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**“A COMPARATIVE STUDY OF CORRECTION OF PRE-EXISTING CORNEAL ASTIGMATISM BETWEEN INCISION ON THE STEEPEST MERIDIAN AND LIMBAL RELAXING INCISIONS IN PHACOEMULSIFICATION SURGERY – A ONE YEAR RANDOMIZED CONTROL TRIAL AT KLES DR. PRABHAKAR KORE HOSPITAL AND MEDICAL RESEARCH CENTRE, BELAGAVI”**

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## **Dissertation**

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**KLE ACADEMY OF HIGHER EDUCATION AND RESEARCH,  
BELAGAVI, KARNATAKA**

**Endorsement by the Head Of Department,  
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This is to certify that the dissertation/thesis entitled “**A COMPARATIVE STUDY OF CORRECTION OF PRE-EXISTING CORNEAL ASTIGMATISM BETWEEN INCISION ON THE STEEPEST MERIDIAN AND LIMBAL RELAXING INCISIONS IN PHACOEMULSIFICATION SURGERY – A ONE YEAR RANDOMIZED CONTROL TRIAL AT KLES DR. PRABHAKAR KORE HOSPITAL AND MEDICAL RESEARCH CENTRE, BELAGAVI**” is a bonafide and genuine research work carried out by **REG. NO. BK0116005**.

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## LIST OF ABBREVIATIONS USED

AE	–	Angle of error
AK	–	Astigmatic keratotomy
ATR	–	Against the rule
BCVA	–	Best corrected visual acuity
CE	–	Correction index
CRI	–	Corneal relaxing incision
D	–	Diopters
ECCE	–	Extracapsular cataract extraction
FE	–	Flattening effect
IOL	–	Intraocular lens
ISM	–	Incision on the steepest meridian
K <sub>H</sub>	–	Horizontal meridian
K <sub>V</sub>	–	Vertical meridian
LASIK	–	Laser in situ keratomileusis
LRI	–	Limbal relaxing incisions
NAPA	–	Nichamin age and pachymetry adjusted
OCCI	–	Opposite side clear corneal incision
ORA	–	Ocular residual astigmatism
PEA	–	Pre-existing astigmatism
PMMA	–	Polymethylmethacrylate
PRK	–	Photorefractive keratectomy
SIA	–	Surgically induced astigmatism
SICS	–	Small incision cataract surgery
TIA	–	Target induced astigmatism
UCVA	–	Uncorrected visual acuity
WTR	–	With the rule

## **ABSTRACT**

### **Background and objectives**

As physiological astigmatism is practically invariable, upto 95% of eyes have some clinically detectable astigmatism. More than 1.0 D of pre-operative corneal astigmatism is seen in approximately 40 % of the patients who undergo cataract surgery. The cataract surgery has evolved from the ancient technique of couching to modern manual SICS and phacoemulsification. Earlier, ECCE induced more postoperative astigmatism due to longer incisions and sutures. With the advent of phacoemulsification through a small clear corneal incision and foldable intraocular lens, the focus has transformed from reduction of surgically induced astigmatism to correction of pre-existing astigmatism, if any present.

Various techniques have been described for the correction of astigmatism during the cataract surgery like incision on steep meridian, limbal relaxing incisions, toric intraocular lens and laser vision correction. The purpose of this study is to compare the effect of phacoemulsification incision on the steepest meridian alone and in combination with paired limbal relaxing incisions in reducing the pre-existing corneal astigmatism.

1. To compare the clear corneal phacoemulsification incision on the steepest meridian alone and along with limbal relaxing incisions (LRIs) for the reduction of preexisting corneal astigmatism at the time of cataract surgery.
2. To assess the safety and efficacy of limbal relaxing incisions for the correction of pre-existing corneal astigmatism during phacoemulsification surgery.

## **Methodology**

The present one - year randomized control trial was conducted in the Department of Ophthalmology, KLES Dr. Prabhakar Kore hospital and Medical Research Centre, Belagavi on patients undergoing cataract surgery during the period of January 2017 – December 2017. The patients with pre-existing astigmatism in the range of 0.5D – 2.5 D were included in the study and underwent either phacoemulsification with incision on the steepest meridian (Group A) or phacoemulsification along with the paired limbal relaxing incisions placed on the steepest meridian (Group B). They were evaluated at 3 weeks and 6 weeks postoperatively.

## **Results**

In the present study, the mean age in Group A was  $61.87 \pm 10.12$  years and Group B was  $66.17 \pm 8.30$  years with majority being in the range of 61-70 years. 57% patients were male and 43 % patients were female in Group A and 63% patients were male and 37% patients were female in Group B.

In this study, 37% patients in Group A and 17% patients in Group B had pre-existing astigmatism in the range of 0.5 D – 1 D, 53% in the range of 1D – 1.5D in both groups, 10% in Group A and 13% in Group B in the range of 1.5 D – 2 D and no patient in Group A and 17% in Group B had pre-existing astigmatism in the range of 2 D – 2.5 D.

In the present study, majority of the patients in Group A that is 22 (73%) had post-operative astigmatism in the range of 0.0 – 0.5 D, followed by 08 patients that is 27% in the range of 0.5 – 1D. In Group B, 28 patients that is 93% had post-operative

astigmatism in the range of 0.0 – 0.5D whereas only 2 patients (7%) had post-operative astigmatism in the range of 0.5 – 1D.

In Group A, the mean pre-operative and post-operative astigmatism was  $1.01 \pm 0.27$  D and  $0.45 \pm 0.28$  D respectively which was highly significant statistically ( $p < 0.0001$ ). Similarly, in Group B, the mean pre-operative and postoperative astigmatism was  $1.27 \pm 0.53$  D and  $0.34 \pm 0.20$  D respectively which was highly significant statistically ( $p < 0.001$ ). The magnitude of astigmatic correction was more in the LRI group ( $0.93 \pm 0.33$ ) compared to incision on the steep meridian group ( $0.56 \pm 0.01$ ) as LRI corrected upto 2.5 D of astigmatism.

The mean surgically induced astigmatism in Group A was 0.67 with the standard deviation of 0.27 and in Group B the mean surgically induced astigmatism was 1.02 with the standard deviation of 0.46. This comparison of difference of surgically induced astigmatism between the two groups was highly significant statistically ( $p = 0.0007$ ).

In this study, the mean correction index in Group A was  $0.75 \pm 0.4$  and in Group B the mean correction index was  $0.82 \pm 0.26$  which was not statistically significant. In the present study, the mean flattening effect in Group A was 0.67 with the standard deviation of 0.27 and the mean flattening effect in Group B was 1.02 with the standard deviation of 0.46. The comparison between the two groups was highly significant statistically ( $p = 0.0007$ ).

In this study, by taking the phacoemulsification incision on the steepest meridian on the basis of pre-existing astigmatism, that is in Group A, the mean keratometric difference was  $0.95 \pm 0.92$  which was statistically significant ( $p < 0.001$ ). By placing the paired limbal relaxing incisions on the steepest meridian along with

phacoemulsification incision as in Group B, the mean keratometric difference was  $1.08 \pm 0.96$  which was statistically significant ( $p < 0.001$ )

The visual rehabilitation was good. 93% patients in Group A and 97% patients in Group B had UCVA in the range of 6/12 – 6/6 and 97 % patients in Group A and all the patients in group B had BCVA in the range of 6/12 – 6/6.

### **Conclusion and interpretation**

Clear Corneal phacoemulsification incision placed at the steepest meridian and paired limbal relaxing incisions along with phacoemulsification incision helps in reducing the pre-existing corneal astigmatism. Mild cases of astigmatism can be treated by incision on steepest meridian alone whereas in cases of moderate to severe astigmatism, limbal relaxing incisions provide a better option.

**Key words:** Phacoemulsification, Pre-existing astigmatism, Limbal relaxing incisions

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## **INTRODUCTION**

As physiological astigmatism is practically invariable, upto 95% of eyes have some clinically detectable astigmatism. <sup>(1,2)</sup> Astigmatism of more than 0.50 diopters (D) is seen in 44%, greater than 1.00 D in 10% and 1.50 D or more in 8% of the general population. <sup>(1,3)</sup> More than 1.0 D of pre-operative corneal astigmatism is seen in approximately 40 % of the patients who undergo cataract surgery. <sup>(4)</sup>

One of the important goals of cataract surgery over the course of time is the management of astigmatism. Earlier, intracapsular cataract extraction left the patient aphakic. Then extracapsular cataract extraction with intraocular lens came into picture which corrected aphakia but induced more post-operative astigmatism because of larger incision.

Introduction of phacoemulsification by Kelman in 1967 is considered as the major milestone in the field of cataract surgery. This procedure significantly reduced the amount of surgically induced astigmatism as the size of the incision was smaller compared to ECCE. With the newer developments in phacoemulsification devices, different operating techniques, better quality instruments and most of all the advent of foldable lenses has changed the whole perspective of cataract surgery where the focus has shifted from managing postoperative astigmatism to reducing pre-existing astigmatism.

Today, cataract surgery is considered as a refractive surgery, where the surgical technique has transformed from mere cataract extraction to providing best quality of vision aiming pseudophakic emmetropia, with no spectacle dependence.

The spherical component of refractive error is corrected with accurate IOL power calculations while the corneal astigmatism remains uncorrected.

There are various modalities that deal with the pre-existing astigmatism intraoperatively as well as different approaches that deal with residual or induced astigmatism post-operatively. They include on axis cataract incision, corneal relaxing incision, opposite clear corneal incision, limbal relaxing incisions, toric IOLs, piggy bag lenses and epikeratophakia.

Preexisting corneal astigmatism can be reduced through different incisional techniques during cataract surgery which flattens the steep axis of cornea. It includes placing clear corneal cataract incision on steepest meridian based on the type of pre-operative astigmatism or applying relaxing incisions at the limbus or in the cornea.

The corneal refractive changes depend on the size and location of the corneal incision. The smaller incisions induce lesser surgically induced astigmatism and result in better optical quality. However; pre-operative assessment to know the axis and magnitude along with the cause of astigmatism is the most important and critical step before treating any patient with astigmatism. It also helps the treating surgeon to decide which technique is appropriate for the patient.

The aim of this study is to compare the clear corneal phacoemulsification incision on the steepest meridian and paired limbal relaxing incisions (LRIs) along with cataract incision, in the correction of preexisting corneal astigmatism during cataract surgery.

## **AIMS AND OBJECTIVES**

### **1. PRIMARY:**

To compare limbal relaxing incisions (LRIs) and the clear corneal incision on the steepest meridian (ISM) for the reduction of pre-existing corneal astigmatism at the time of phacoemulsification surgery.

### **2. SECONDARY:**

To assess the safety and efficacy of limbal relaxing incisions for the correction of pre-existing corneal astigmatism during the phacoemulsification surgery.

## **REVIEW OF LITERATURE**

The word cataract, which means both an opacity of the lens and a torrent of water is derived from the Greek word *kataráktis* meaning the fall of water.

### **Evolution of cataract surgery:**

Cataract surgery is being performed since centuries. The concept of cataract surgery as a mere extractive procedure designed to overcome visual impairment of lens opacity has now completely transformed into the new, broader paradigm of refractive surgery with no spectacle dependence.

#### ➤ **Era of couching:**

Couching is one of the ancient surgical techniques practiced by Maharshi Sushruta, an Indian Surgeon, as early as 800 B.C. In this procedure ‘couching needle’ which was a curved needle was used to push the lens posteriorly and out of the visual axis. <sup>(5)</sup>

#### ➤ **Era of early extracapsular and intracapsular cataract extraction:**

- Jacques Daviel, a French ophthalmologist, was the first person to perform extracapsular cataract extraction in 1747 by a limbal section of 180° in the inferior half of eye.
- In 1865 Von Graefe designed Graefe cataract knife through which he made the superior limbal section.
- Though Samuel Sharp was the first person to advocate intracapsular cataract extraction in 1773, the technique was popularized by Pagenstecher in 1877 who delivered the lens complete in its capsule by indenting the cornea in front of the limbus.

➤ **Era of modern extracapsular cataract extraction:**

- From 1945, planned extracapsular cataract extraction came into practice where the incision size was reduced to 8-12 mm.
- In 1949, the first Intraocular lens was implanted behind the pupil by Harold Ridley. The implant was made of an inflexible material called polymethylmethacrylate (PMMA).
- Kratz and Sanders proved that smaller incisions were better and produced less early induced astigmatism in 1982.
- In 1990, Richard Kratz introduced the concept of scleral tunnel incision.
- Michael Mc Farland demonstrated the development of a sutureless incision in late 1990. He showed that the subsequent closure of scleral tunnel incision was due to posterior corneal lip acting as one-way valve imparting self-sealing characteristics.
- Manual small incision cataract surgery was developed over the years (1983-2003) by Keener, Fry, Bluementhal which proved better than conventional ECCE.
- The most remarkable development in cataract surgery was the technique of phacoemulsification introduced by Charles D. Kelman in 1967, which gained popularity after 1980.
- In 1992, Howard Fine introduced clear corneal incisions in phacoemulsification.

**Advantages of Phacoemulsification over extra capsular cataract extraction:**

- Fast visual recovery.
- Small and sutureless self-sealing incision.
- Minimal astigmatism.
- Decentration of intra ocular lens is less as it is in the bag.
- Less chances of iris injury intraoperatively.

- Less chances of wound leak, flat anterior chamber and infection.
- Eye remains quite being sutureless.
- Photophobia and foreign body sensation is minimal.
- Hospitalization and suture removal not needed.
- Chances of vitreous loss and cystoid macular edema are less.
- Postoperative retinal examination is possible soon after surgery because of clear cornea.
- Patient rehabilitation is faster as stay is not required and early return to work is possible.

Pallin SL et.al compared astigmatism after phacoemulsification and conventional extra capsular cataract extraction and concluded that phacoemulsification group had less postoperative astigmatism than conventional extra capsular cataract extraction group. <sup>(6)</sup>

Small incision cataract surgery is still a popular technique and serves as an inexpensive alternate option to phacoemulsification in developing countries even though phacoemulsification has few advantages over SICS.

**Merits of phacoemulsification:**

- Topical anaesthesia
- Post-operative congestion is minimal as performed through clear corneal incision
- Small incision (2.8 - 3.2 mm)
- Less corneal complications
- Visual rehabilitation is comparatively quicker
- Post-operative astigmatism is less because of the smaller incision.

Dr. Fine IH developed the clear corneal incision which had obvious advantages over scleral tunnel incisions like less bleeding, prevention of cautery and induced astigmatism, view during surgery is unhampered by conjunctival flap and a good visualization of intraocular structures during surgery. <sup>(7)</sup>

➤ **Era of foldable intraocular lenses:**

The journey from Sir Harold Ridley's invention of intraocular lens to the introduction of foldable IOLs has been possible by the great work of many contributors. The foldable IOL allowed the surgeon to implant the lens without enlarging 3-mm phacoemulsification incision.

The foldable lens from a conventional relatively rigid implant had the ability to undergo deformation and also reformation after insertion. These foldable intraocular lenses fulfilled a prerequisite of ophthalmic surgeon – Extraction of cataractous lens and implantation of intraocular lens through a smallest incision.

Neuman AC et.al compared surgically induced astigmatism between phacoemulsification with silicone foldable IOLs and rigid PMMA IOL through 6 mm incision and conventional extra capsular cataract extraction through 10 mm incision. At the end of 3 and 6 months post operatively, the mean induced astigmatism was less in the foldable IOL group compared to conventional extra capsular cataract extraction and PMMA IOL group. <sup>(8)</sup>

➤ **The 'refractivization' of cataract surgery:**

By the end of 2000, cataract surgery was refractive surgery. It aimed at not only removal of cataractous lens but also correction of pre-existing spherical as well as cylindrical component of the refraction.

With the introduction of intraocular lens, the spherical component of refractive error was eliminated through a meticulous calculation of IOL power whereas corneal astigmatism remained uncorrected. Despite the use of small incisions, less manipulation, better wound closure and innovative technical advancements, astigmatism was still a problem.

The history of surgical treatment for astigmatism dates back to the late 1800s. AK appears to have been the first refractive corneal procedure performed by ophthalmologists. Based on the Gauss's law for a perfectly elastic dome any change in one axis, results in an equal or comparable change in the opposite axis. <sup>(9)</sup>

- Snellen suggested that placing a corneal incision perpendicular to the steep meridian might cause corneal flattening in that meridian. <sup>(10)</sup>
- In 1885, Schiötz reduced a higher degree of iatrogenic astigmatism, occurred after cataract surgery by placing a penetrating limbal incision in the steep meridian. <sup>(11)</sup>
- Idiopathic astigmatism was reduced by Faber, using perforating anterior transverse incisions. <sup>(12)</sup>
- Non-penetrating incisions to correct astigmatism was first reported by Lucciola in 1886. <sup>(13)</sup>
- In 1894, Bates <sup>(14)</sup> described patients in whom flattening of the cornea occurred in the meridian where a surgical or traumatic scar intersected. He set down few basic principles of astigmatic surgery –
  - The radius of curvature is lengthened in the meridian perpendicular to the corneal incision and there is no effect on any other meridian.
  - The astigmatism produced is permanent after a length of time – at least a month after the cornea has healed.

- The amount of astigmatism produced is greater near the centre of the cornea
- He recognized the ability of relaxing incisions to produce flattening of steep curvature.
- Lans <sup>(15)</sup> suggested that flattening in the meridian perpendicular to a transverse incision was associated with steepening in the opposite meridian.
- In 1940s, Sato <sup>(16,17,18)</sup> investigated radial and astigmatic keratotomy and demonstrated that transverse incisions simultaneously flatten both steep and flatter meridian.
- Thornton <sup>(19)</sup> proposed placement of paired arcuate incisions at the 7.0 mm and 8.0 mm optical zones, considering age factor and timing after surgery, while Chayez et al <sup>(20)</sup> recommended optical zone sizes as small as 5.0 mm.
- Nichamin developed *Intralimbal relaxing incision nomogram for modern phaco surgery* for correction of both against-the-rule and with-the-rule astigmatism as per the age with a blade-depth setting of 600  $\mu\text{m}$ . <sup>(21)</sup>

**History and fundamentals of astigmatism:**

- In 1801, Thomas Young first described ocular astigmatism and Airy in 1827 used cylindrical lens to correct astigmatism.
- In 1862, Knapp and Donders characterized corneal astigmatism and Donders described regular astigmatism in 1864.
- In 1869, Snellen suggested that corneal astigmatism can be reduced by placing the incision on the steep axis. <sup>(10)</sup>

The term astigmatism is derived from Latin word “Stigma” (meaning a point). Thus astigmatism means “without a point”. It is the type of refractive anomaly in which no point focus is formed owing to the unequal refraction of the incident light by the dioptric system of the eye in different meridians. <sup>(22)</sup>

Miller Stephen J defined astigmatism as an “error of refraction in which a point of light cannot be made to produce a punctate image upon the retina by a correcting spherical lens”. There are two principal meridians, one with the greatest power and the other with the least. <sup>(23)</sup>

**Classification:**

A) Regular Astigmatism

- i) With the rule
- ii) Against the rule
- iii) Oblique
- iv) Bi-oblique

B) Irregular Astigmatism

**Regular Astigmatism:**

Here, the two principal meridians i.e. direction of greatest and least curvatures of cornea lies at right angles to one another. This is determined by manifest refraction and manual keratometry.

*i) With the Rule (Direct) (WTR):*

It is a physiological type where in the vertical curve is greater than the horizontal i.e. the meridian with the greatest refractive power is near vertical in orientation or close to 90° or the meridian of least curvature makes an angle of less than 30° with horizontal plane.

ii) Against the Rule (ATR):

The meridian of least curvature makes an angle of less than  $30^\circ$  with vertical plane or the meridian with greatest refractive power is near the horizontal in orientation or close to  $180^\circ$ .

