magnitude and axis respectively. Pearson's coefficient (r) of 0.92 and 0.85, coefficient of determinations (R^2) of 0.34 and 0.12 for astigmatic magnitudes and axes found respectively. T values of 0.31 and 1.06 calculated for astigmatic magnitude and axis by student chi-square test. *p* value less than 0.05 considered as statistically significant difference at 95% confident intervals. Validity compared with existing surgically induced astigmatism calculators 1.1 and 2.1 versions. Predictability assessed by $y=4.07+0.94x$ and $y=58.24+0.35x$ equations.

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

Keywords: surgery induced astigmatism (SIA), Pythagorean principle, trigonometric and calculus formulae, astigmatic magnitude and direction

Introduction

Unexpected and post cataract surgical refractive astigmatic surprises not uncommon in clinical practice. Understanding surgically induced astigmatism enlightens modifications in astigmatic control that provides near emmetropic vision. Clinical prediction about pre and postoperative astigmatic magnitude and axis after cataract surgery improves acceptable modifications of surgeons' incision techniques that provide least astigmatic amount to the patients. Surgically induced astigmatism (SIA) determination uses subtraction method, vector analysis, vector decomposition, Cravy's vertical vector, Naeser's polar values and algebraic method for calculations.¹⁻³

Recently minimum standard format for reporting astigmatic outcomes and terminology to defined astigmatism was formulated by astigmatic project group of the American national standard institute (ANSI).⁴ Because astigmatism is manifested in magnitude and direction, principles of vector Cartesian coordinate system calculations adapted in the present study. Research rationale of this novel simple Microsoft (MS) excel 2007 software construction is to validate and correlate with existing astigmatic method software calculators. Furthermore predictability of post operative SIA magnitude and axis was evaluated in pseudophakic eyes.

Subjects and Methods

Present experimental study 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. The project was approved by an institutional ethics committee and conducted in accordance with the Declarations of Helsinki of 1975. A new yet a simple MS excel software functions employed to analyze SIA on the basis of Cartesian coordinate vector system. Twenty three eyes of 20 cataracts patients included after three months of surgery as refraction stabilizes by this time correlated with previous prospective study.⁵ Procedure followed was temporal scleral incision cataract surgery in the bag/sulcus fixated intra ocular lens implantation. Eyes with intra operative complications excluded. Pre and post operative keratometric horizontal (Kh) and vertical meridians (Kv) measured with specified axis by Bausch and Lomb keratometer. (Appasamy KMS 6)

MS excel SIA software-Basic Principles

Microsoft Excel spread sheet opened for SIA calculator construction. Formulae were constructed accordingly as astigmatism characterizes power in diopters and axis direction in degrees abide by vector analysis system. Surgically induced astigmatic magnitude expressed in diopters and axis direction in degrees. 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 SIA magnitude.

Pythagorean principle applies to right angle triangles composed of adjacent and opposite sides with hypotenuse. (Figure 1) 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 side that represents net astigmatic magnitude in diopters. (Figure 1) Pre and post operative keratometric horizontal and vertical values substituted for opposite coordinate (a) and adjacent coordinate (b) respectively. Resultant displacement vector is SIA magnitude in place of hypotenuse value that is expressed in diopters of astigmatism.

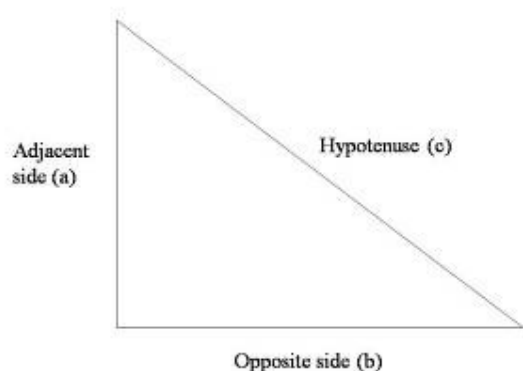


Figure 1 Calculation of SIA vector magnitude based on Pythagorean principle

Figure 1 Calculation of SIA vector magnitude based on Pythagorean principle

For example 1

Pre operative cylinder -1.00 DX90 degrees

Post operative cylinder -2.00 DX 180degrees

$$c^2 = a^2 + b^2$$

$1+4=\text{square root of } 5=2.2 \text{ D}$ which is the resultant displaced SIA vector magnitude.

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

Adjacent side

opposite side

$$\begin{aligned} \text{Cosine } \emptyset &= \frac{\text{Adjacent side}}{\text{Hypotenuse}} & \text{sine } \emptyset &= \frac{\text{Opposite side}}{\text{hypotenuse}} \end{aligned}$$

84

85 Therefore, adjacent side = hypotenuse $\cos \emptyset$ and opposite side = hypotenuse $\sin \emptyset$. This formula is for
86 understanding law of cosines to calculate the vertical and horizontal components when hypotenuse is known and
87 vice versa. However we want to find out the angle of hypotenuse which is the SIA axis. Value for astigmatic angle
88 is calculated from tangent formula as shown below.

89

$$\begin{aligned} \text{Tan } \emptyset &= \frac{\text{Opposite side (horizontal curvature)}}{\text{Adjacent side (vertical curvature)}} & \text{OR} \end{aligned}$$

93

94 $\emptyset = \tan^{-1} \{Kh/Kv\}$ that is derived from referring to tables and Microsoft excel trigonometry functions. Since
95 astigmatic axis doubles in direction, the formula is multiplied by 2. Then $\emptyset = 2 \tan^{-1} \{Kh/Kv\}$ which is the final
96 formula for calculating pre and post operative resultant SIA axes in degrees.

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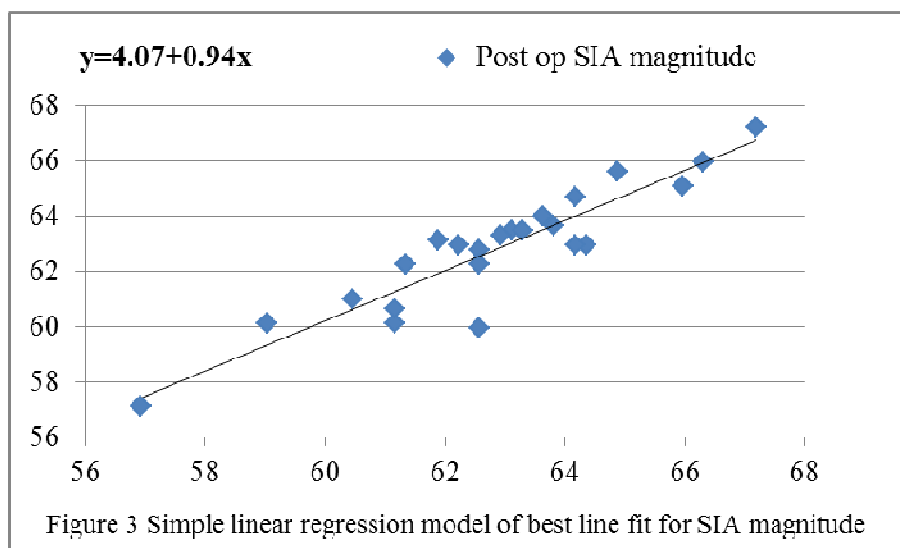
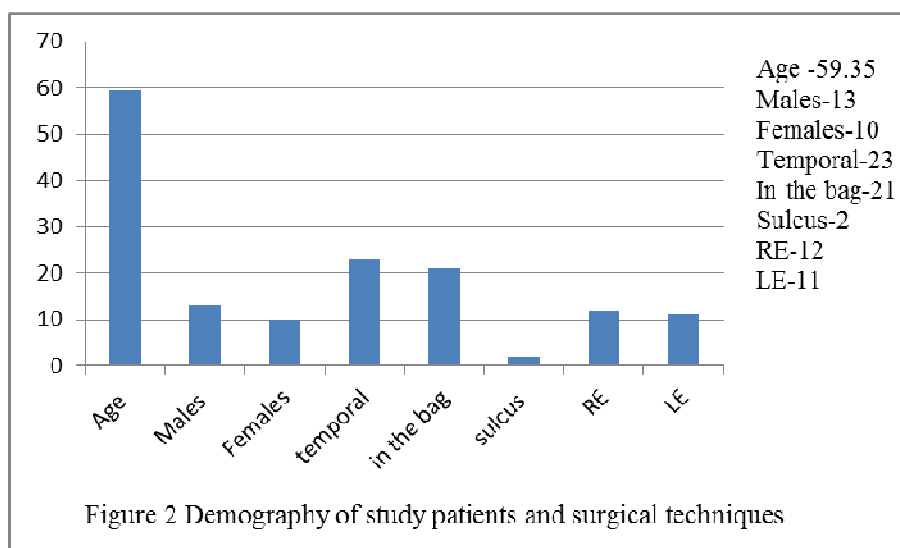
98 For example, Substituting our pre operative keratometric readings, when Kh is 42.74 diopters and Kv is 42.25
99 diopters in the formula we get, $\text{Tan } \emptyset = 42.74/42.25$ is equal to 0.99. Because $\emptyset = 2 \tan^{-1} \{0.99\}$ which is equal to
100 0.78 radians converted into 89.34 degrees automatically in present software calculator. Therefore practically
101 resultant SIA axis becomes 90 degrees. Subtracting post operative SIA axis from pre operative SIA axis, resultant
102 SIA axis is obtained. This new SIA calculator applied for validation in pseudophakic eyes irrespective of
103 incision dimensions however scleral incisions ranged from 5.5 mm to 8.00 mm and the results from new
104 calculator compared with presently available SIA calculator version 1.1 and 2.1.