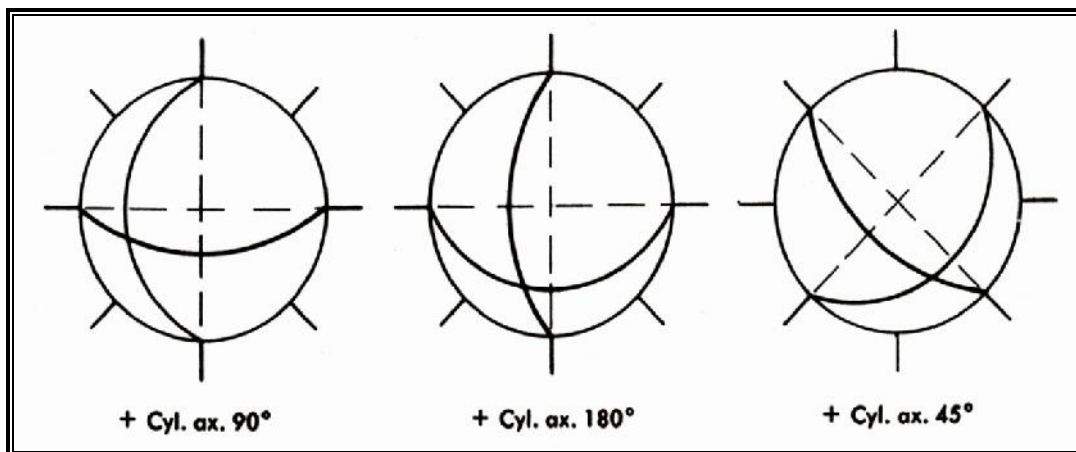
iii) Oblique Astigmatism:

The principle meridians are greater than  $30^\circ$  from the vertical or horizontal meridian but still at right angles to each other.

iv) Bi-oblique Astigmatism:

The principle meridians are not at right angle to each other.

**FIGURE NO – 1: CORNEAL ASTIGMATISM**



**With the rule**

**Against the Rule**

**Oblique**

**Refractive types of regular astigmatism:**

**Simple Astigmatism:**

Where one of the foci falls upon the retina and the other focus may fall in front or behind the retina i.e. –

- a) Simple hypermetropic astigmatism: Where one of the foci falls on retina and the other falls behind the retina.
- b) Simple myopic Astigmatism: One of the foci falls on retina and the other falls in front of the retina.

**Compound Astigmatism:**

Neither of the two foci lies upon the retina but both are –

- a) Compound hypermetropic astigmatism where both foci are placed in front of the retina.
- b) Compound myopic astigmatism where both foci are placed behind the retina.

**Mixed Astigmatism:**

Where one focus is in front of the retina and the other behind the retina so that refraction is hypermetropic in one direction and myopic in the other.

**Irregular Astigmatism:**

Refraction in different meridians conforms to no geometrical plane and the refracted rays have no planes of symmetry. This is found only in pathological conditions of the cornea i.e. irregular healing following any injury, inflammation or

ulceration. This refractive error cannot be corrected with spherocylindrical spectacles.

### **Changes in astigmatism with age:**

The prevalence of severe (6D average) ATR astigmatism is more in the early months of life. Pre-term and the low birth weight newborns are more prone to have astigmatism with steep corneas. Emmetropisation of astigmatism occurs with the growth of the infant. Due to the pressure on the cornea by eyelids, there is a shift to WTR astigmatism by the age of 4 – 5 years and hence the children and young adults typically present with low grades of WTR astigmatism. Over time, again the shift occurs and the older individuals display ATR astigmatism in most of the cases. Changes in the curvature of the cornea leads to the astigmatic alterations as the internal astigmatism remains stable throughout life.

### **Causes of astigmatism**

1. Both genetic and environmental influences have a role in development of astigmatism.
2. Eye lid pressure has been proposed as a cause of WTR astigmatism.
3. Nystagmus – people with nystagmus usually have high degrees of corneal WTR astigmatism.
4. Visual tasks – Certain visual tasks like prolonged reading habit in down gaze have a potential for inducing ATR astigmatism.
5. Surgically induced astigmatism occurs after surgeries for cataract, trabeculectomy, ptosis, scleral buckling, pterygium excision.

**The visual state in astigmatism:**

Astigmatism induces distortion of image. The two principal meridians have differential magnification which leads to the distorted retinal images in astigmatism. There is 0.3% image distortion per diopter of astigmatism<sup>(24)</sup>

In WTR astigmatism, the weaker principal meridian power produces a vertical line focus. In printed matter the vertical strokes of the letter are more important for recognition for example b, d, h, also there is less space between letters than between lines. Hence it is useful to have a better focus in vertical meridian as is there in myopic WTR astigmatism, resulting in better Snellen's visual acuity.

Another benefit of WTR astigmatism is that less cylinder is required in spectacle correction than ATR astigmatism of same magnitude. In corrected, astigmatic eye, retinal image distortion arises due to unequal spectacle magnification in the two principal meridians, representing 1.6% distortion per diopter cylinder correction.

More over spectacle cylinder will be less than the ocular astigmatism when the spherical equivalent is positive and greater than the ocular astigmatism when spherical equivalent is negative. So, in general myopic ATR astigmatism will result in proportionally larger spectacle correction, which will produce more distortion. A certain degree of myopic astigmatism is useful as it may produce a situation of pseudo accommodation in pseudophakic patient.<sup>(25)</sup>

The importance of astigmatism lies in the fact that it is particularly liable to cause the worst form of asthenopic symptoms. It usually results in headache, eye ache due to blurring of vision.

The astigmatism produced by the contraction of scar post cataract surgery results in flattening of the cornea in the meridian at right angles to the wound. <sup>(14)</sup> This change in the corneal curvatures continues to alter for some weeks after the surgery. So, the final spectacle correction should always be done after at least 6 weeks postoperatively.

Uncorrected astigmatism causes blurred image, glare, monocular diplopia. Even with appropriate spectacle correction the meridional magnification may create distortion. The patients having preoperative astigmatism may experience difficulty adapting to axis shift induced by surgery. Any of these effects may create not only dissatisfaction with visual outcome, but also discomfort with an otherwise uneventful surgery.

Singh A et.al <sup>(26)</sup> studied the relation between uncorrected astigmatism and visual acuity in pseudophakia and concluded uncorrected hyperopic and myopic astigmatism results in deterioration of both near and distance visual acuities in pseudophakic eyes.

## **Measurement of corneal curvature:**

### **1. Keratoscopes:**

Placido's disc: This instrument is 20 cm in diameter and forms an erect, virtual image of concentric rings a few millimeters behind the cornea after light from an attached or external source is reflected from the rings onto the cornea to be examined. The examiner views the image through a central hole usually with the aid of a positive lens to reduce accommodation and provide some magnification.

**Photokeratoscope:**

It provides information about corneal topography by photographing the imaged placido's disc and measuring the distortion and displacement of each ring at many points. Modern instruments have spherical, ellipsoidal or cylindrical target planes.

**Astigmometer:**

Manufactured by Keeler to control corneal astigmatism during suturing. A ring of light emitting diode is mounted on the operating microscope in the focal plane of one eyepiece and the image formed by the cornea is viewed through the eyepiece. An astigmatic cornea produces an ellipsoidal image of lights. By tilting the ring of lights, the image can be made circular and the angle of tilt can be used to estimate the amount of astigmatism. The instrument can reduce postoperative astigmatism.

**2. Keratometer (Ophthalmometers):**

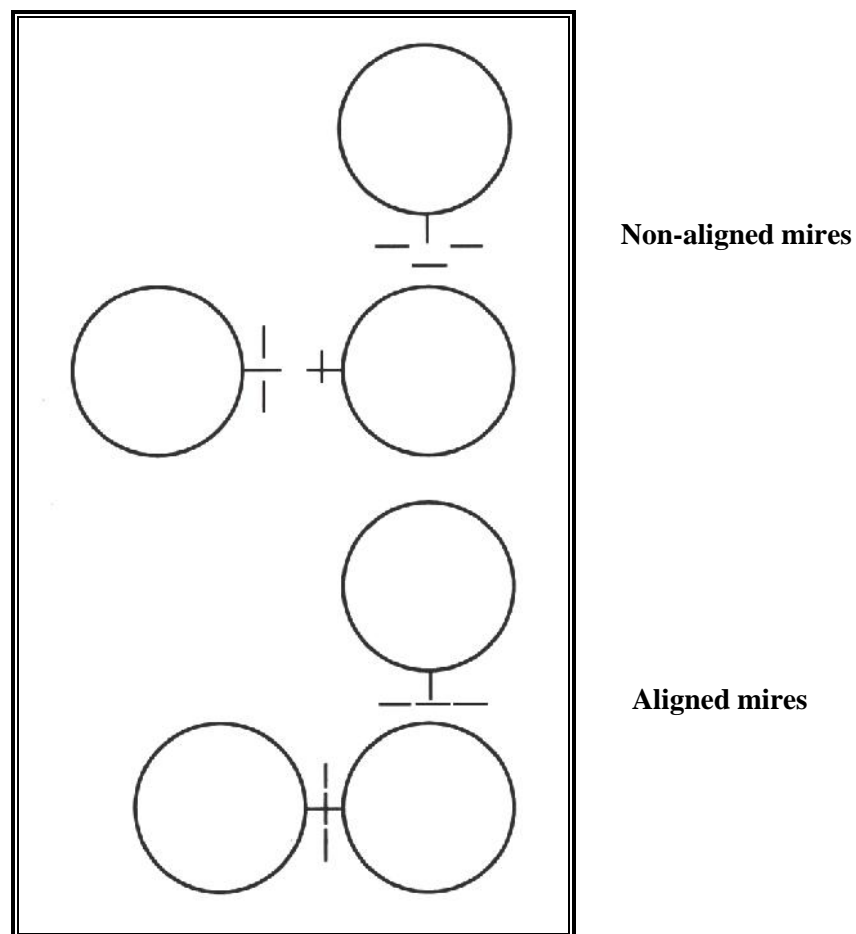
The instrument uses an image doubling technique to measure the radius of curvature and location of refracting surfaces of the eye. Following the Javal-Schoitz keratometer, Bausch and Lomb keratometers have come into vogue.

Although techniques were available to measure the radius of curvature by reflection, measurements on the eye were difficult because of image movement. Doubling the image, which involves separating the image beam into two parts and measuring the distance between the two images, eliminated this problem since the two images move together when the eye moves.

**The Bausch and Lomb Keratometer:**

The instrument comprises of a lamp system that illuminates the mires by a diagonal mirror. Light from the mire strikes the cornea producing an image behind it. The mire having fixed dimensions, image size depends on the corneal radius. The image formed now acts as an object for the optical system.

**FIGURE NO – 2: MIRES OF KERATOMETER**



Light from the object is gathered by an objective lens and focused to a plane farther along the central axis. A four aperture diaphragm is located near the objective lens. Beyond the diaphragm are two doubling prisms, one with base up and the other with base out. The prisms can be moved independently, parallel to the central axis of

the instrument. Light passing through the left aperture of the diaphragm is deviated by the base up prism to place one image above the control axis. Light passing through the right aperture is deviated by the base out prism placing a second image to the right of the control axis.

Light through the upper and lower apertures does not pass through either prism and an image is produced on the axis. The total area of upper and lower apertures is equal to the area of each of the apertures, making the brightness of all three images equal. The upper and lower apertures also act as a Scheiner's Disc, doubling the central image when the instrument is not properly focused on the corneal mire image. The eye piece lens gives a magnified view of the double images.

#### **Automated Keratometry:**

Here, the reflected image of a target is focused onto a photodetector which measures the image size and the radius of curvature is computed. The target mires are illuminated with infrared light and an infrared photodetector is used. The image is measured in many meridians and the power and axis of the major meridians are computed. As the performance here is quicker than ocular movements, no doubling device is needed.

#### **Intraoperative Keratometry:**

Barraquer was the first surgeon to advocate the use of keratometer during a surgical procedure. Troutman developed a qualitative device that projects a series of dots onto the cornea in the form of a circle. In the presence of astigmatism, the circle is seen as an eclipse. Terry was the first to develop a quantitative surgical keratometer. While some studies have shown intraoperative keratometry to reduce

suture induced astigmatism, some have found a poor correlation between intraoperative keratometric readings and final postoperative astigmatism.

### **3. Computed Corneal Topography:**

A computed screen simulates a piece of graph paper divided into many small squares or pixels. Video camera signals are put into the computer resulting in an image on the screen. The curvature of the cornea that corresponds to the rings in every location is determined. A detailed map of the cornea is obtained in which values of corneal curvature at each location of the ring appear. These numerical values can be represented as color maps, where cooler colors represent flatter areas and warmer colors represent steeper areas.

#### **Javal's rule:**

Total astigmatism also termed as refractive astigmatism is the combination of corneal and internal astigmatism. Unequal corneal curvature leads to corneal astigmatism whereas unequal anterior and posterior surface of lens or the misalignment of optic axis of cornea and lens due to tilting of lens leads to internal astigmatism.

Javal proposed a rule that the total astigmatism of the eye can be predicted based on the corneal astigmatism. <sup>(27)</sup>

It stated:  $A_t = p (A_c) + K$ , where

$A_t$  = refractive astigmatism

$A_c$  = corneal astigmatism

The terms 'K' and 'p' are constants approximated by 0.5 (ATR astigmatism) and 1.25 respectively. This rule considers residual astigmatism to be constant and ATR in most of the people.

A study conducted by Keller et.al <sup>(28)</sup> supported Javal's rule where videokeratoscope was used to measure corneal astigmatism to depict the relationship between corneal and total astigmatism.

### **SURGICAL CORRECTION OF ASTIGMATISM DURING CATARACT SURGERY:**

Around 70% of the general population with cataract have astigmatism of 1.0 D and approximately 33% of patients who undergo cataract operation are eligible for the treatment of pre-existing astigmatism. <sup>(29,30)</sup>

Ferrer-Blasco et al <sup>(31)</sup> conducted a study on the prevalence of corneal astigmatism in patients undergoing cataract surgery and concluded that corneal astigmatism was not present in 13.2% of eyes, 0.25 and 1.25 diopters (D) was present in 64.4% and 22.2% had 1.50 D or more of corneal astigmatism. This implies surgeons should simultaneously plan treating pre-existing astigmatism during cataract surgery for better outcome.

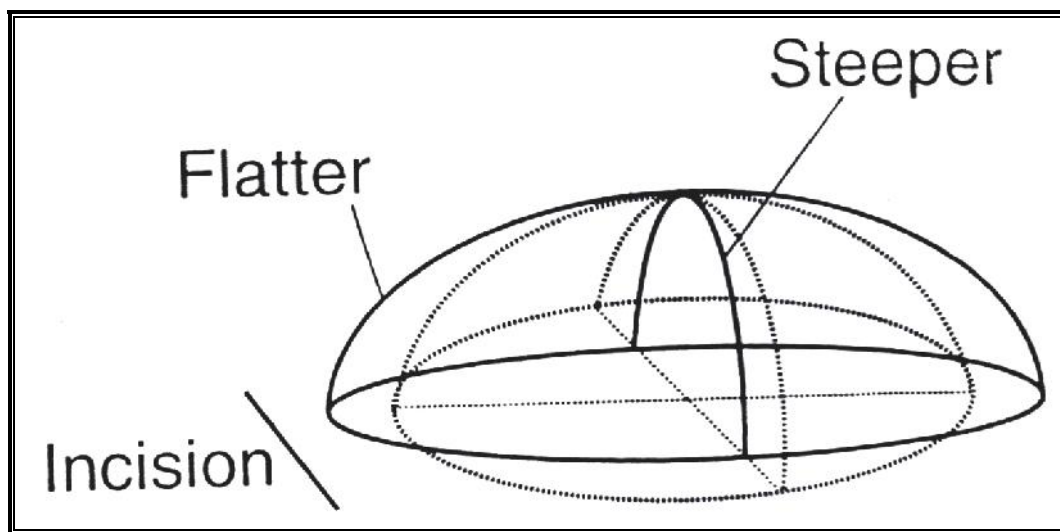
There are two methods:

1. Correction with incisions
2. Correction with intraocular lenses

**Post-operative corneal changes:**

The astigmatism after cataract surgery is generally of “against the rule” type as the corneal meridian perpendicular to the direction of the incision undergoes some degree of flattening. That is when the incision is made above, a postoperative flattening of cornea in the meridian occurs at right angles to the wound.

**FIGURE NO - 3: POSTOPERATIVE CORNEAL CHANGES**



➤ **Basic concepts of corneal incisions:**

- Larger incisions, create greater flattening. More the arc length of the incision, more is the amount of flattening in that corneal meridian. Due to the coupling effect, arc lengths of more than 90° are ineffective.
- Incisions nearer to the optical centre reveal greater flattening.
- A shorter tunnel length in a penetrating incision creates greater flattening while a longer creates smaller effect.
- A deeper incision creates greater flattening.

- It may be kept in mind that incisions more than 90% of pachymetry, although the fact they may create greater flattening effect, may result in corneal perforation.
- Arcuate incisions are easier to perform and produce more flattening with less surgery, besides they do not make a change in the circumference of the cornea.

➤ **CORRECTION WITH INCISIONS:**

**A clear corneal phacoemulsification incision on the steepest meridian of astigmatism:**

Pre-existing <sup>(32)</sup> astigmatism can be reduced by modifying the shape, length, type and localization of the incision during the cataract surgery. Depending on whether the incision is superior, temporal or oblique, the flattening of the cornea is seen along that axis. The SIA is against the rule for a superior location and with the rule for a temporal location.

**Advantages of temporal clear corneal incision:**

- Bridle sutures are not required as the surgeon is positioned on the side, working at the temporal periphery and it is not necessary to turn the eye downwards.
- With the iris plane parallel to the light of microscope, the red reflex is enhanced and there is marked improvement in visualization of intraocular structures.
- This location allows greater access to the incision than when working over the brow.

- At this location, the irrigation fluid is drained naturally as the lateral canthal angle is directly below the incision.
- The temporal location is farthest from the visual axis, and thus the endothelial damage postoperatively is much less than superiorly placed incisions, and any flattening at the site of the wound is less likely to affect the curvature of cornea at the visual axis.
- With respect to against the rule drift, temporal incisions are more stable.
- Eyelid blink and gravity tend to create a tug on the incision if placed superiorly. These forces are neutralized with the temporal location.
- At this location, the astigmatism induced is “with the rule”, which is advantageous for the aged patients whose preoperative astigmatism was ‘against the rule’.

**Advantages of superior clear corneal incision:**

- Safety –Due to the incision under the eyelid.
- Patient comfort - A superior incision is almost completely away from the blink of an eyelid, so theoretically reducing post-operative discomfort and foreign body sensation.
- Patients who do not have deep set eyes are preferably taken for superior incision if the patient has WTR astigmatism.
- Easier to abandon and convert to large section surgery should the need arise
- Lesser incidence of post-operative endophthalmitis

### **Clear Corneal Incision – Biomechanics of wound healing**

Once the wound is created, the wound edges become quite edematous and opaque due to fluid imbibition by the corneal layers. Anterior and posterior apices are formed corresponding to the superficial and deep edges of the wound respectively. Healing of the anterior triangle is brought by two mechanics. Firstly, epithelial cells surrounding the area migrate to cover the defect. Secondly, mitotic activity is increased in the epithelial cells.

Healing of the posterior triangle is by filling the defect with endothelial cells that rearrange themselves by sliding, mitosis and thinning. Collagen formation is increased gradually which in turn increases the tensile strength that leads to healing of the stroma. The new connective tissue formed pushes out the epithelial plug outwards and also fills in the posterior triangle such that the normal layering of the cornea is restored. <sup>(33)</sup> The burn wound created by hard/brown cataract slows down the healing process and induces more postoperative astigmatism. By placing a clear corneal incision at the steepest meridian causes flattening of the cornea in that meridian and steepening of the opposite meridian.

Roman S et.al <sup>(34)</sup> compared surgically induced astigmatism with superior and temporal incisions with foldable IOL. The incision was taken depending on the preexisting astigmatism i.e. temporal incision in case of ATR and superior incision for WTR astigmatism. The postoperative SIA was 0.98D with superior and 0.58D with temporal incisions. Superiorly placed corneal incision rarely allows reaching a lowest postoperative astigmatism as with a temporal location.

Simsek S et.al <sup>(35)</sup> conducted a study on 20 patients comparing the clear corneal incisions taken superiorly and temporally. Mean postoperative astigmatism was 1.60D in superior group and 0.83D in the temporal group. The temporal incision group showed significantly lesser astigmatism.

Ermiss SS et.al <sup>(36)</sup> evaluated SIA after small 3.5mm superotemporal and superonasal clear corneal incision phacoemulsification in 56 eyes of 28 patients. SIA induced by superonasal incision was significantly higher compared to SIA by superotemporal incision which was statistically significant.

Brian J Jacobs et.al <sup>(37)</sup> studied astigmatism after clear corneal phaco incision, i.e. 52 eyes of 52 patients, whose keratometer reading was taken preoperatively and 1<sup>st</sup>, 3<sup>rd</sup> and 6<sup>th</sup> months postoperatively. They concluded that superior position clear corneal incision does not induce a clinically important amount of astigmatism.

Oshima Y et.al <sup>(38)</sup> compared astigmatism of phacoemulsification with foldable intra ocular lens through 3mm temporal clear corneal and 3mm superior scleral tunnel incision on 78 patients with preexisting ATR astigmatism. Decrease in the preexisting astigmatism was seen in the temporal clear corneal incision group compared to superior scleral tunnel group. 0.65 D at 3<sup>rd</sup> month postoperative scleral tunnel group, 0.56 D at 3<sup>rd</sup> month postoperatively in temporal clear corneal group.

James Tejedor et.al <sup>(39)</sup> studied the preferred location of clear corneal incision in phacoemulsification, depending on pre-existing astigmatism. It demonstrated that more corneal changes were induced in superior than temporal incision in patients with no corneal astigmatism. The study concluded, superior incision is preferred in cases of astigmatism with atleast 1.5 D and steep axis at 90 degrees. Temporal incision is more

favorable with < 1.5 D and minimal or < 0.75 D of astigmatism with steep axis at 90 degrees and steep axis at 180 degrees respectively.

Pistarini Fernando Goncalves et.al <sup>(40)</sup> studied phacoemulsification using clear corneal incision in steepest meridian. They concluded that by knowing the pre-existing astigmatism is in which meridian, can reduce surgically induced astigmatism.

Ken Hayashi et.al <sup>(41)</sup> studied the effect of clear corneal incision on the steepest meridian for reducing pre-existing corneal astigmatism using a meridian marking method or surgeon's intuitions and concluded the meridian marking group showed significantly smaller mean meridian misalignment of clear corneal incisions compared to surgeon's intuition group.

Pre-operative marking of the steep axis is necessary to ensure the surgical incision is taken at the exact keratometric axis that flattens the cornea. Technical difficulties are encountered in cases of superonasal or inferonasal incisions as per the localization of steep meridian. This technique may be used to correct mild cases of astigmatism upto 1.0 D by adjusting the length, depth and distance of the corneal incision from the center. <sup>(40)</sup>

**Opposite side clear corneal incision (OCCI):**

In this technique, the corneal incisions are made on opposite sites 180 degrees apart, on the steepest meridian of cornea. It is based on the assumption that a healing tissue forms between those incisions, and this tissue-adding effect results with flattening of the cornea. The incisions were facilitated by creating two biplanar 3.2mm incisions 180 degrees from each other along the steep meridian of the cornea, 1.5-2mm inside the edge of the limbal vessels.

Lever and Dahan introduced this technique by modifying the standard procedure of clear corneal incision. <sup>(42)</sup> Here, an identical incision was added on the opposite side that is 180 degrees away from the main corneal incision. Their study included 33 eyes, which showed changes in the mean corneal astigmatism from 2.80 D preoperatively to 0.75 D postoperatively.

Mostafa et al <sup>(43)</sup> compared the effect of single clear corneal incision (CCI) on the steep meridian with opposite clear corneal incisions (OCCIs) on pre-existing regular corneal astigmatism in patients undergoing phacoemulsification surgery and concluded OCCIs on the steep axis were more effective than single CCI in the correction of mild to moderate pre-existing corneal astigmatism.

Similar studies conducted by Khokhar et al <sup>(44)</sup> and Nemeth et al <sup>(45)</sup> who reported a mean astigmatism correction of 1.66 D at the end of 3 months and an astigmatism correction of 1.0 D at the end of 9 weeks respectively with OCCI.

Risk of endophthalmitis was more in this procedure as it consists of penetrating incisions when compared to other non-penetrating methods which limits the use of this technique.

### **Limbal Relaxing Incisions:**

L.J. Lans, a Dutch ophthalmologist, was the first person to demonstrate the effect of non-penetrating incisions placed at limbus to treat astigmatism in 1898. <sup>(15)</sup>

Limbal relaxing incisions are one of the simplest, most cost-effective procedures available to reduce astigmatism. This technique consists of paired arcuate incisions placed at the limbus in the steep corneal meridian which causes flattening of

that meridian due to the tissue addition effect along with steepening of the orthogonal meridian.

**Merits of LRI:**

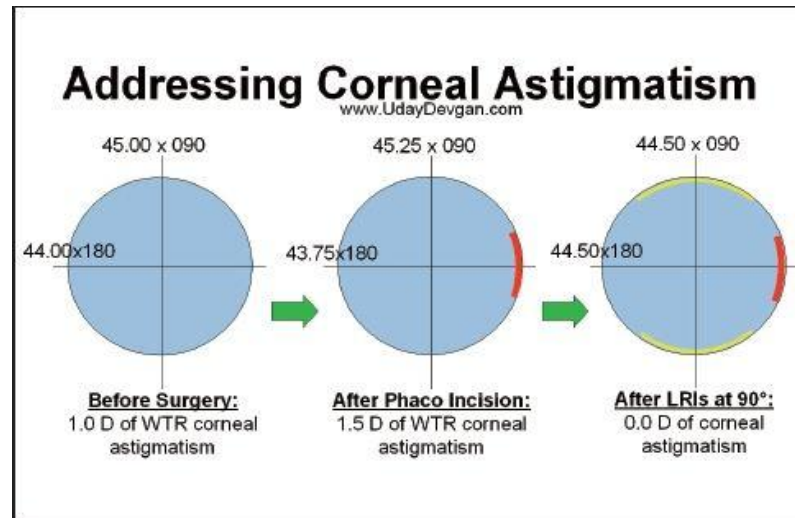
- Quick, simple and easy technique with low technology.
- Cost-effective.
- Due to the limbal placement of incisions, minimal distortion and irregularity seen on corneal topography.
- Less variability in refraction.
- Early postoperative visual stability.
- Produce less glare and patient discomfort.
- Lower risks of corneal perforation and overcorrection of astigmatism.

**Incorporating the principle of coupling:**

Coupling is a term that describes the change in corneal power at the incision site compared with the change in corneal power 90 degrees away. The amount of flattening produced by an incision relative to the flattening or steepening 90 degrees away is called the coupling ratio. This flattening produces a hyperopic shift, whereas steepening produces a myopic shift. Therefore, the term maximum coupling denotes a low coupling ratio.

It is possible for 2 procedures to correct the same amount of astigmatism but produce a different coupling ratio. For example, a single, long LRI produces a greater hyperopic shift (or higher coupling ratio) than 2 shorter CRIs (which produce a low coupling ratio). Shorter incisions require more central placement and should be within a 15-degree arc. When shorter incisions are used, there is a lower coupling ratio and thus less impact on the postoperative spherical equivalent.

FIGURE NO – 4: EFFECTS OF LRI



#### Determining the incision depth:

Measuring corneal thickness at the incision site has become an important part of surgical planning. Because the cornea varies in thickness from the center to periphery and in different meridians, it is important to measure pachymetry at the incision site. Even-though corneal pachymetry is helpful most of the surgeons prefer using a preset diamond or disposable metal blade at 600 microns depth to treat empirically. With LRI technique the decrease in the mean astigmatism is reported to be between 25-52% by various authors. <sup>(29,46,47,48,49,50,51,52,53,54)</sup>

Nichamin et al. recommended that depth of the LRIs should be approximately 90% of minimum corneal thickness around the limbus. 600 μm cutting depth was set in the empiric blade. <sup>(29,46,47,48)</sup>

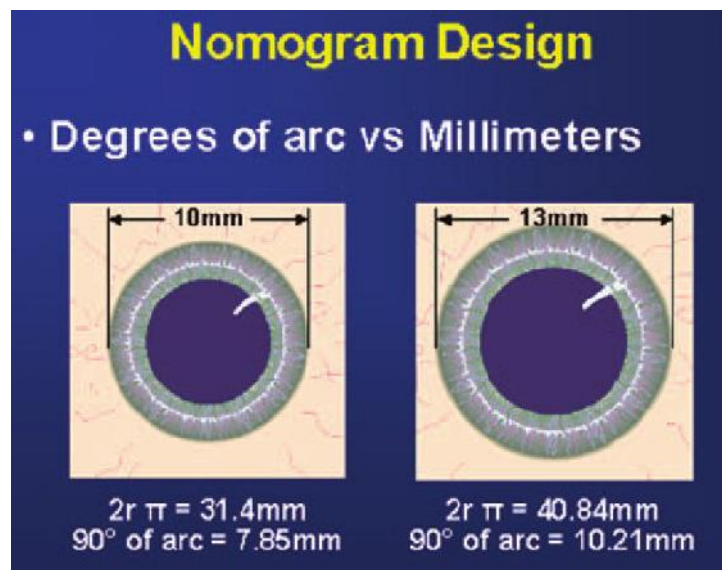
However, Dong et al suggested, since patients present with variable corneal thicknesses, the cutting depth should be set depending on the preoperative measurement of corneal thickness. He also showed that acceptable amount of astigmatism can be corrected even when less than 90% cutting depth is used. <sup>(49)</sup>

**Nomograms:**

A nomogram should be considered to calculate the arc length of the incisions, once the degree of astigmatism to be corrected has been computed. With-the-rule astigmatism is considered to be from 45 to 135 degrees, and against-the-rule astigmatism is from 0 to 44 degrees or 136 to 180 degrees, as the arc length of the incisions differs based on this distinction. The arc length of the incisions is calculated after aligning the patient's age with the quantity of pre-existing cylinder to be corrected.

Symmetric corneal flattening can be achieved with the help of paired incisions. They are preferably expressed in degrees of arc and not in chord length. The length of the incision and its resultant effect depends on the corneal diameter. Hence, the over-correction or under-correction can be diminished by presenting in degrees of arc specially in cases of small or large corneas.

**FIGURE NO – 5: NOMOGRAM DESIGN**



There are various nomograms that are used to calculate the length of the LRIs:

➤ **The NAPA Nomogram (Nichamin Age and Pachymetry-Adjusted):**

In this nomogram, the length of the incision decreases with age and increases with the magnitude of astigmatism requiring correction. Nichamin <sup>(21)</sup> has developed two nomograms, based on patient's age and type and magnitude of pre-existing astigmatism which specify the use of LRIs. An empirical preset blade of 600 micrometers depth was used in the standard nomogram developed by Nichamin. He did not perform corneal pachymetry or used adjustable blade-depth settings. This would seem to be a reasonable practice when treating cataract patients; and hence the same nomogram is being used in our study. Nomogram modifications and adjustments in the blade depth setting may be required depending on the individual surgeon's technique and the instruments used in particular, the style of the blade.

**FIGURE NO – 6: NICHAMIN NOMOGRAM**

**"With The Rule" (Steep Axis 45°-135°)**

Preop-Cyl (Diopters)	Paired Incisions in Degrees of Arc					
	20-30 yo	31-40 yo	41-50 yo	51-60 yo	61-70 yo	71-80 yo
0.75 D	40	35	35	30	30	25
1.00 D	45	40	40	35	35	30
1.25 D	55	50	45	40	35	35
1.50 D	60	55	50	45	40	40
1.75 D	65	60	55	50	45	45
2.00 D	70	65	60	55	50	45
2.25 D	75	70	65	60	55	50
2.50 D	80	75	70	65	60	55
2.75 D	85	80	75	70	65	60
3.00 D	90	90	85	80	70	65

*"Blade depth setting is at 90% of the thinnest pachymetry"*

**"Against The Rule" (Steep axis 0-44°/136-180°)**

Preop-Cyl (Diopters)	Paired Incisions in Degrees of Arc					
	20-30 yo	31-40 yo	41-50 yo	51-60 yo	61-70 yo	71-80 yo
0.75 D	45	40	40	35	35	30
1.00 D	50	45	45	40	40	35
1.25 D	55	55	50	45	40	35
1.50 D	60	60	55	50	45	40
1.75 D	65	65	60	55	50	45
2.00 D	70	70	65	60	55	50
2.25 D	75	75	70	65	60	55
2.50 D	80	80	75	70	65	60
2.75 D	85	85	80	75	70	65
3.00 D	90	90	85	80	75	70

*"Blade depth setting is at 90% of the thinnest pachymetry"*

➤ **The DONO Nomogram (Dr. Eric D. Donnenfeld Nomogram):**

In this nomogram, more the amount of astigmatic correction required, more is the length and the number of incisions.

**FIGURE NO – 7: DONNENFELD NOMOGRAM**

TABLE. THE DONNENFELD NOMOGRAM FOR LRIs	
Astigmatism	Incision
0.50 D	One incision, 1 ½ clock hours (45° each)
0.75 D	Two incisions, 1 clock hour (30° each)
1.50 D	Two incisions, 2 clock hours (60° each)
3.00 D	Two incisions, 3 clock hours (90° each)

➤ **The Gills LRI Nomogram (Dr. James P. Gills):**

This nomogram titrates surgery by the length and number of LRIs. <sup>(50)</sup>

**FIGURE NO – 8: GILLS NOMOGRAM**

TABLE 4-1. GILLS LRI NOMOGRAM		
AMOUNT OF ASTIGMATISM	NUMBER OF INCISIONS	LENGTH OF INCISIONS
1 D	1	6 mm
2 D	2	6 mm
3 D	2	7 mm
4 D	2	8 mm
>4 D	2	10 mm
	CRIs based on correction desired over 4 D	2 mm for every D over 4 D at 8 mm OZ
LRI blade setting: 600 μm for most patients. CRI blade setting: 99% of pachymetry. (Exception: LRI blade setting of 500 μm for patients over 80 and for those with corneo-scleral thinning.)		

➤ **The Wallace LRI Nomogram (Dr. R. Bruce Wallace III):**

In this nomogram, the number of LRIs and their length increases as the amount of astigmatism correction increases and decreases with age.

Other surgeons like Dr. Thornton, Lindstrom, and Buzzard, have their own variation of one of these commonly used nomograms or have developed their own

personal LRI nomograms determined from analyses of their own studies retrospectively.

Different techniques can be applied when LRIs are used to correct corneal astigmatism:

➤ **Using the Phacoemulsification Incision as One of the Pair of LRIs:**

In this method, the position of the phacoemulsification incision is changed based on the steep corneal meridian of the pre-existing astigmatism. The phacoemulsification incision needs to “mimic” the effect of the opposing LRI. The LRI will then be placed 180 degrees away from this phacoemulsification incision. This technique requires 2 incisions in total.

➤ **Using a Phacoemulsification Incision Together with Paired LRIs:**

Placing a phacoemulsification incision away from the steepest corneal meridian will have an “off-axis” rotational effect on the preoperative corneal astigmatism. This must be taken into account when planning for the effect required from the additional pair of LRIs and their positioning. This technique requires a total of 3 incisions.

Dong et al <sup>(49)</sup> compared the effects of phacoemulsification incision with single LRI and paired LRI. He concluded both are equally effective in treating astigmatism.

➤ **Paired LRIs Not Associated with a Phacoemulsification Incision:**

This technique can be used when the natural lens is clear without any cataractous changes and the total astigmatism of the eye requires correction. Here the ocular

residual astigmatism (ORA) needs to be calculated which is the vectoral difference between the corneal astigmatism and the refractive cylinder at the corneal plane. The effective position and degree of LRI usually lies in between the two refractive and corneal astigmatisms. A higher degree of ORA leads to lesser reduction of astigmatism with more left uncorrected postoperatively.

**The technique of limbal relaxing incisions:**

**Pre-operative:**

- Perform keratometry, in addition to a manifest refraction on the patients who are planned for cataract surgery to know the amount of pre-existing corneal astigmatism, followed by A-scan biometry to calculate IOL power.
- The length of the LRI incisions can be calculated using the LRI calculator which applies vector analysis or Nichamin nomogram (as done in the present study) based on the patients pre-operative keratometry and the surgeons induced astigmatism and provides a visual map of the axis along with the length of the incisions.
- A printout of the same to be carried inside the operating room as a guide to help during the procedure.
- Place limbal reference marks at 12 o'clock and 6 o'clock with the patient sitting upright and looking straight ahead at a fixation target.

**Intraoperative:**

- After the phacoemulsification and the intraocular lens implantation, before the viscoelastic removal, place the Mendez axis marker on the cornea.
- Mark the axis with the forceps.

- The borders of the paired incision are then marked with the surgical marker; for example; 30 degrees on each side for a 60-degree arc.
- Dry the corneal marks with a swab.
- Fixate the globe with the forceps.
- Advance the preset blade of 600µm depth towards the point of fixation with the blade perpendicular to the corneal surface.
- Complete the corneal arc incision just about 0.5mm inside the surgical limbus.

**Post-operative:**

- Standard postoperative medications are prescribed after the procedure. Topical antibiotic with steroid 6 times a day and a course of systemic antibiotic.

**Complications of LRI:**

Limbal relaxing incisions present with fewer complications when compared to central corneal incisions as it is safe and forgiving procedure. Incisions placed on the wrong axis would be the most common complication encountered. Hence the surgeons have to pay special attention and double check the axis before the procedure.

Corneal perforation is possible but rare complication as the blade depth is empirically set at 600µm. Perforation may be due to improper setting of blade depth, defect in micrometer mechanism or repeated autoclaving in case disposable blades are not used. The other complications are infection, decreased corneal sensation or foreign body sensation, dry eye and over or under-correction.

Coloma-González et al <sup>(51)</sup> conducted a study where one group of 30 underwent phacoemulsification with clear corneal temporal incision and in the other group of 32

limbal relaxing incisions were placed along with clear corneal incision. They proved LRI group was more effective in treating pre-operative astigmatism where mean astigmatic correction was 0.55 D compared to 0.04 D of other group three months postoperatively.

Similar study was conducted by Müller-Jensen K et al <sup>(52)</sup> who also proved limbal relaxing incisions were better with mean astigmatic correction of 0.09 +/- 0.50 D compared to 0.39 +/- 0.70 D of control group six months postoperatively.

Bayramlar H et al <sup>(53)</sup> demonstrated the effectiveness of LRI in treating primary and postoperative mixed astigmatism where the mean preoperative and postoperative refractive astigmatism was 3.31 diopters (D) +/- 1.50 (SD) and 1.59 +/- 1.28 D, respectively (P <.001). The mean preoperative and postoperative UCVA was 0.29 +/- 0.22 and 0.54 +/- 0.31, respectively (P =.0001) and the mean BCVA, 0.61 +/- 0.30 and 0.74 +/- 0.30, respectively (P =.0001) with no serious postoperative complications.

Mohamed Hosny et al <sup>(54)</sup> compared limbal relaxing incisions (LRI) with penetrating limbal relaxing incisions (PLRI) on two groups of 20 each. They proved astigmatic outcome was more predictable and consistent in LRI group with average corneal cylinder change of 1.178 D compared to -0.095 D of PLRI group at 1 month.

### **Femtosecond laser limbal relaxing incisions:**

Recent developments in femtosecond laser technology have shifted attention from manual LRIs to femtosecond laser-guided surgery. These lasers follow the mechanism of photo-disruption where extremely short pulse duration allows the cutting of tissue with considerably less energy. The incisions created by femtosecond

laser are more precise and have accurate depth, arc length and angular position compared to manual methods. <sup>(55)</sup>

A study conducted by Nagy Z et al <sup>(56)</sup> showed that with the femtosecond laser, astigmatism was successfully corrected, with an improved best-corrected visual acuity that was better than that which was predicted by preoperative values. Subsequently, the position and depth of the incisions were consistent with the surgical plan. This report serves to confirm that laser technology is able to create uniform corneal incisions precisely and predictably.