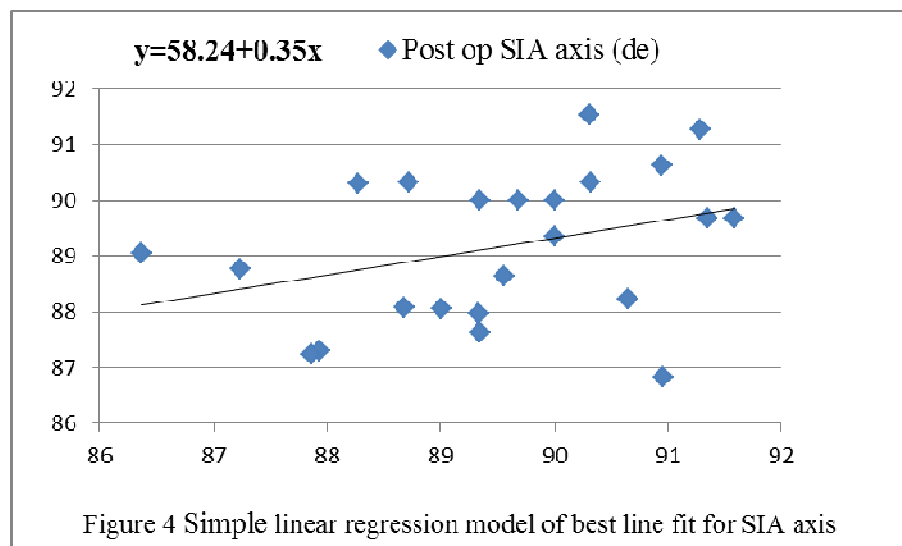
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106 Results

107 Surgically induced astigmatism in 23 pseudophakic eyes of 20 patients studied by applying newly formulated
108 Microsoft Excel software calculator. Mean age was 59.35 (+/-1.98) years with 13 males (56.52%) and 10
109 (43.48%) females. All cases operated from temporal side and in the bag intraocular lens placement performed in
110 21 (91.30%) eyes and sulcus implantation in 2 (8.70%) eyes by same surgeon. Right eyes were 12 (52.17%) with