**Single or paired peripheral corneal relaxing incisions (CRIs):**

Corneal relaxing incisions (CRIs) run parallel to the limbus which can be single or paired, straight or arcuate, may treat slightly greater amounts of astigmatism (about 1-3D) as LRIs. They straddle the meridian of the steepest corneal curvature. These can be applied either during the surgery or post-operatively. They may be necessary when implanting multifocal intraocular lenses in eyes with more than 1 diopter of astigmatism.

**Tracking of the results:**

To analyze the astigmatic outcome, Alpins method of vector analysis <sup>(57,58,59,60)</sup> is used where the preoperative and postoperative corneal astigmatism are compared vectorially. This method is based on the relationship between three vectors namely:

- Surgically induced astigmatism (SIA) vector: The vectoral difference between the preoperative and postoperative corneal astigmatism.

- Target induced astigmatism (TIA) vector: The amount of astigmatism the surgeon is attempting to correct either by incision on steep meridian or paired limbal relaxing incisions.
- The difference vector: The correction that would be required to achieve the planned target of the initial surgery.

This method determines whether the astigmatism was overcorrected or under-corrected and whether the treatment was on or off- axis. <sup>(59,60)</sup>

The different parameters calculated are:

➤ **Correction Index:**

The correction index (CI) is the amount of astigmatism correction achieved. It is calculated by dividing the SIA by the TIA; the ideal value is 1.0. Correction index values greater than 1.0 indicate an overcorrection, and values less than 1.0 indicate an under-correction.

➤ **Angle of Error:**

The angle of error (AE) is the angle between the TIA and the SIA on a polar diagram. If the SIA is anticlockwise to the TIA, AE is taken positive and if the SIA is clockwise to the TIA it is taken negative.

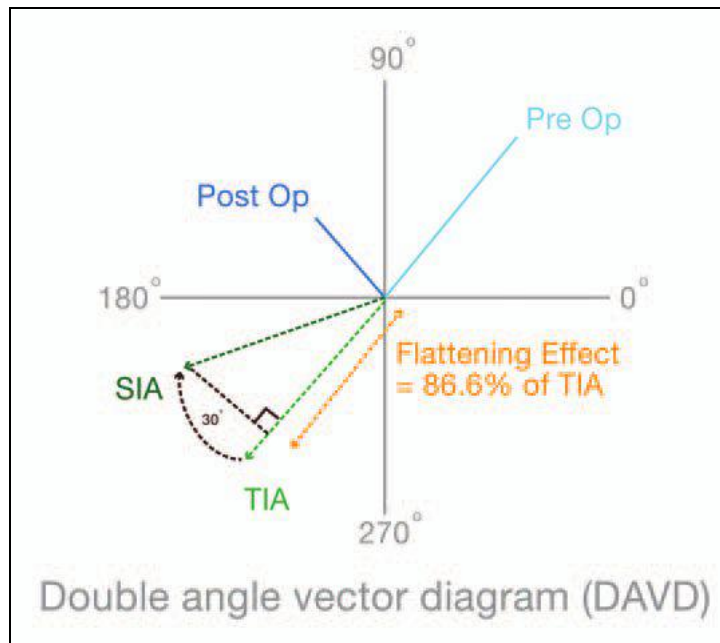
➤ **Flattening effect:**

The flattening effect (FE) is calculated using a double-angle vector diagram (DAVD), where the effect of the SIA on the TIA axis is calculated using

trigonometric principles. The DAVD is then converted to a polar diagram. The FE is defined as:

$$FE = SIA \cos 2.AE \quad (57,58,59,60)$$

**FIGURE NO – 9: DOUBLE ANGLE VECTOR DIAGRAM**



➤ **CORRECTIONS WITH INTRAOCULAR LENSES**

**Toric intraocular lens implantation:**

Toric lenses are indicated in patients with higher degree of astigmatism. It is a reliable procedure which is independent of postoperative tissue healing response. The main issue with the toric IOLs are their tendency to rotate. However, a recent study by Poll et al <sup>(61)</sup> demonstrated that surgical correction of mild to moderate degrees of astigmatism by peripheral corneal relaxing incisions and toric IOLs showed similar results.

The success of a toric IOL is assessed by taking two things into consideration, the amount of astigmatism corrected and the ability of the IOL to maintain a stable position in the capsular bag in the longer term.

Limbal relaxing incisions can be used in conjunction in patients undergoing cataract surgery with toric IOL implantation. It is mainly helpful in patients with larger amount of astigmatism where the LRIs enhance the result of the surgery.

**Piggy-back toric lenses:**

Piggyback T-IOLs are a combination of two toric IOLs. They can be used to reduce high pre-operative astigmatism. The problem of rotation is described in these IOLs similar to toric IOLs which affects the cylinder correction seriously.

**Enhancement techniques:**

Although current methods to reduce pre-existing astigmatism, such as limbal relaxing incisions (LRIs) or toric intraocular lenses (IOLs), can effectively reduce corneal astigmatism at the time of cataract surgery, the patient may still have postoperative residual spherical or astigmatic refractive error that evokes symptoms worthy of further surgical correction.

**Spectacles and contact lenses:**

The simplest form of management of residual refractive error is the use of spectacles or contact lenses. Few patients may find it difficult to adapt to the spectacle correction as it produces meridional aniseikonia, that becomes problematic with binocular vision. Contact lenses are good alternative option but superior wound gape with horizontal steepening may cause inferior ride of lens.

**Laser vision correction:**

The residual refractive error may be best managed through the laser vision correction as most patients achieve excellent uncorrected visual acuity. Photorefractive keratectomy (PRK) and laser in situ keratomileusis (LASIK) are the widely accepted procedures for correcting various types and degrees of ametropia, including astigmatism. <sup>(62)</sup>

Laser vision enhancement techniques can be performed after 3 months of primary surgery despite the refractive stability occurs in one month postoperatively as no concern for wound dehiscence is seen. LASIK provides a quicker visual recovery than PRK, even-though PRK can be considered in cases with thin corneas, suspicious topographic patterns and anterior basement membrane dystrophy.

**Stepladder approach to management of astigmatism:**

Arzu Taskiran Comez et al <sup>(63)</sup> explained the numerous techniques available to correct astigmatism during cataract surgery and concluded either one or a combination of procedures can be selected according to the patient requirement to correct astigmatism.

Eric C. Amesbury and Kevin M. Miller <sup>(64)</sup> reviewed the various options to correct astigmatism during phacoemulsification and found incision on steep meridian is sufficient to correct small amount of astigmatism, greater degree of astigmatism requires relaxing incisions on the cornea or at the limbus and toric lens implantation may be necessary for higher amount of astigmatism.

Mukesh Taneja <sup>(65)</sup> also reviewed management of astigmatism in cataract surgery and concluded the technique should be selected based on the magnitude of preexisting astigmatism, expertise and familiarity of the surgeon regarding the procedure.

**FIGURE NO – 10: STEPLADDER APPROACH TO MANAGEMENT OF  
ASTIGMATISM**

<b>Magnitude of Astigmatism</b>	<b>Treatment Approach</b>
<1.0 D	Phaco-incision on steep axis
1.0-1.5 D	Paired Opposite Clear Corneal Incision
1.0-3.0 D	Limbal Relaxing Incision
1.0-4.0 D	Toric IOL
4.0-7.0 D	High powered Toric IOLs Or combination of Toric IOL & LRI Or Bioptics

## **METHODOLOGY**

The present study was conducted in the Department of Ophthalmology, KLES Dr. Prabhakar Kore Hospital and Medical Research Centre, Belagavi on patients who underwent phacoemulsification cataract surgery to compare limbal relaxing incisions (LRIs) and the clear corneal incision on the steepest meridian (ISM) for the reduction of pre-existing corneal astigmatism.

**Source of Data:** All the patients with cataract and pre-existing astigmatism of 0.5 D – 2.5 D undergoing phacoemulsification surgery with foldable IOL, at KLES Dr. Prabhakar Kore Hospital and Medical Research Centre, Belagavi.

### **METHOD OF COLLECTION OF DATA**

#### **STUDY DESIGN:**

A One Year Randomized Control Trial

#### **STUDY PERIOD:**

One year – January 2017 to December 2017

#### **SAMPLE SIZE:**

A sample size of 60 cases

#### **SAMPLING PROCEDURE:**

Sample size for the study is calculated by following formula:

$$n = \frac{2(Z_{\alpha} + Z_{\beta})^2 S^2}{(x_1 - x_2)^2}$$

Where n = sample size

S = common standard deviation = 1

Mean difference = 0.8

Effect size = Mean difference/ SD

$$= 0.8/1$$

$$= 0.8$$

Z alpha = 1.96

Z beta = 0.84

**Group A:** with incision on steepest meridian: n= 30

**Group B:** with limbal relaxing incisions: n= 30

The study subjects will be randomized into two groups using computer generated random numbering system.

**Selection criteria:**

*Inclusion criteria*

- Patients with pre-senile/ senile cataract and pre-existing astigmatism of 0.5D – 2.5 D undergoing phacoemulsification surgery with foldable posterior chamber IOL implantation at KLES Hospital, Belagavi.
- Age group between 40 to 80 years.
- Patients with cataract up to grade 3 nuclear sclerosis.
- Pre-existing symmetric corneal astigmatism of 0.5 D to 2.5 D
- Patients willing to give informed consent.

*Exclusion criteria*

- Patients having hard brown cataract.
- Patients with corneal opacities, complicated cataracts, cataract with chronic uveitis, traumatic cataract, congenital cataract
- Patients with irregular astigmatism, keratoconus, marked corneal scarring.

**METHODOLOGY PROPER**

The ethical clearance was taken by JNMC Institutional Ethics Committee. All the patients who satisfy the inclusion criteria were included in the study. The patients were enrolled into the study and written informed consent was taken from them by the investigator.

Data regarding demographic parameters such as age, sex, occupation and address were noted on a predesigned proforma by the investigator at the time of first visit.

Detailed history of following symptoms was noted:

- H/O Diminution of vision Right Eye/Left Eye
  - ✓ Duration
  - ✓ Gradual/Sudden
  - ✓ Progressive/static
  - ✓ Distant/Near vision
  - ✓ Visual improvement with bright light or dim light
  - ✓ Painful/ Painless

- Diplopia/Polyopia
- Photophobia
- Flashes of light
- Colored halos
- Floaters
- Watering
- Redness
- Discharge
- Black spots in front of the eye
- H/O Curtain falling in front of the eyes
- H/O wearing glasses
- H/O Diabetes Mellitus, Hypertension.

History was followed by ocular examination that included:

- Visual Acuity with Snellen's chart
- Ocular examination proper (Adnexa, conjunctiva, cornea, Anterior chamber, iris, pupil and lens).
- Detailed slit lamp biomicroscopy to grade the cataract as:-
  - Cortical Cataract
  - Nuclear Sclerosis
  - Posterior Subcapsular Cataract
- Schiottz tonometry
- Best corrected Visual Acuity
- Retinoscopy
- Fundus examination

- **Pre operative Keratometry (Manual Bausch and Lomb Keratometer)**
- A scan biometry (SRK II Formula)
- Blood Pressure

Routine laboratory investigations included are:-

- ❖ Routine haemogram
- ❖ Diabetic Status

The study included 60 patients who were assigned into either of the two groups that is:

**Group A (30):** Phacoemulsification with incision on the steepest meridian

**Group B (30):** Phacoemulsification with limbal relaxing incisions

All the patients underwent phacoemulsification surgery. Single surgeon performed all the surgeries using the same standard technique. All the cases were operated under local anaesthesia following aseptic precautions.

**Surgical technique:**

**Group A:**

- Preoperative measures like consent for surgery, antibiotic eye drops, dilatation of pupil was done.
- The steepest meridian was marked with the surgical marking pen before anesthesia in slit lamp.
- Peribulbar block was given
- The eye was painted and draped.
- Eyelids retracted with speculum.
- Side ports made with 1.2 mm side-port blade depending on the incision site.

- Anterior chamber was filled with visco-elastic material
- Continuous curvilinear capsulorrhexis was carried out with a modified cystitome.
- A clear corneal self-sealing incision was made with a 3.2 mm keratome on pre-decided meridian.
- Astigmatic ring was placed over the cornea.
- Depending on the markings and the axis, superior incision is marked or temporal incision is marked.
- For superior clear corneal incision, surgeon sits at the head end and incision taken at 12.00 o'clock position.
- For temporal clear corneal incision, surgeon sits at the temporal side and takes incision according to the astigmatic ring axis.
- Hydrodissection and hydro delineation was performed to separate the capsule and nucleus and free rotation of nucleus was ensured.
- Phacoemulsification was done by chip and flip or by stop and chop procedure.
- Bimanual irrigation and aspiration was performed to remove the cortex.
- Following this, capsular polishing done.
- A foldable intraocular lens was inserted through a 3.2 mm incision with the help of an injector. Intra ocular lens inserted within the capsular bag.
- Residual visco-elastic was removed.
- The clear corneal wound was sealed by hydration.
- Eye was padded and bandaged after intracameral antibiotic injection.

**Group B:**

- Patients in Group B also underwent phacoemulsification surgery and the same steps were followed as in Group A till the implantation of the foldable intraocular lens.
- Mendez astigmatic ring was placed on the cornea.
- The paired incision borders are then marked with the surgical marker.
- The limbal relaxing incision is placed in clear cornea, just about 0.5mm inside the surgical limbus, centered over steep meridian and concentric to the limbus using a preset blade of 600µm depth.
- Residual visco-elastic was removed.
- The clear corneal phacoemulsification wound was sealed by hydration.
- Eye was padded and bandaged after intracameral antibiotic injection.

The extent of limbal relaxing incision was according to the Nichamin intralimbal arcuate astigmatic nomogram and calculated using Ircalculator.com.

Postoperatively all the patients received,

- Topical antibiotic with steroid 6 times x 1 week tapering the dosage every week for one month.
- Systemic antibiotics i.e. Oral Levofloxacin 500 mg OD given for 3 days.
- Postoperative assessment of the patient was carried out on 1<sup>st</sup> day, 3 weeks and 6 weeks.

Ocular examination during follow-up involved assessing:-

- Visual acuity

- Wound sealing
- Corneal clarity
- Intra ocular lens placement
- Fundus visibility
- Keratometry readings were taken on 3 and 6 weeks postoperative visit.

The amplitude of preoperative astigmatism and postoperative astigmatism was calculated from the difference in keratometric values in the steeper meridian and flatter meridian. Surgically induced astigmatism, correction index and flattening effect was calculated using SIA calculator version 3.1 and Alpins method of vector analysis.

### **Statistical analysis**

Unpaired 't' test and Paired 't' test were used for the calculation of the results.

## **RESULTS**

The present study was conducted on 60 eyes who underwent phacoemulsification at the Department of Ophthalmology, KLES Dr. Prabhakar Kore Charitable Hospital and Medical Research Centre, Belagavi during the study period. It included patients having 0.5 – 2.5 Diopters(D) of pre-existing corneal astigmatism who were assigned to either of the two surgical techniques by computer generated random numbering system.

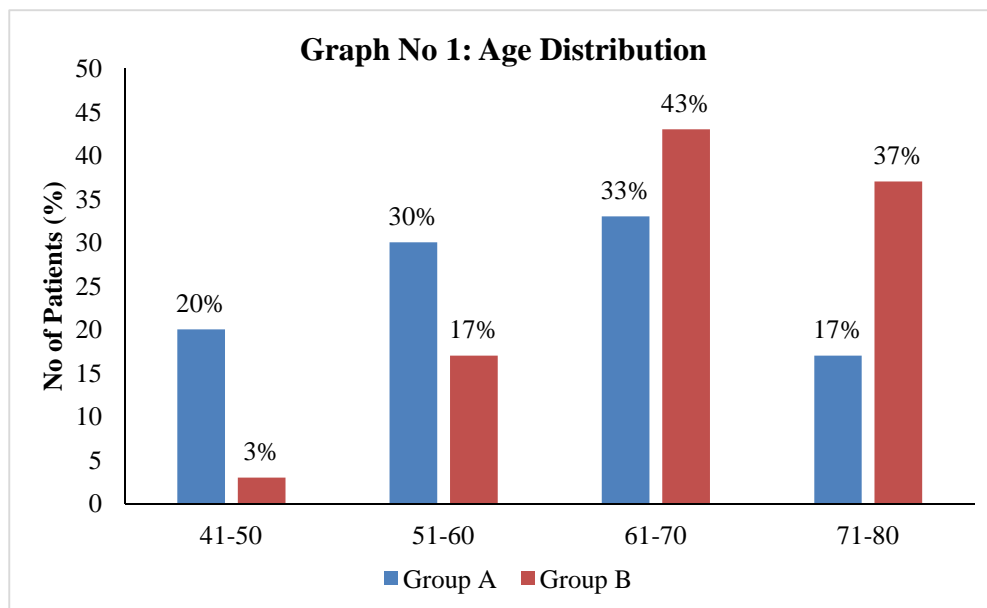
**Group A:** Phacoemulsification with a single clear corneal incision placed on the steepest meridian.

**Group B:** Phacoemulsification with paired limbal relaxing incisions straddling the steepest corneal meridian.

Pre-operative and post-operative keratometric readings and subjective refraction were used for analysis. All calculations were performed using SIA calculator version 3.1, a free software programme and Alphins method of vector analysis.

Table No 1: Age Distribution

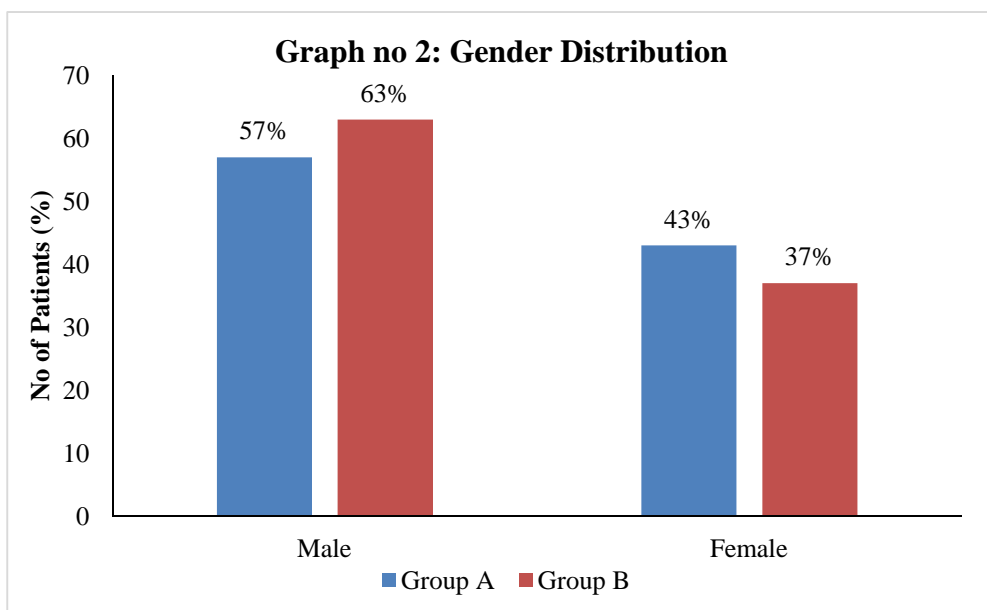
Age (in years)	Group A	Group B
	No. of patients (%)	No. of patients (%)
41-50	6 (20)	1 (3)
51-60	9 (30)	5 (17)
61-70	10 (33)	13 (43)
71-80	5 (17)	11 (37)
<b>Total</b>	30 (100)	30 (100)



In the present study, the mean age in Group A was  $61.87 \pm 10.12$  years and Group B was  $66.17 \pm 8.30$  years. Majority of the patients were in the range of 61 – 70 years in both the Groups.

Table no 2: Gender Distribution

Gender	Group A	Group B
	No. of patients (%)	No. of patients (%)
Male	17 (57)	19 (63)
Female	13 (43)	11 (37)
Total	30 (100)	30 (100)

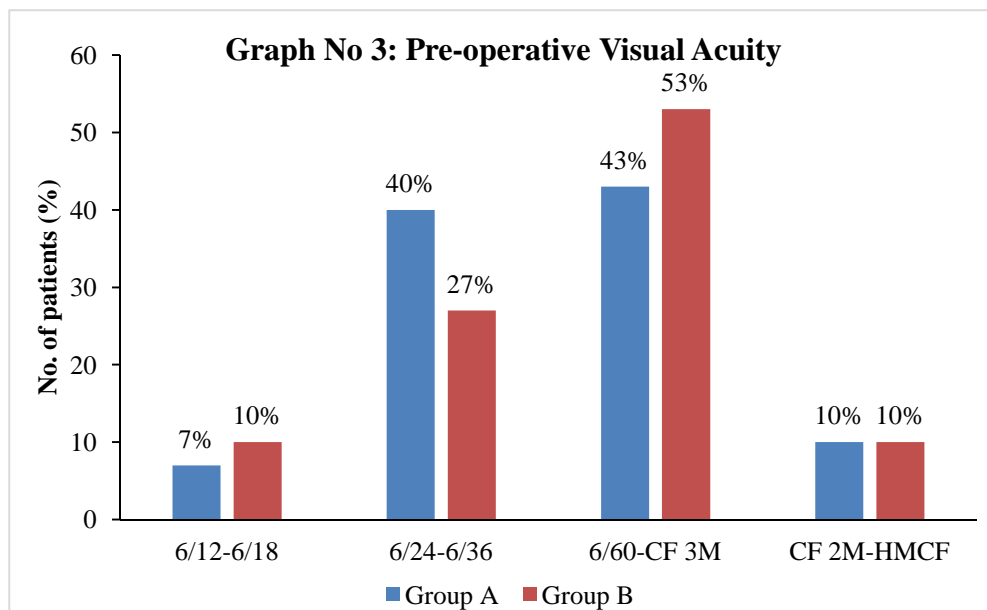


In the present study, 57% patients were male and 43 % patients were female with male : female ratio of 1.3:1 in Group A.

63% patients were male and 37% patients were female with male : female ratio of 1.7:1 in Group B.

Table No 3: Pre-operative Visual Acuity

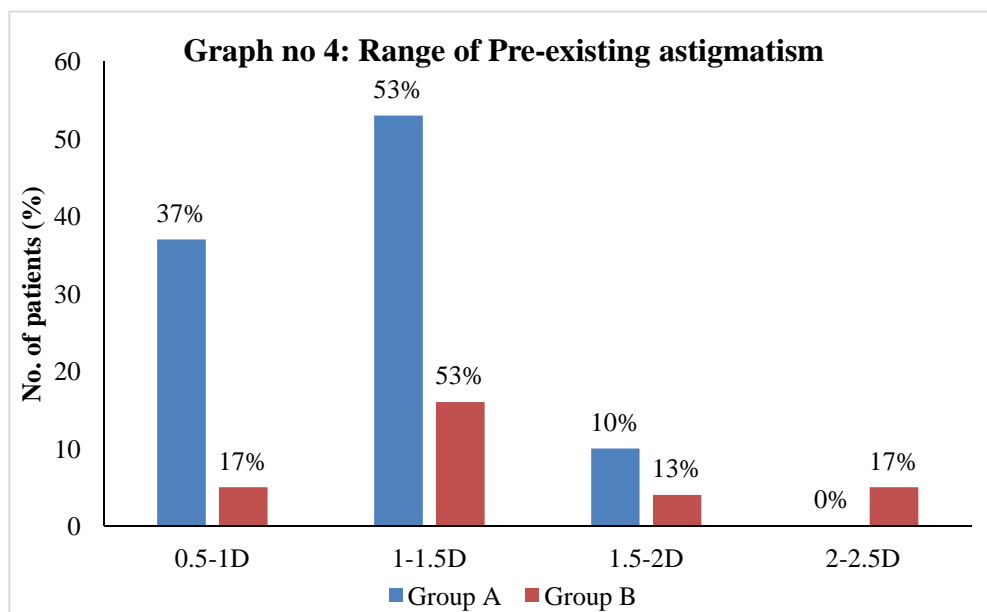
Pre-Op Visual Acuity	Group A	Group B
	No. of Patients (%)	No. of Patients (%)
6/12 -6/18	2 (7)	3 (10)
6/24 -6/36	12 (40)	8 (27)
6/60 –CF 3M	13 (43)	16 (53)
CF 2M - HMCF	3 (10)	3 (10)
<b>TOTAL</b>	30 (100)	30 (100)



In the present study, majority of the patients had pre-operative visual acuity in the range of 6/60 to CF 3 meters in both Group A and Group B being 43% and 53% respectively, followed by 40% in Group A and 27% in Group B with pre-operative visual acuity in the range of 6/24 – 6/36.

**Table no 4: Range of Pre-existing astigmatism**

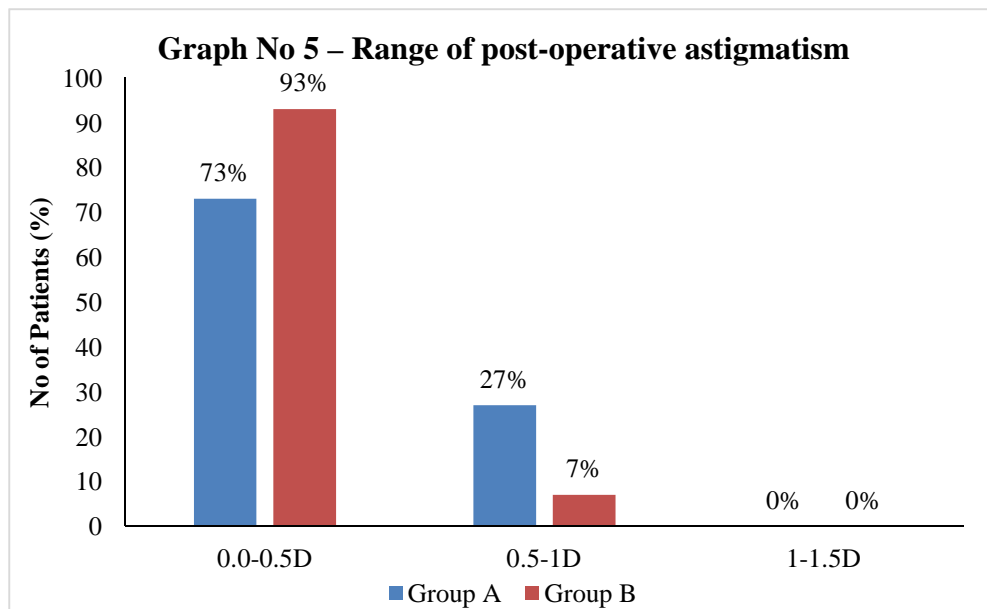
Diopters	Group A	Group B
	No. of Patients (%)	No. of Patients (%)
<b>0.5 – 1 D</b>	11 (37)	5 (17)
<b>1 – 1.5 D</b>	16 (53)	16 (53)
<b>1.5 – 2 D</b>	3 (10)	4 (13)
<b>2 – 2.5 D</b>	0	5 (17)
<b>TOTAL</b>	30 (100)	30 (100)



In this study, 37% patients in Group A and 17% patients in Group B had pre-existing astigmatism in the range of 0.5 D – 1 D, 53% in the range of 1D – 1.5D of pre-existing astigmatism in both groups, 10% in Group A and 13% in Group B in the range of 1.5 D – 2 D and no patient in Group A and 17% in Group B had pre-existing astigmatism in the range of 2 D – 2.5 D.

**Table No 5 – Range of post-operative astigmatism**

Post-operative Astigmatism	Group A	Group B
	No. of Patients (%)	No. of Patients (%)
<b>0.0 – 0.5 D</b>	22 (73)	28 (93)
<b>0.5 – 1 D</b>	08 (27)	02 (07)
<b>1 – 1.5 D</b>	0	0
<b>TOTAL</b>	30 (100)	30 (100)

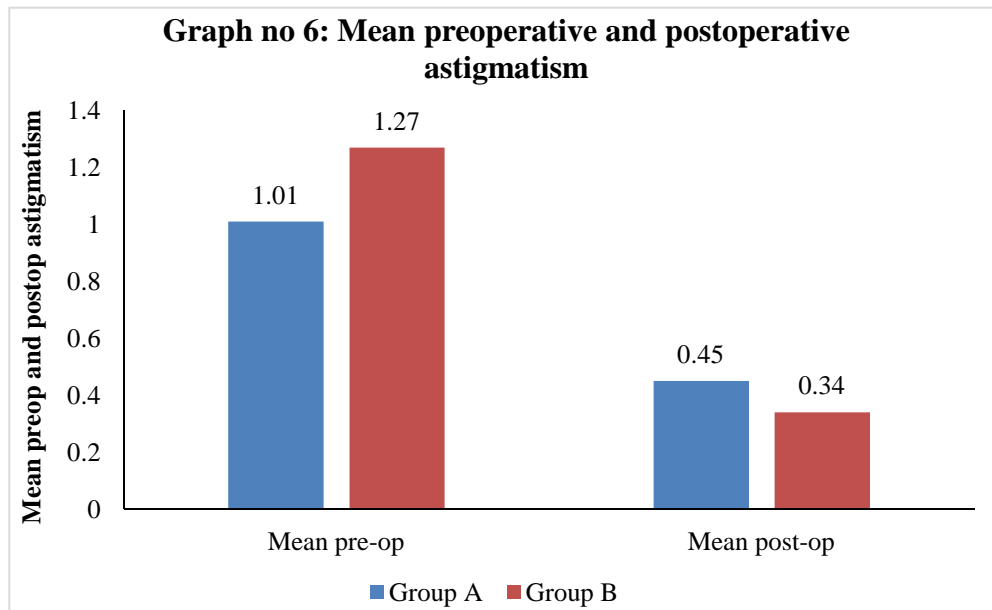


In this study, 73% patients had post-operative astigmatism in the range of 0.0 - 0.5 D followed by 27% patients in the range of 0.5 – 1D of post-operative astigmatism in Group A.

93% patients had post-operative astigmatism in the range of 0.0 - 0.5 D followed by 7 % patients in the range of 0.5 – 1D of post-operative astigmatism in Group B. No patient had post-operative astigmatism >1.0 D in both groups.

**Table no 6: Mean preoperative and postoperative astigmatism**

Group	Mean preoperative astigmatism	SD	Mean postoperative astigmatism	SD
Group A	1.01	0.27	0.45	0.28
Group B	1.27	0.53	0.34	0.20

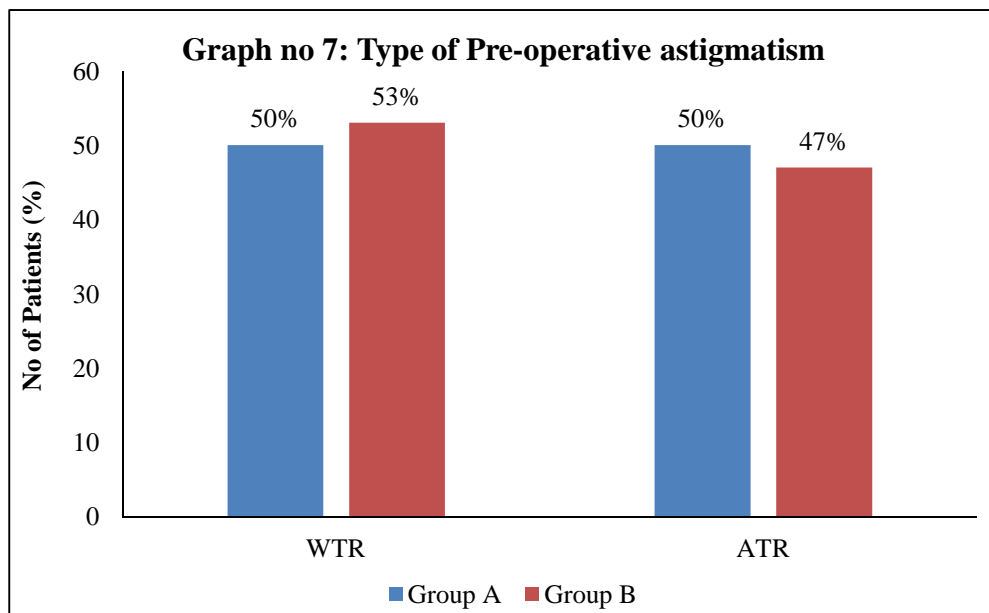


In Group A, the mean pre-operative and post-operative astigmatism was  $1.01 \pm 0.27$  D and  $0.45 \pm 0.28$  D respectively which was highly significant statistically ( $p < 0.0001$ ). The mean astigmatic correction in Group A was  $0.56 \pm 0.01$  D.

In Group B, the mean pre-operative and postoperative astigmatism was  $1.27 \pm 0.53$  D and  $0.34 \pm 0.20$  D respectively which was highly significant statistically ( $p < 0.001$ ). The mean astigmatic correction in Group B was  $0.93 \pm 0.33$  D.

**Table no 7: Type of Pre-operative astigmatism**

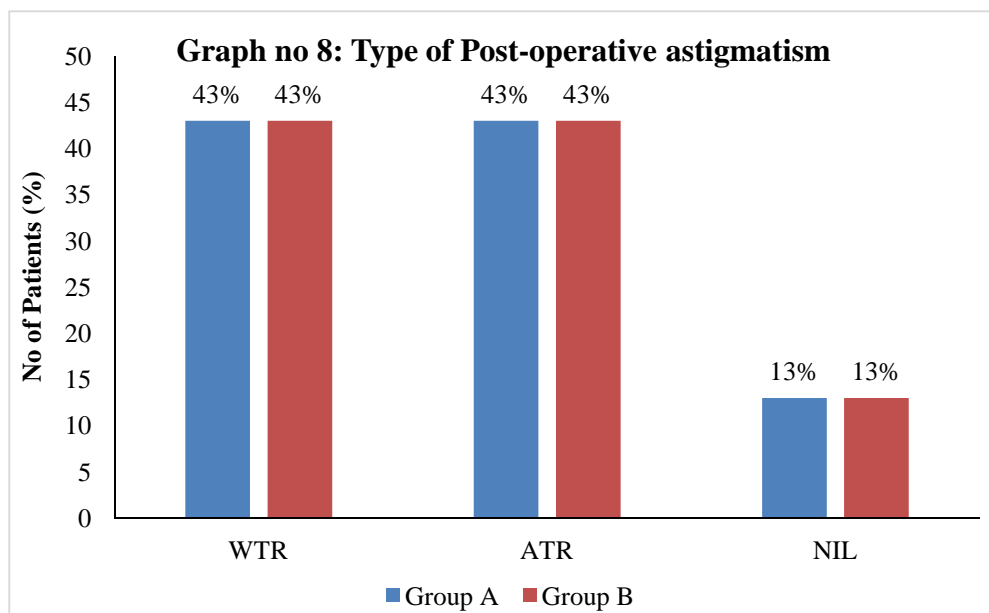
Pre-operative Astigmatism	Group A	Group B
	No. of Patients (%)	No. of Patients (%)
WTR	15 (50)	16 (53)
ATR	15 (50)	14 (47)
TOTAL	30 (100)	30 (100)



In this study 50% patients had WTR astigmatism and 50% had ATR astigmatism in Group A and 53% patients had WTR astigmatism and 47% had ATR astigmatism in Group B.

Table no 8: Type of Post-operative astigmatism

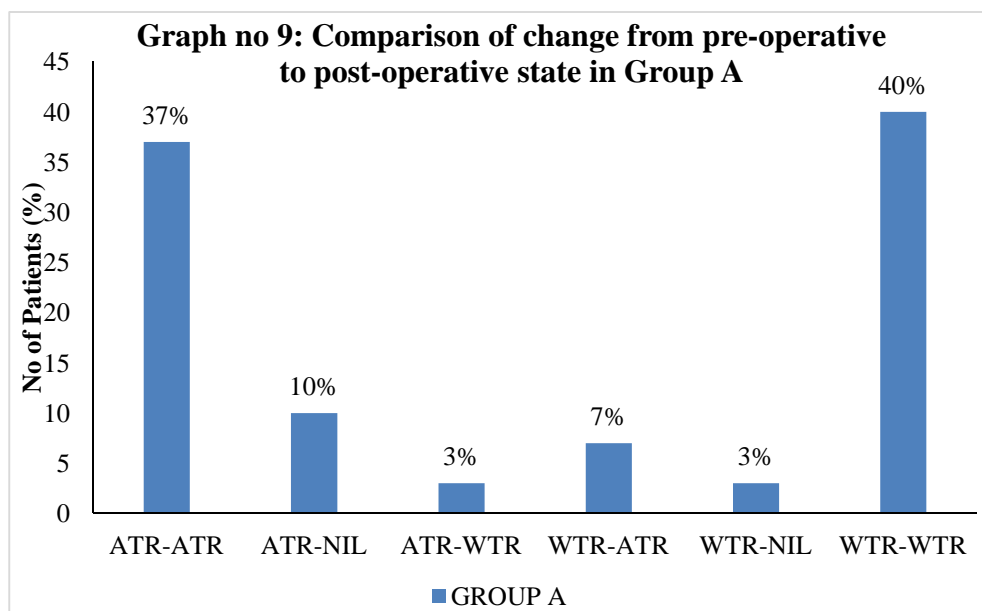
Post-Operative Astigmatism	Group A	Group B
	No. of Patients (%)	No. of Patients (%)
WTR	13 (43)	13 (43)
ATR	13 (43)	13 (43)
NIL	4 (13)	4 (13)
<b>TOTAL</b>	<b>30 (100)</b>	<b>30 (100)</b>



In the present study, the type of post-operative astigmatism was 43% WTR, 43% ATR and 13% of patients with no post-operative astigmatism in both the groups.

**Table no 9: Comparison of change from pre-operative to post-operative state in Group A**

GROUP A	Post-operative astigmatism			TOTAL
	ATR	NIL	WTR	
Pre-operative astigmatism				
ATR	11(37%)	3(10%)	1(3%)	15
WTR	2(7%)	1(3%)	12(40%)	15
TOTAL	13	4	13	30



Of the 15 patients having pre-operative ATR astigmatism, 11 patients (37%) continued to remain so post-operatively.

03 patients (3%) showed a post-operative ATR drift.

01 patients (10%) showed no astigmatism post-operatively.

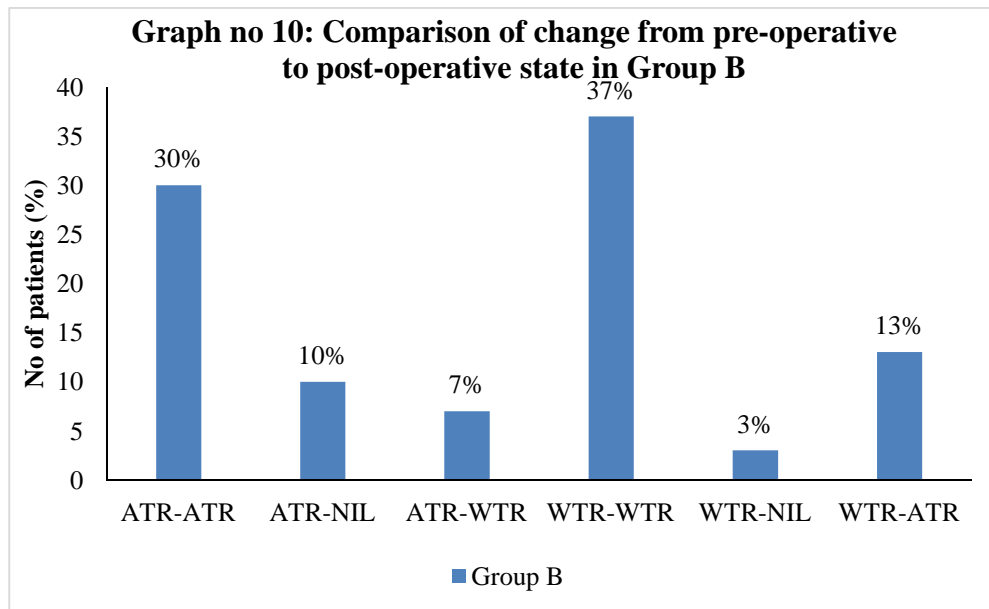
Of the 15 patients having pre-operative WTR astigmatism, 12 patients (40%) continued to remain so post-operatively.