111 11 (47.23%) left eyes. (Figure 2) Linear relationship and line of best fit between pre and post operative SIA
 112 magnitude and axis is shown in Figure 3 and 4.
 113





Descriptive statistics of pre and post operative calculations with resultant and adjusted SIA magnitude in diopters is shown in Table 1. Descriptive statistics of pre and post operative results in addition to resultant and adjusted SIA axis in degrees is shown in Table 2. Student t test accomplished to calculate p value and its significance for SIA magnitude and axis. Statistical significant levels set at 0.05 p value. Regression equation adopted to find out predictability of astigmatic vectors and values for 'y', that is calculated from the equation $y=a+bx$, where 'y' is dependant variable, 'a' is intercept and 'b' is slope for SIA magnitude and axis. (Table 3) Validity tested by comparing with available SIA calculator version 1.1 and 2.1.

Table 1 Descriptive statistics of surgically induced astigmatic magnitude in diopters (D)

n=23	Mean	Standard deviation	Standard error (SEM)	Minimum	Maximum
Pre op SIA magnitude	62.87 D	+/- 2.31 D	0.48	56.93 D	67.20 D
Post op SIA magnitude	62.80 D	+/- 2.27 D	0.47	57.11 D	67.20 D
Resultant SIA magnitude	0.07 D	+/- 0.92 D	0.19	-1.20 D	2.64 D
Adjusted SIA magnitude	0.70 D	+/- 0.58 D	0.12	0.002 D	2.64 D

Table 2 Descriptive statistics of surgically induced astigmatic axes in degrees (d)

n=23	Mean	Standard deviation	Standard error	Minimum	Maximum
Pre op SIA axis	89.48 d	+/- 1.37 d	0.29	86.37 d	91.58 d
Post op SIA axis	89.16 d	+/- 1.34 d	0.28	86.82 d	91.54 d

Resultant SIA axis	0.32 d	+/- 1.57 d	0.33	-2.67 d	4.14 d
Adjusted SIA axis	1.24 d	+/- 0.97 d	0.20	0.008 d	4.14 d

Table 3 Student t test results and regression equations for SIA magnitude and axes

	SIA magnitude in Diopters (D)	SIA axis in degrees
Pearson correlation (r)	0.92	0.34
Coefficient of determination (R^2)	0.85	0.12
Degree of freedom	22	22
T value	0.31	1.06
t critical one tail value	1.72	1.72
p value	0.38	0.15
Regression equation	$y=4.07+0.94x$	$y=58.24+0.35x$
Confident intervals	-1.30 to 1.42	-0.50 to 1.12

Discussion

Present study attempted to design a new SIA calculator using Microsoft office excel 2007 functions and applied on 23 psuedophakic eyes intended for study on anterior corneal curvature analysis following temporal scleral incision cataract surgery.

Surgically induced astigmatism is calculated from subtraction method, vector method and polar methods. Simple subtraction method involves subtracting the post operative average keratometric reading from preoperative reading that is insufficient to address overall change in anterior corneal curvature. 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. Polar analysis of SIA is complicated and involves diopteric conversion in to plus cylinder form that involves laborious work up.

Present SIA calculator architected on the basis of vector analysis since astigmatism constitutes cylindrical power and axis due to perpendicularity of principle meridians in most cases. Pythagorean Theorem and trigonometric functions used to arrive at astigmatic quantity in magnitude and axis in direction. Resultant SIA

magnitude and axis calculated after subtracting post operative values from pre operative values. Pre and post operative corneal power unchanged and resultant astigmatic magnitude was similar with narrow standard error of mean. (SEM) Resultant displaced SIA magnitude was 0.07 with narrowed standard deviation and SEM compared to previous SIA calculator version 2.1 that showed resultant magnitudes of 0.09 which is closure to the results of present new SIA calculator. Resultant corneal dioptric power ranged from -1.20 diopters to +2.64 diopters in the present study. Adjusted SIA magnitudes calculated after removing minus component that showed SIA magnitude of 0.70 diopters that was not calculated from the previous SIA calculator.¹