02 patients (7%) showed a post-operative ATR drift.

01 patient (3%) showed no astigmatism post-operatively.

**Table no 10: Comparison of change from pre-operative to post-operative state in Group B**

GROUP B	Post-operative astigmatism			TOTAL
	ATR	NIL	WTR	
Pre-operative astigmatism				
ATR	9(30%)	3(10%)	2(7%)	15
WTR	4(13%)	1(3%)	11(37%)	15
TOTAL	13	4	13	30



Of the 14 patients having pre-operative ATR astigmatism, 9 patients (30%) continued to remain so post-operatively.

02 patients (7%) showed a post-operative ATR drift.

03 patients (10%) showed no astigmatism post-operatively.

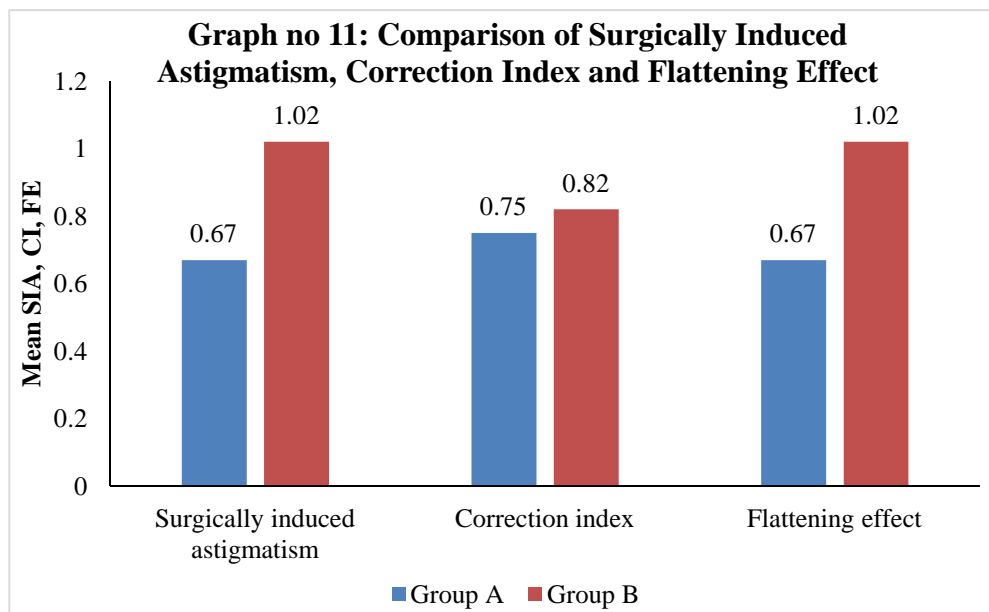
Of the 16 patients having pre-operative WTR astigmatism, 11 patients (37%) continued to remain so post-operatively.

04 patients (13%) showed a post-operative ATR drift.

01 patient (3%) showed no astigmatism post-operatively.

**Table no 11: Comparison of Surgically Induced Astigmatism, Correction Index and Flattening Effect**

	GROUP A		GROUP B	
	MEAN	S.D.	MEAN	S.D.
<b>SIA</b>	0.67	0.27	1.02	0.46
<b>CI</b>	0.75	0.40	0.82	0.26
<b>FE</b>	0.67	0.27	1.02	0.46



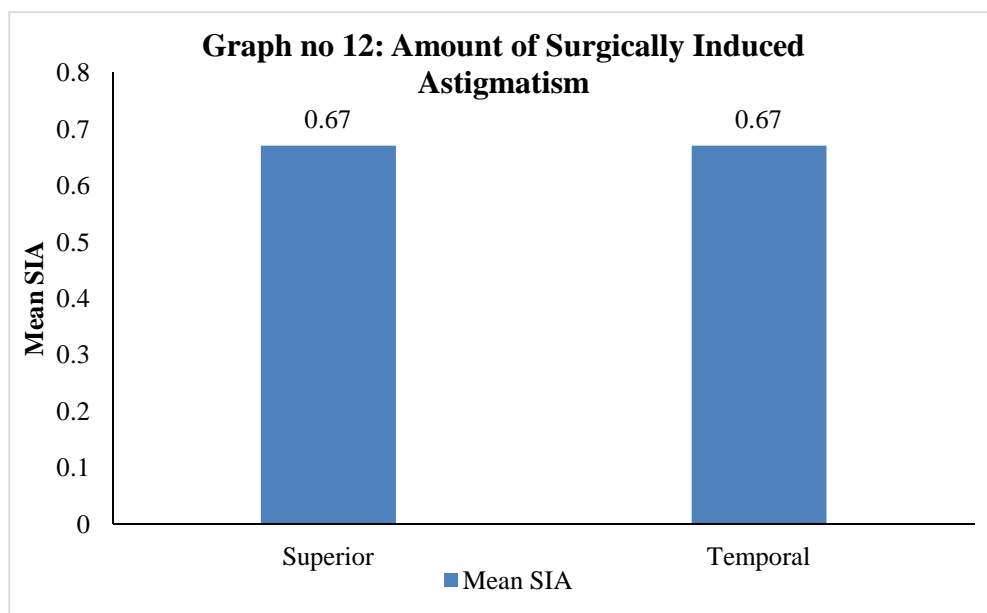
In the present study, the mean surgically induced astigmatism in Group A was 0.67 with the standard deviation of 0.27 and in Group B the mean surgically induced astigmatism was 1.02 with the standard deviation of 0.46. This comparison of difference of surgically induced astigmatism between the two groups was highly significant statistically ( $p=0.0007$ ).

In this study, the mean correction index in Group A was  $0.75 \pm 0.4$  and in Group B the mean correction index was  $0.82 \pm 0.26$  which was not statistically significant.

In the present study, the mean flattening effect in Group A was 0.67 with the standard deviation of 0.27 and the mean flattening effect in Group B was 1.02 with the standard deviation of 0.46. The comparison between the two groups was highly significant statistically ( $p=0.0007$ ).

**Table no 12: Amount of Surgically Induced Astigmatism**

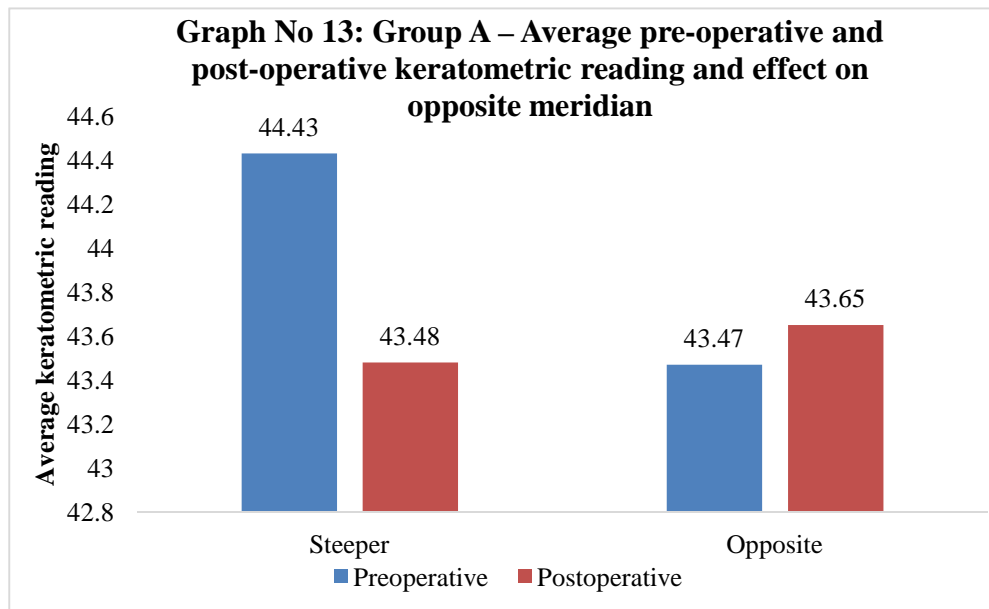
<b>TYPE OF SIA</b>	<b>Mean</b>	<b>SD</b>
<b>Superior</b>	0.67	0.24
<b>Temporal</b>	0.67	0.29



The average SIA induced by superior incision was  $0.67 \text{ D} \pm 0.24$  and the average SIA induced by temporal incision was  $0.67 \text{ D} \pm 0.29$  which was not statistically significant.

**Table No 13: Group A – Average pre-operative and post-operative keratometric reading and effect on opposite meridian**

	<b>Pre-operative Average Keratometric reading</b>	<b>Post-operative Average Keratometric reading</b>
<b>Steeper Meridian</b>	44.43	43.48
<b>Opposite Meridian</b>	43.47	43.65

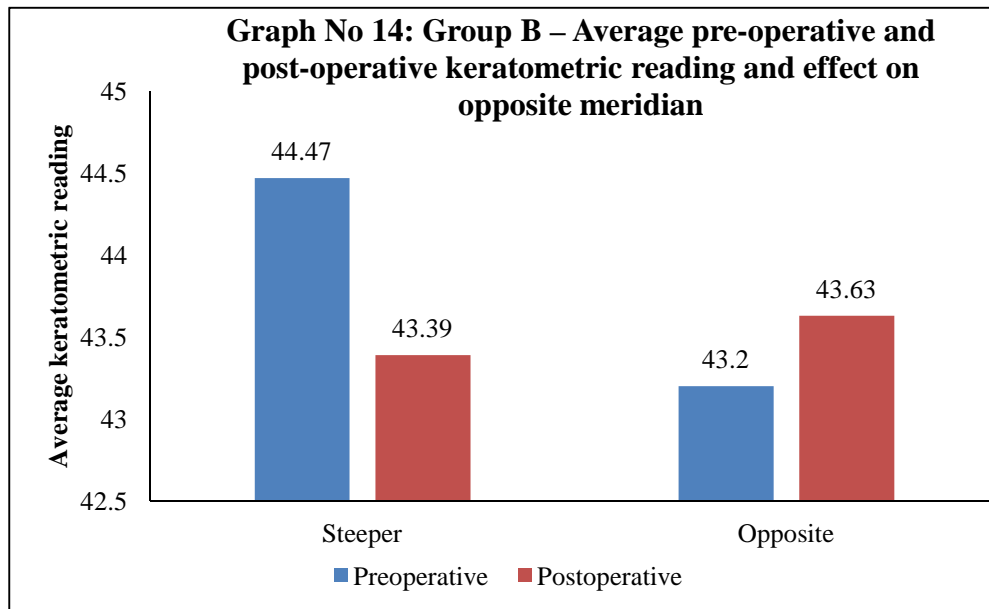


In Group A, the average pre-operative keratometric reading is 44.43 and the average post-operative keratometric reading is 43.48. The difference is  $0.95 \pm 0.92$  with  $p < 0.001$  (Statistically significant).

The effect on the opposite meridian is as follows, the average pre-operative keratometric reading is 43.47 and the average post-operative keratometric reading is 43.65. Not statistically significant ( $p < 0.1760$ )

**Table No 14: Group B – Average pre-operative and post-operative keratometric reading and effect on opposite meridian**

	<b>Pre-operative Average Keratometric reading</b>	<b>Post-operative Average Keratometric reading</b>
<b>Steeper Meridian</b>	44.47	43.39
<b>Opposite Meridian</b>	43.20	43.63

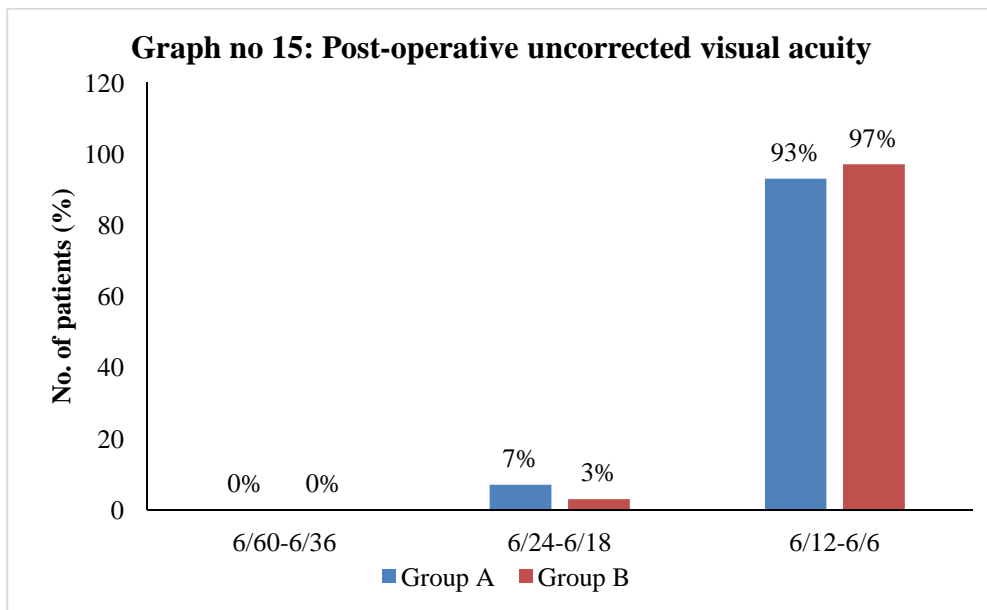


In Group B, the average pre-operative keratometric reading is 44.47 and the average post-operative keratometric reading is 43.39. The difference was  $1.08 \pm 0.96$  with  $p < 0.001$  (Statistically significant).

The effect on the opposite meridian is as follows, the average pre-operative keratometric reading is 43.20 and the average post-operative keratometric reading is 43.63. Not statistically significant ( $p < 0.1731$ )

**Table no 15: Post-operative uncorrected visual acuity**

Range of visual acuity	Group A	Group B
	No. of patients (%)	No. of patients (%)
<b>6/60 -6/36</b>	0	0
<b>6/24 – 6/18</b>	02 (07)	01 (03)
<b>6/12 – 6/6</b>	28 (93)	29 (97)

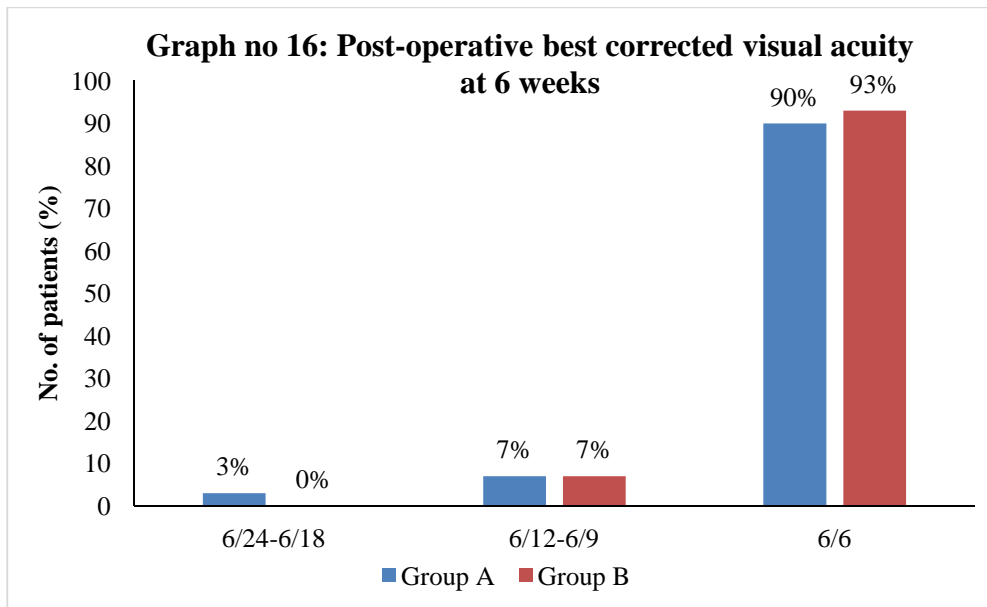


In Group A, post-operatively 7% patients had uncorrected visual acuity in the range of 6/24 – 6/18 and 93% patients had uncorrected visual acuity in the range of 6/12 – 6/6.

In Group B, post-operatively 03% patients had uncorrected visual acuity in the range of 6/24 – 6/18 and 97% patients had uncorrected visual acuity in the range of 6/12 – 6/6.

**Table no 16: Post-operative best corrected visual acuity at 6 weeks**

Range of visual acuity	Group A	Group B
	No. of patients (%)	No. of patients (%)
<b>6/24 – 6/18</b>	1 (3)	0
<b>6/12 – 6/9</b>	2 (7)	2 (7)
<b>6/6</b>	27 (90)	28 (93)



In Group A,

3% of patients had BCVA in the range of 6/24-6/18.

7% of patients had BCVA in the range of 6/12-6/9.

90% of patients had BCVA in the range of 6/6.

In Group B,

7% of patients had BCVA in the range of 6/12-6/9.

93% of patients had BCVA in the range of 6/6.

## **DISCUSSION**

There has been a constant development in the field of cataract surgery over the years. It has evolved from couching in ancient times to modern day manual Small Incision Cataract Surgery (SICS) and phacoemulsification to latest femtosecond laser assisted micro incision cataract surgery. After the introduction of phacoemulsification through a small clear corneal incision and foldable intraocular lens, the aim of the surgeon has changed from mere cataract extraction to reduction of surgically induced astigmatism and also correct the pre-existing astigmatism, if any present. Thus, cataract surgery today can be modified as a '**Refractive Cataract Surgery**'.

Early visual rehabilitation and satisfaction of patients who undergo phacoemulsification depends on two factors: The implantation of appropriate power of IOLs and postoperative astigmatism. After phacoemulsification surgery, the source of residual refractive error often is corneal astigmatism. The goal of modern cataract surgery is to minimize corneal curvature changes postoperatively which reduces surgically induced astigmatism and corrects the pre-existing astigmatism. This requires an exact pre-operative evaluation of corneal curvature and astigmatism.

The corneal refractive changes depend on the size and location of the corneal incision. The smaller incisions induce lesser SIA and result in better optical quality. Preexisting corneal astigmatism can be reduced through different incisional techniques during cataract surgery which flattens the steep axis of cornea. It includes placing clear corneal cataract incision on steepest meridian based on the type of pre-operative astigmatism or applying relaxing incisions at the limbus or in the cornea.

Previous studies show that the pre-existing corneal astigmatism can be reduced by the modification of the incision location knowing the steepest meridian and by placing paired limbal relaxing incisions during the phacoemulsification surgery. Any surgical incision placed on the cornea, results in a change of the corneal curvature. This induces a flattening in the axis of incision and steepening 90 degrees away. Our study is based on the same principle.

The present study was conducted on 60 eyes that underwent phacoemulsification at the Department of Ophthalmology, KLES Dr. Prabhakar Kore Charitable Hospital and Medical Research Centre, Belagavi during the study period of 1 year from January 2017 – December 2017. It included patients having 0.5-2.5 Diopters(D) of pre-existing corneal astigmatism who were divided into two groups of 30 each by computer generated random numbering system and underwent the following surgical techniques:

**Group A:** Phacoemulsification with a single clear corneal incision placed on the steepest meridian.

**Group B:** Phacoemulsification with a single clear corneal incision along with Limbal relaxing paired incisions straddling the steepest corneal meridian.

In the present study, the mean age in Group A was  $61.87 \pm 10.12$  years and Group B was  $66.17 \pm 8.30$  years. Majority of the patients were in the range of 61 – 70 years in both the Groups as cataract is more common in this age group which is comparable to the study conducted by Nauljira Prakairungthong et al <sup>(66)</sup> and Ferrer-Blasco et al <sup>(31)</sup>. Male : Female ratio in Group A and Group B was 1.3:1 and 1.7:1

respectively. Even though, gender distribution was co-related between the two groups, it did not have any effect on the postoperative results.

Majority of the patients in our study had pre-operative visual acuity in the range of 6/60 to CF 3 meters in both Group A and Group B being 43% and 53% respectively and only 10% in both Group A and Group B had pre-operative visual acuity in the range of CF 2M – HMCF as cases upto grade III nuclear sclerosis were taken excluding hard/brown cataract.

#### **Pre-operative and postoperative astigmatism:**

Our study included patients with pre-existing astigmatism in the range of 0.5 D to 2.5 D who underwent phacoemulsification surgery either by clear corneal incision on the steepest meridian or paired limbal relaxing incisions on the steepest meridian along with phacoemulsification incision.

In this study, 37% patients in Group A and 17% patients in Group B had pre-existing astigmatism in the range of 0.5 D – 1 D. Greater number of patients in both Group A (63%) and Group B (83%) had more than 1 D of pre-existing astigmatism which is comparable to the study conducted by Nauljira Prakairungthong et al <sup>(66)</sup> and Guan Z et al <sup>(67)</sup> who evaluated the Prevalence of Preoperative Corneal Astigmatism in Patients Undergoing Cataract Surgery and concluded majority of the patients had astigmatism of more than 1.0 D which is similar to our study. However, Group B had patients with higher degree of astigmatism compared to Group A.

A study conducted by Ninn Pedersen K et al <sup>(68)</sup> proved that the most important predisposing factor for rapid changes in the postoperative astigmatism were large preoperative astigmatism and young age. Anders N et al <sup>(69)</sup> confirmed that age

and preoperative astigmatism were found to influence induced astigmatism significantly.

The length of the paired incisions in Group B was calculated using Ircalculator.com considering the NAPA nomogram. Post-operatively, keratometric readings were taken at 3 weeks and 6 weeks followed by subjective refraction. Keratometric readings at 3 weeks postoperatively were inconsistent and hence postoperative keratometric readings at 6 weeks is considered in our study.

In the present study, majority of the patients in Group A that is 22 (73%) had post-operative astigmatism in the range of 0.0 – 0.5 D, followed by 08 patients that is 27% in the range of 0.5 – 1D. In Group B, 28 patients that is 93% had post-operative astigmatism in the range of 0.0 – 0.5D whereas only 2 patients (7%) had post-operative astigmatism in the range of 0.5 – 1D and no patient in both groups had more than 1 D of post-operative astigmatism.

In Group A, the mean pre-operative and post-operative astigmatism was  $1.01 \pm 0.27$  D and  $0.45 \pm 0.28$  D respectively which was highly significant statistically ( $p < 0.0001$ ). Similarly, in Group B, the mean pre-operative and postoperative astigmatism was  $1.27 \pm 0.53$  D and  $0.34 \pm 0.20$  D respectively which was highly significant statistically ( $p < 0.001$ ). Both the methods were effective in correcting pre-existing astigmatism. The magnitude of astigmatic correction was more in the LRI group ( $0.93 \pm 0.33$ ) compared to incision on the steep meridian group ( $0.56 \pm 0.01$ ) as LRI corrected upto 2.5 D of astigmatism.

A study conducted by Carvalho MJ et al <sup>(70)</sup> showed similar results as our study with mean pre-operative and postoperative astigmatism being  $1.93 \pm 0.58$  D

and 1.02 +/- 0.60 D respectively where they evaluated safety and efficacy of LRIs during cataract surgery.

Budak K et al <sup>(71)</sup> also concluded LRI is a practical and forgiving approach in the correction of astigmatism where the preoperative corneal cylinder was 2.46 +/- 0.81 diopters (D) and postoperative corneal cylinder was 1.12 +/- 0.74 D at 1 month.

In another study conducted by Muhammad Asif Sadiq et al, <sup>(72)</sup> the effect of clear corneal temporal versus steepest meridian phacoemulsification incision on pre-existing astigmatism was studied. On 12 weeks post-operatively, corneal astigmatism of both group A ( $0.98 \pm 0.44$ ) and group B ( $0.46 \pm 0.377$ ) was significantly less than pre-operative astigmatism but the effect of phaco-incision in reducing pre-existing astigmatism was much superior in group B than in group A. This study concluded that steepest meridian phaco-incision results in significant decrease in pre-operative astigmatism similar to our study.

Out of the total 30 eyes in Group A, 15 eyes had pre-operative WTR astigmatism ( $K_V > K_H$ ) and so underwent phacoemulsification through superior incision. Another 15 eyes had pre-operative ATR astigmatism who underwent phacoemulsification through temporal incision ( $K_H > K_V$ ).

Salvatore Cillino et al <sup>(73)</sup> who studied temporal versus superior approach phacoemulsification and determined short term post-operative astigmatism, 50% patients had pre-operative WTR astigmatism and 50% patients had pre-operative ATR astigmatism which was similar to our study.

In Group B, out of the total 30 eyes, 16 eyes had pre-operative WTR astigmatism ( $K_V > K_H$ ) and so paired limbal relaxing incisions were placed in vertical

meridian and remaining 14 eyes had pre-operative ATR astigmatism ( $K_H > K_V$ ) where limbal relaxing incisions were placed in the horizontal meridian. All the patients in Group B underwent phacoemulsification with a single clear corneal incision.

In the present study, the type of post-operative astigmatism was 43% WTR, 43% ATR and 13% of patients with no post-operative astigmatism in both the groups. We also compared the change from pre-operative to post-operative astigmatism. We concluded in Group A, out of 15 patients having pre-operative ATR astigmatism, 11 patients (37%) continued to remain so post-operatively with less magnitude. 1 patient (3%) showed a post-operative WTR drift and 3 patients (10%) showed no post-operative astigmatism. Of the rest 15 patients who had WTR pre-operative astigmatism, 12 patients that is 40% continued to have WTR astigmatism of less magnitude. 2 patients (7%) showed a post-operative ATR drift whereas 1 patient (3%) showed no post-operative astigmatism.

Similarly, in Group B, out of 14 patients who had ATR pre-operative astigmatism, 9 patients that is 30% continued to have ATR astigmatism of less magnitude. 2 patients (7%) showed a post-operative WTR drift whereas 3 patients (10%) showed no post-operative astigmatism. Of the rest 16 patients having pre-operative WTR astigmatism, 11 patients (37%) continued to remain so post-operatively with less magnitude. 4 patients (13%) showed a post-operative ATR drift and 1 patient (3%) showed no post-operative astigmatism. This observation has not been mentioned in any other study.

By knowing a preexisting astigmatism preoperatively, one can reduce postoperative astigmatism by selecting an appropriate incision i.e. astigmatism is decreased by taking incision on the steeper meridian. <sup>(74)</sup>

**Surgically induced astigmatism, correction index and the flattening effect:**

Surgically induced astigmatism, correction index and flattening effect were evaluated based on pre-operative and post-operative keratometric readings. All calculations were performed using SIA calculator version 3.1, a free software programme and Alpins method of vector analysis.

In the present study, the mean surgically induced astigmatism in Group A was 0.67 with the standard deviation of 0.27 and in Group B the mean surgically induced astigmatism was 1.02 with the standard deviation of 0.46. This comparison of difference of surgically induced astigmatism between the two groups was highly significant statistically ( $p=0.0007$ ). SIA in Group A was less compared to Group B as more number of incisions were placed in the LRI group.

In this study, the mean correction index in Group B was more compared to Group A which was  $0.82 \pm 0.26$  and  $0.75 \pm 0.4$  respectively even-though it was not statistically significant.

The mean flattening effect in Group A was 0.67 with the standard deviation of 0.27 and the mean flattening effect in Group B was 1.02 with the standard deviation of 0.46. The comparison between the two groups was highly significant statistically ( $p=0.0007$ ). This implies that limbal relaxing incisions are more effective in flattening the steep meridian of cornea compared to a single clear corneal incision.

Claude Kaufmann et al <sup>(75)</sup> compared LRIs with on axis incisions (OAI) on two groups of 38 and 33 patients each. Surgically induced astigmatism was 1.30 D (0.74 to 2.42) and 0.81 D (0.54 to 1.48), correction index was 0.67 (0.35 to 0.90) and 0.45 (0.28 to 0.65) and flattening effect was 1.21 D (0.43 to 2.25) and 0.41 D (0.15 to

0.78) in LRI group and on axis incision group respectively at 6 weeks postoperatively. This result is similar to our study. They concluded LRI technique was more favourable in achieving reduction of pre-existing astigmatism and remained consistent throughout the follow-up.

Mohammad Ali Zare et al<sup>(76)</sup> showed LRIs were safe and effective in treating mild to moderate corneal astigmatism. Mean corneal astigmatism reduction was statistically significant with  $1.9\pm 0.83$  D preoperatively to  $1.4\pm 0.84$  D and  $1.4\pm 0.92$ , 2 months and 6 months postoperatively ( $P<0.001$ ). Surgical induced astigmatism (SIA) was  $0.90\pm 0.48$  at 2 months and  $0.96\pm 0.59$  at 6 months. Correction index (CI) was  $0.55\pm 0.41$  and  $0.57\pm 0.32$  at 2 and 6 months, respectively which is comparable to our study.

Chang Rae Rho et al,<sup>(77)</sup> studied the effects of steeper meridian incision on pre-existing corneal astigmatism in phacoemulsification. Patients were grouped according to the incision site (temporal, supero-temporal, superior). This study concluded that choosing the corneal incision based on the preoperative steepest meridian significantly decreased keratometric astigmatism at the temporal, supero-temporal and superior locations. So, it is wise to place the corneal incision on the steepest meridian in eyes with corneal astigmatism greater than 0.50 D which is similar to our study.

The patients in Group A were subdivided into two groups based on type of pre-existing astigmatism. 15 patients had WTR astigmatism pre-operatively. So, underwent phacoemulsification through superior incision. The amount of surgically induced astigmatism through the superior incision was 0.67 D with standard deviation of 0.24.

Pre-operatively 15 patients had ATR astigmatism. So, underwent phacoemulsification through temporal incision. The amount of surgically induced astigmatism through the temporal incision was 0.67 D with standard deviation of 0.29.

Studies have shown temporal incision induces less SIA compared to superior incision. However, in our study, comparison of difference of surgically induced astigmatism between temporal and superior incision was not statistically significant ( $p=1.000$ ).

A study by Marek R et al, <sup>(78)</sup> indicated that a clear corneal incision of 2.75 mm for a cataract surgery induced little change in astigmatism in eyes with low pre-operative corneal cylinder, regardless of the incision site. But later a retrospective study was done, which concluded that larger changes were induced by superior rather than temporal 2.8 mm incision.

Pistarini Fernando Goncalves et al <sup>(40)</sup> conducted a study to evaluate the effect of phacoemulsification with clear corneal incision in the steepest meridian on the magnitude of the pre-operative astigmatism. The mean SIA was  $0.61 \text{ D} \pm 0.25$  through the temporal incision which is similar to our study.

**Effect on steeper and opposite meridians:**

In the present study, by taking the phacoemulsification incision on the steepest meridian on the basis of pre-existing astigmatism, that is in Group A the average pre-operative keratometric reading is 44.43 and the average post-operative keratometric reading is 43.48. The difference was  $0.95 \pm 0.92$  with  $p < 0.001$  (Statistically significant). So, our study shows that there is a 0.95D reduction in the keratometric

reading after the cataract surgery performed by taking incision on the steepest meridian.

The effect on the opposite meridian is as follows, the average pre-operative keratometric reading is 43.47 and the average post-operative keratometric reading is 43.65. There was not much difference on the opposite meridian by taking incision on the steepest meridian (Not statistically significant).

Similarly, by placing the paired limbal relaxing incisions on the steepest meridian along with phacoemulsification incision, that is in Group B, the average pre-operative keratometric reading is 44.47 and the average post-operative keratometric reading is 43.39. The difference was  $1.08 \pm 0.96$  with  $p < 0.001$  (Statistically significant). Our study shows that there is a 1.08D reduction in the keratometric reading after the cataract surgery performed by placing limbal relaxing incisions on the steepest meridian.

The effect on the opposite meridian is as follows, the average pre-operative keratometric reading is 43.20 and the average post-operative keratometric reading is 43.63. There was not much effect on the opposite meridian (Not statistically significant).

**Uncorrected visual acuity and best corrected visual acuity at 6 weeks:**

In group A, 6 weeks post-operatively 7% patients had uncorrected visual acuity ranging from 6/24 – 6/18. 93% patients had uncorrected visual acuity ranging from 6/12 – 6/6. Similarly, in Group B, 3% patients had uncorrected visual acuity ranging from 6/24 – 6/18. 97% patients had uncorrected visual acuity ranging from 6/12 – 6/6.

In this study, 97% patients in Group A and all patients in Group B had BCVA in the range of 6/12-6/6. 1 patient (3%) in Group A remained with the visual acuity of 6/18 as there was clinically significant macular edema secondary to diabetes mellitus.

Our study results are comparable with the studies conducted by Valentina Lacmanovi Lon ar et al <sup>(79)</sup> where UCVA and BCVA were identical at 8 weeks postoperatively being in the range of 6/9-6/6 in all patients and Ganekal S et al <sup>(80)</sup> where UCVA was 6/12-6/6 in 94.5% and BCVA was 6/12-6/6 in 99.5% at 6 weeks postoperatively.

No complication was seen in our study intraoperatively or postoperatively which was comparable to the study conducted by Mehvash Hussain et al <sup>(81)</sup> who also concluded there were no serious complications following the limbal relaxing incisions and LRIs are safe and more forgiving in nature.

The present study concluded that taking the clear corneal incision in the steepest meridian may be helpful in cases of mild astigmatism but it is desirable to place the paired limbal relaxing incisions on the steepest meridian in cases of moderate to severe astigmatism.

## **CONCLUSION**

The present study was conducted on 60 eyes that underwent phacoemulsification at the Department of Ophthalmology, KLES Dr. Prabhakar Kore Charitable Hospital and Medical Research Centre, Belagavi during the study period of one year from January 2017 – December 2017.

It included patients having 0.5 - 2.5 Diopters (D) of pre-existing corneal astigmatism who were divided into two groups of 30 each by computer generated random numbering system and underwent the following surgical techniques: Group A: Phacoemulsification with a single clear corneal incision placed on the steepest meridian and Group B: Phacoemulsification with a single clear corneal incision along with Limbal relaxing paired incisions straddling the steepest corneal meridian.

The following conclusions were drawn from the study.

- The mean astigmatic correction in both Group A and Group B was statistically significant. Both the techniques resulted in the corneal flattening in the meridian of incision.
- The mean pre-operative and postoperative astigmatism in group A was  $1.01 \pm 0.27$  D and  $0.45 \pm 0.28$  D with ( $p < 0.0001$ ) and in group B was  $1.27 \pm 0.53$  D and  $0.34 \pm 0.20$  D with ( $p < 0.001$ ) which was highly statistically significant.
- Patients who had ATR pre-operative astigmatism continued to remain so post-operatively with less magnitude in 37% of patients in Group A and 30% of patients in Group B. 3% in Group A and 7 % in Group B showed a post-operative WTR drift and 10% in both Group A and Group B showed no post-operative astigmatism.

- Patients who had WTR pre-operative astigmatism continued to remain so post-operatively with less magnitude in 40% of patients in Group A and 37 % of patients in Group B. 7% in Group A and 13 % in Group B showed a post-operative ATR drift whereas 3% in both Group A and Group B showed no post-operative astigmatism.
- Mean surgically induced astigmatism in Group A was 0.67 with the standard deviation of 0.27 and in Group B the mean surgically induced astigmatism was 1.02 with the standard deviation of 0.46. This comparison of difference of surgically induced astigmatism between the two groups was highly significant statistically (p=0.0007)
- The mean correction index in Group B was more compared to Group A which was  $0.82 \pm 0.26$  and  $0.75 \pm 0.4$  respectively even-though it was not statistically significant.
- In the present study, the mean flattening effect in Group A was 0.67 with the standard deviation of 0.27 and the mean flattening effect in Group B was 1.02 with the standard deviation of 0.46. The comparison between the two groups was done by unpaired 't' test and was statistically significant(p=0.0007).
- In group A, the mean keratometric difference was  $0.95 \pm 0.92$  which was statistically significant (p<0.001). In group B, the mean keratometric difference was  $1.08 \pm 0.96$  which was statistically significant (p< 0.001)
- In the present study limbal relaxing incisions had greater flattening effect compared to incision on the steepest meridian.
- The visual rehabilitation was good in our study. In group A, 93 % patients and in group B 97% patients had UCVA in the range of 6/12 – 6/6. In group A, 97 % patients and in group B all the patients had BCVA in the range of 6/12 – 6/6.

In conclusion, clear corneal cataract incision on the steep meridian can be used to correct mild forms of astigmatism upto 1.0 D. Astigmatism of 1.0 – 2.5 D can be reduced using limbal relaxing incisions.

Limbal relaxing incisions are safe, simple and more forgiving approach to correct pre-existing astigmatism at the time of cataract surgery.

## **SUMMARY**

Cataract surgery has been there since 20 centuries. It has evolved from couching in ancient times to modern day manual SICS and phacoemulsification. Currently, after the introduction of phacoemulsification through a small clear corneal incision and foldable intraocular lens, the focus has transformed from reduction of surgically induced astigmatism to correction of pre-existing astigmatism, if any present.

Various techniques have been described for the correction of astigmatism during the cataract surgery like incision on steep meridian, limbal relaxing incisions, toric intraocular lens and laser vision correction. The purpose of the study is to compare the two different techniques that is incision on steep meridian and limbal relaxing incisions along with phacoemulsification incision to correct the pre-existing corneal astigmatism and also assess the safety and efficacy of limbal relaxing incisions.

The present one - year randomized control trial was conducted in the Department of Ophthalmology, KLES Dr. Prabhakar Kore hospital and Medical Research Centre, Belagavi on patients undergoing cataract surgery during the period of January 2017 – December 2017. The patients with pre-existing astigmatism in the range of 0.5D – 2.5 D were included in the study and underwent either phacoemulsification with incision on the steepest meridian (Group A) or phacoemulsification along with the paired limbal relaxing incisions placed on the steepest meridian (Group B). They were evaluated at 3 weeks and 6 weeks postoperatively.

In the present study, the mean age in Group A was  $61 \pm 2$  years and Group B was  $66 \pm 2$  years. In this study, 57% patients were male and 43 % patients were female with male : female ratio of 1.3 : 1 in Group A and 63% patients were male and 37% patients were female with male : female ratio of 1.7 : 1 in Group B.

Majority of the patients had pre-operative visual acuity in the range of 6/60 to CF 3 meters in both Group A and Group B being 43% and 53% respectively, followed by 40% in Group A and 27% in Group B with pre-operative visual acuity in the range of 6/24 – 6/36.

In this study, 37% patients in Group A and 17% patients in Group B had pre-existing astigmatism in the range of 0.5 D – 1 D, 53% in the range of 1D – 1.5D of pre-existing astigmatism in both groups, 10% in Group A and 13% in Group B in the range of 1.5 D – 2 D and no patient in Group A and 17% in Group B had pre-existing astigmatism in the range of 2 D – 2.5 D.

Majority of the patients in Group A that is 22 (73%) had post-operative astigmatism in the range of 0.0 – 0.5 D, followed by 08 patients that is 27% in the range of 0.5 – 1D. In Group B, 28 patients that is 93% had post-operative astigmatism in the range of 0.0 – 0.5D whereas only 2 patients (7%) had post-operative astigmatism in the range of 0.5 – 1D. No patient had  $> 1.0$  D of astigmatism in both groups.

In the present study, the mean surgically induced astigmatism in Group A was 0.67 with the standard deviation of 0.27 and in Group B the mean surgically induced astigmatism was 1.02 with the standard deviation of 0.46. This comparison of

difference of surgically induced astigmatism between the two groups was highly significant statistically ( $p=0.0007$ ).

The mean correction index in Group A was  $0.75 \pm 0.4$  and in Group B the mean correction index was  $0.82 \pm 0.26$  which was not statistically significant. In the present study, the mean flattening effect in Group A was 0.67 with the standard deviation of 0.27 and the mean flattening effect in Group B was 1.02 with the standard deviation of 0.46. The comparison between the two groups was highly significant statistically ( $p=0.0007$ ).