Mean pre and post of SIA axis seems to be similar with equivalent standard deviation and SEM. Resultant SIA axis displaced by 0.32 degrees where as adjusted SIA axis varied by 1.24 degrees. Resultant SIA axis was displaced in a range from -2.67 degrees to 4.14 degrees. (Table 2) Pearson's correlation coefficient and coefficient of determination showed high interrelationship for SIA magnitude however showed poor correlation for axis. There was no statistical significant difference discerned either of SIA magnitude or axis. (p 0.38, p 0.15) No significant difference perceived on comparing means of SIA magnitude and axis as the t value calculated from student t test unveiled less than the t critical one tail values. (Table 3)

Linear regression analysis demonstrated data point distribution closure to trend line that suggested best fit line. Predictability assessed by substituting pre operative SIA magnitude in place of independent variable 'x' in the regression equation $y=4.07+0.94x$. (Figure 3) Similarly for SIA axis, predictability assessed by regression equation $y=58.24+0.35x$. Data points' distribution was not closure to trend line suggesting SIA axis discrepancy as majority of data points scattering widely and sparsely. (Figure 4)

Working of new SIA software

Novel calculator consists of five excel spreadsheets named as pre op SIA, post op SIA, pre op SIA axis, post op SIA axis and lastly predictability for right and left eyes. Simply enter horizontal and vertical keratometric values; automatically software calculates SIA magnitude and axis. Subtracting post operative from pre operative SIA magnitude or axis arrives at resultant magnitude or axis respectively. Predictability for post operative SIA magnitude and axis can be calculated in the last spreadsheet. Innumerable patients' data entry can be performed with the present new calculator

Comparative analysis of new SIA calculator

Samar K 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. Astigmatic magnitude of 0.09 diopters calculated on computing our patient data in both versions and procured 0.07 diopters with accurate axis direction from present study calculator. However existing calculator did not show post operative predictability formulae to prognosticate astigmatic vector magnitude and direction.¹

Dam johansen M 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.⁶ Jauhari N studied SIA 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 0.07 (+/- 0.92) diopters as resultant astigmatic magnitude irrespective of incision configuration.⁷

Mallik VK studied 110 eyes in superior and temporal incision manual cataract surgery cases and reported a mean SIA magnitude of 1.45 (+/- 0.74) diopters in superior group and 0.75 (+/-0.41) diopters in temporal incision category by SIA version 1.0 calculator with Z score of 5.71 with statistically significant difference. Similar values obtained from present new calculator for temporal incision cataract surgery, that revealed 0.70 (+/- 0.58) diopters as adjusted SIA magnitude. However statistical significant difference not found in the current study either for SIA vector magnitude or axis.⁸⁻⁹

Marek R 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 outcomes.¹⁰ Naeser K 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.¹¹ Polar methods not analyzed in the present study. Ernest 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.¹²⁻¹⁴

Ofir S 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 lamb keratometry used to assess SIA in the present study.¹⁵ Hala M Ali 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, when calculating SIA using the doctor-hill.com online SIA calculator.¹⁶

Derya BK reported lower SIA astigmatic values for superior limbal incision group on the basis of vector analysis although the difference was not statistically significant.¹⁷ Yoon JH reported 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.¹⁸

Kawahara A 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.¹⁹ Denoyer A recommended consideration of biomechanical features of cornea such as corneal hysteresis and corneal resistance factor for better predictability of refractive outcomes of cataract surgery.²⁰

Limitations of study

SIA magnitude and axis quantified irrespective of incision dimensions and configuration. Small sample size was chosen for new calculator application to corroborate validity and predictability. Strength of new calculator is in determining accurate axis and post operative predictability of SIA magnitude and axis.

In conclusion, new SIA calculator provided comparable results with existing calculators in addition to predictability judgment on astigmatic quantification and axis direction. 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.

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