In this study, by taking the phacoemulsification incision on the steepest meridian on the basis of pre-existing astigmatism, that is in Group A, the mean keratometric difference was  $0.95 \pm 0.92$  which was statistically significant ( $p<0.001$ ). By placing the paired limbal relaxing incisions on the steepest meridian along with phacoemulsification incision as in Group B, the mean keratometric difference was  $1.08 \pm 0.96$  which was statistically significant ( $p<0.001$ ).

The visual rehabilitation was good. 93% patients in Group A and 97% patients in Group B had UCVA in the range of 6/12 – 6/6 and 97 % patients in Group A and all the patients in Group B had BCVA in the range of 6/12 – 6/6.

Clear Corneal phacoemulsification incision placed at the steepest meridian alone or in combination with the limbal relaxing incisions help in lowering the pre-existing corneal astigmatism. These incisions cause flattening of the incised meridian and steeping of the opposite meridian.

Mild cases of astigmatism can be treated by incision on steepest meridian alone. Limbal relaxing incisions are easy, simple, forgiving with fewer complications and can be used in conjunction with phacoemulsification surgery to correct moderate to severe forms of pre-existing astigmatism.

**BIBLIOGRAPHY**

1. Guyton DL. Prescribing cylinders the problem of distortions. *Surv Ophthalmol.* 1977;22(3):177-188.
2. Donders FC, Moore WD. *On the Anomalies of Accommodation and Refraction of the Eye: With a Preliminary Essay on Physiological Dioptrics.* London, England: New Sydenham Society; 1864.
3. Duke-Elder S, Stewart S, Abrams D. Ophthalmic optics and refraction. In: Duke-Elder S, ed. *System of Ophthalmology.* Vol 5. St Louis, MO: CV Mosby; 1970:274-295.
4. Beiko G. Treatment of Corneal Astigmatism at the Time of Cataract Surgery, what can be Promised. *European Ophthalmic Review,* 2015;9(2): 102–3.
5. Duke-Elder S. (1969). “Sushruta Samhita-Uttar Tantra”, chap. 17, verses 57-70. In: *System of Ophthalmology.* Duke-Elder S. Vol. II, pp. 249, Kimpton. London.
6. Pallin SL. Chevrol suture less closure: A preliminary report. *J Cataract Refract Surg.* 1991; 17:706-709.
7. Fine IH. Architecture and construction of a self-sealing incision for cataract surgery. *J Cataract Refract Surg.* 1991; 17:677-688.
8. Neumann AC. Small incision to control astigmatism during cataract surgery. *J Cataract Refract Surg.* 1989; 15(1):78-84.
9. Chaudhuri Z, M Vanathi. *Incisional Keratorefractive Surgeries.* Chapter 7. In *Post-Graduate Ophthalmology.* 2<sup>nd</sup> edition. New Delhi: Jaypee Brothers Medical Publishers; 2012.
10. Leo D. Bores. *Surgical management of Astigmatism.* Chapter 9. In *Refractive eye surgery.* 2<sup>nd</sup> edition. United States Of America: Blackwell science; 2001.

11. Schiøtz LJ. Hinfall von hochgradigem hornhautastigmatismus nach staarextraction, besserung auf operativem wege. Arch Augenheilkd. 1885;15: 178-181.
12. Faber E. Operative Behandeling van Astigmatisme. Ned Tijdschr Geneesk. 1895;2:495-496.
13. Lucciola J. Traitement chirurgical de l'astigmatisme. Arch d'Ophthalmol 1886;16: 630.
14. Bates WH. A suggestion of an operation to correct astigmatism. 1894. Refract Corneal Surg 1989;5(1):58-9.
15. Lans LJ. Experimentelle Untersuchungenuber Entsehung von Astigmatismus durch nich-perforirende Corneawunden. Arch fur Ophthalmologie 1898;45:117-152.
16. Sato T. Treatment of conical cornea by incision of Descemet's membrane. Acta Soc Ophthalmol Jpn 1939;43:541.
17. Sato T. Experimental study on surgical correction of astigmatism. Juntendo Kenkyukaizasshi 1943;589:37.
18. Sato T. Posterior incision of cornea; surgical treatment for conical cornea and astigmatism. Am J Ophthalmol 1950;33(6):943-8.
19. Thornton SP, Sanders DR. Graded nonintersecting transverse incisions for correction of idiopathic astigmatism. J Cataract Refract Surg 1987;13(1):27-31.
20. Chayez S, Chayet A, Celikkol L, Parker J, Celikkol G, Feldman ST. Analysis of astigmatic keratotomy with a 5.0-mm optical clear zone. Am J Ophthalmol 1996;121:65-76.

21. Nichamin LD. Nomogram for limbal relaxing incision. *J Cataract Refract Surg* 2006; 32(9):1408.
22. Duke-Elder S, Stewart S, Abrams D. Ophthalmic optics and refraction. In: Duke-Elder S, ed. *System of Ophthalmology*. Vol 5. St Louis, MO: CV Mosby; 1970:274-90.
23. Miller Stephen J. *Parson's Diseases of Eye*. Edinburgh: Butterworth Hienmann International Edition. 20<sup>th</sup> edition. Noida: Elsevier; 1990.p. 63-69.
24. Morlet N, Minassian D, Dart J. Astigmatism and the analysis of its surgical correction. *Br J Ophthalmol*. 2001; 85: 1127–38.
25. Bradbury JA, Hillman JS, Brown CA. Optimal postoperative refraction for good unaided near and distance vision with monofocal intraocular lenses. *Br J Ophthalmol*. 1992; 76: 300–302.
26. Singh A, Pesala V, Garg P, Bharadwaj SR. Relation between uncorrected astigmatism and visual acuity in pseudophakia. *Optom Vis Sci*. 2013 Apr;90(4):378-84.
27. Grosvenor T. Etiology of astigmatism. *Am J Optom Physiol Opt* 1978; 55: 214–218.
28. Keller PR, Collins MJ, Carney LG, Davis BA, Van Saarloos PP. The relation between corneal and total astigmatism. *Optom Vis Sci* 1996; 73: 86–91.
29. Nichamin LD. Astigmatism control. *Ophthalmol Clin North Am* 2006;19(4):485-493.
30. Xu L, Zheng DY. Investigation of corneal astigmatism in phacoemulsification surgery candidates with cataract. *Zhonghua Yan Ke Za Zhi* 2010;46(12):1090-4.

31. Ferrer-Blasco T, Montés-Micó R, Peixoto-de-Matos SC, González-Méijome JM, Cerviño A. Prevalence of corneal astigmatism before cataract surgery. *J Cataract Refract Surg* 2009;35(1):70-5.
32. Armeniades CD, Boriek A, Knolle GE,Jr. Effect of incision length, localization and shape on local corneoscleral deformation during cataract surgery. *J Cataract Refract Surg* 1990;16(1):83-87.
33. Juan P Alvarez de Tolendo Elizalde et al. Cataract incision in Modern Cataract Surgery.Chapter 11. In *Phaco without the Phaco*.1<sup>st</sup> edition. New Delhi: Jaypee Brothers Publisher; 2005
34. Roman S, Ullern M. Astigmatism caused by superior and temporal corneal incisions in cataract surgery. *J Fr Ophthalmol*. 1997; 20(4):277-83.
35. Simsek S, Yasar T, Demirok A, Cinal A, Yilmaz OF. Effect of superior and temporal clear corneal incisions on astigmatism after sutureless phacoemulsification. *J Cataract Refract Surg*. 1998; 24(4):515-8.
36. Ermiss SS, Inan UU, Ozturk F. Surgically induced astigmatism after superotemporal and superonasal clear corneal incisions in phacoemulsification. *J Cataract Refract Surg*. 2004; 30(6):1316-19.
37. Brian J, Jacobs BS, Bruce I Gaynes, OD, Pharm D, and Thomas A Deutsch MD. Refractive astigmatism after oblique clear corneal phacoemulsification cataract incision. *J Cataract Refract Surg*. 1999; 1-6.
38. Oshima Y, Tsujikawa K, Oh A, Harino S. Comparative study of intraocular lens implantation through 3.0 mm temporal clear corneal and superior scleral tunnel self-sealing incisions. *J Cataract Refract Surg*. 1997; 23(3):347-53.

39. Jaime Tejedor, Juan Murube. Choosing the location of corneal incision based on pre-existing astigmatism in phacoemulsification. *AM J Ophthalmol.* 2005; 139:767-776.
40. Gonçalves FP, Rodrigues AC. Phacoemulsification using clear cornea incision in steepest meridian. *Arq Bras Oftalmol* 2007;70(2):225-8.
41. Ken Hayashi, Motoaki Yoshida, Koichi Yoshimura. Effect of steepest-meridian clear corneal incision for reducing pre-existing corneal astigmatism using a meridian – marking method or surgeon’s intuitions. *J Cataract Refract Surg.* 2014; 40:2050-2056.
42. Lever J, Dhan E. Opposite clear corneal incision to correct pre existing astigmatism in cataract surgery. *J Cataract Refract Surg* 2000;26(6): 803-5.
43. Mostafa K. N, Khaled E. G, Osama A. M, Dina S. G. Management of pre-existing regular astigmatism in phacoemulsification. *Menoufia Medical Journal* 2015;28:197–202
44. Khokhar S, Lohiya P, Murugiesan V, Panda A: Corneal astigmatism correction with opposite clear corneal incisions or single clear corneal incision: comparative analysis. *Journal of cataract and refractive surgery* 2006; 32:1432-7.
45. Nemeth G, Kolozsvari B, Berta A, Laszlo M: Paired opposite clear corneal incision: time-related changes of its effect and factors on which those changes depend. *European journal of ophthalmology* 2014:0.
46. Nichamin LD. Changing approach to astigmatism management during phacoemulsification: peripheral arcuate astigmatic relaxing incisions. Paper presented at: Annual Meeting of the American Society of Cataract and Refractive Surgery; 2000; Boston, Mass.

47. Nichamin LD. Bioptics for the pseudophakic patient. In: Gills JP, ed. A complete guide to astigmatism management: An ophthalmic manifesto. Thorofare, NJ: SLACK Inc; 2003:37-39.
48. Nichamin LD. 2003. Management of astigmatism in conjunction with clear corneal phaco surgery. Available at; [ww.mastel.com/pdf/napa](http://www.mastel.com/pdf/napa). Pdf
49. Dong HK, Won RW, Jin HL, Mee KK. The Short Term Effects of a single limbal relaxing incision combined with clear corneal incision. Korean J Ophthalmol 2010; 24(2): 78–82.
50. Gills JP. Curr Opin Ophthalmol. 2002 Feb;13(1):2-6. Treating astigmatism at the time of cataract surgery.
51. Coloma-González II, González-Herrera M, Mengual-Verdú E, Hueso-Abancens JR. Limbal relaxing incisions and cataract surgery: our experience. Arch Soc Esp Oftalmol. 2007 Sep;82(9):551-4.
52. Müller-Jensen K1, Fischer P, Siepe U. Limbal relaxing incisions to correct astigmatism in clear corneal cataract surgery. J Refract Surg. 1999 Sep-Oct;15(5):586-9.
53. Bayramlar H1, Da lio lu MC, Borazan M. Limbal relaxing incisions for primary mixed astigmatism and mixed astigmatism after cataract surgery. J Cataract Refract Surg. 2003 Apr;29(4):723-8.
54. Hosny A, Azzam S, Oweis W. Limbal Relaxing Incisions versus Penetrating Limbal Relaxing Incisions for the Management of Astigmatism in Cataract Surgery. Adv Ophthalmol Vis Syst 2015 2(5): 00062.
55. Masket S, Sarayba M, Ignacio T, Fram N. Femtosecond laser-assisted cataract incisions: architectural stability and reproducibility. J Cataract Refract Surg. 2010;36(6):1048-1049.

56. Nagy Z, Takacs A, Filkom T, Sarayba M. Initial clinical evaluation of an intraocular femtosecond laser in cataract surgery. *J Refract Surg.* 2009;25(12):1053-1060.
57. Alpins NA. Vector analysis of astigmatism changes by flattening, steepening, and torque. *J Cataract Refract Surg.* 1997;23(10):1503-1514.
58. Alpins NA. New method of targeting vectors to treat astigmatism. *J Cataract Refract Surg.* 1997;23(1):65-75.
59. Alpins NA. A new method of analyzing vectors for changes in astigmatism. *J Cataract Refract Surg.* 1993;19(4):524-533.
60. Alpins NA. Astigmatism analysis by the Alpins method. *J Cataract Refract Surg.* 2001;27(1):31-49.
61. Poll JT, Wang L, Koch DD, Weikert MP Correction of Astigmatism During Cataract Surgery: Toric Intraocular Lens Compared to Peripheral Corneal Relaxing Incisions. *J Refract Surg* 2011;27(3):165-171.
62. Nichamin LD. Expanding the role of bioptics to the pseudophakic patient. *J Cat Refract Surg* 2001; 27(9):1343-1344.
63. Comez A. T and Yelda Ozkurt. Surgical Correction of Astigmatism During Cataract Surgery, *Astigmatism – Optics, Physiology and Management*, 1<sup>st</sup> edition. Turkey: Publisher InTech; February 2012.
64. Amesbury E. C and Miller K. M. Correction of astigmatism at the time of cataract surgery. *Current Opinion in Ophthalmology* 2009, 20:19–24
65. Taneja M. Management of Astigmatism in Cataract. *DJO* 2015; 25:252-258
66. Nauljira Prakairungthong, Puwat Charukamnoetkanok, Saichin Isipradit. Prevalence of Preoperative Corneal Astigmatism in Patients Undergoing

- Cataract Surgery at Mettapracharak Hospital, Thailand. *J Med Assoc Thai* 2015; 98 (9): 878-82
67. Guan Z, Yuan F, Yuan YZ, Niu WR. Analysis of corneal astigmatism in cataract surgery candidates at a teaching hospital in Shanghai, China. *J Cataract Refract Surg.* 2012 Nov;38(11):1970-7.
68. Ninn Pederson K. Cataract patients in a defined Swedish population 1986-90, VIII postoperative astigmatism, intraocular pressure and visual acuity. *Acta Ophthalmol Scand.* 1997; 75(5):558-68.
69. Anders N, et al. Factors modifying postoperative astigmatism after no stitch cataract surgery. *Ophthalmology.* 1997; 94(1):6-11.
70. Carvalho MJ1, Suzuki SH, Freitas LL, Branco BC, Schor P, Lima AL. Limbal relaxing incisions to correct corneal astigmatism during phacoemulsification. *J Refract Surg.* 2007 May;23(5):499-504.
71. Budak K, Friedman NJ, Koch DD. Limbal relaxing incisions with cataract surgery. *J Cataract Refract Surg.* 1998 Apr;24(4):503-8.
72. Muhammad A. S, Sameer S. A, Khan A, Khokhar M. Effect of 5.5 millimeters clear corneal temporal versus steepest meridian phacoemulsification incision on pre-existing astigmatism. *Armed Forces Institute of Ophthalmology.* 2011;December (4).
73. Salvatore Cillino,Daniele Morreale, Antonia Mauceri,Corrado Ajovalasit, Francesco Ponte. Temporal versus superior approach phacoemulsification : Short-term post-operative astigmatism. *J Cataract Refract Surg.* 1997;23:267-271.

74. Pflieger T, Skorpik C, Menapace R, Scholz U, Weghaupt H, Zehetmeyer M. Long term course of induced astigmatism after clear corneal incision cataract surgery. *J Cataract Refract Surg.* 1996;22(1):72-77.
75. Kaufmann C, Peter J, Ooi K, Phipps S, Cooper P, Goggin M. Limbal relaxing incisions versus on-axis incisions to reduce corneal astigmatism at the time of cataract surgery. *J Cataract Refract Surg* 2005;31:2261–2265.
76. Mohammad A. Z, Mehdi H. T, Mohsen G, Mahmood J, Mohammad N. H, Mehrdad M et al. Management of Corneal Astigmatism by Limbal Relaxing Incisions during Cataract Surgery. *Iranian Journal of Ophthalmology* 2010;22(1):15-20.
77. Chang Rae Rho, MD, Choun-Ki Joo, MD, PhD. Effects of steep meridian incision on corneal astigmatism in phacoemulsification cataract surgery. *J Cataract Refract Surg.* 2012; 38:666–671.
78. Marek R, Klu's A, Pawlik R. Comparison of Surgically Induced Astigmatism of temporal versus superior clear corneal incisions. *Klin Oczna.* 2006;108:392-396.
79. Valentina L. L, Ivanka P. V, Renata I and Zdravko M. Limbal relaxing incision during cataract surgery. *Acta Clin Croat* 2012; 51:289-292.
80. Ganekal, S., Dorairaj, S., & Jhanji, V. (2011). Limbal relaxing incisions during phacoemulsification: 6-month results. *Journal of Cataract & Refractive Surgery*, 37(11), 2081–2082.
81. Hussain M, Quraishy M. M. Limbal Relaxing Incision during Phacoemulsification for the Correction of Astigmatism. *Pak J Ophthalmol* 2015, 31(2):77-82.

## ANNEXURE I – CONSENT FORM

### CONSENT FOR PARTICIPATION IN RESEARCH STUDY

ID NO. 

--	--	--

Mr/Mrs/Ms \_\_\_\_\_ You

are invited to participate in our research study titled “**A COMPARATIVE STUDY OF CORRECTION OF PRE-EXISTING CORNEAL ASTIGMATISM BETWEEN INCISION ON THE STEEPEST MERIDIAN AND LIMBAL RELAXING INCISIONS IN PHACOEMULSIFICATION SURGERY – A ONE YEAR RANDOMIZED CONTROL TRIAL AT KLES DR. PRABHAKAR KORE HOSPITAL AND MEDICAL RESEARCH CENTRE, BELAGAVI**”

Conducted by Department of Ophthalmology, J.N. Medical College, Belagavi.

Respected Sir/Madam we request you to enroll yourself to participate in our study as you are eligible for doing so. Your participation in the study is voluntary. Your decision whether or not to participate in the study will not affect your relationship with the hospital. If you decide to participate you are free to withdraw at any time.

**Objective and Purpose of the study:** To compare limbal relaxing incisions (LRIs) along with incision on steepest meridian and placement of the corneal cataract incision on the steepest keratometric axis alone for the reduction of preexisting corneal astigmatism at the time of cataract surgery. To assess the safety and efficacy of limbal relaxing incisions for the correction of pre-existing corneal astigmatism during phacoemulsification with IOL implantation.

**Procedure Involved:** If you agree to enroll yourself in this study, you will be asked to give detailed history. Then you will be clinically examined in detail by slit-lamp examination, refraction, funduscopy, tonometry for measurement of intraocular pressure, syringing for patency of the lacrimal sac, keratometry and A scan ultrasonography and investigations like blood pressure measurement, random blood sugar will be done. Then you will be undergoing Phacoemulsification surgery involving both the incision techniques.

**Risks and Benefits:** As such no major risks are involved, rare complications of surgery includes corneal perforation, posterior capsular rent, vitreous loss, lens dislocation, expulsive choroidal hemorrhage, dry eye for which all necessary precautions will be taken.

Your participation may benefit you and others suffering from same ailment in future, by helping us learn more about the disease process and better treatment modalities.

**Alternatives:** If you are not willing to participate you will be treated according to the existing protocol & it will not affect your relationship with this hospital.

**Costs for participating in this research:** There will not be any extra cost incurred by the participant. The participant will however have to pay for the investigations which are the part of the existing management protocol for this ailment. There is no commitment for any reimbursement or any other compensation for the participant.

**Privacy and Confidentiality:** The only people to know that you are a research subject are members of the research team. No information about you or information provided by you during the research will be disclosed to others without your written permission.

**Authorization to Publish Results:** When the results of the research are published or discussed, in a conference, no information will be displayed that would disclose your identity. Any information that is obtained in connection with this study and that can be identified with you will remain confidential.

**Compensation:** In the event of injury related to the study, treatment will be made available through KLES Dr. Prabhakar Kore Hospital & MRC, Belagavi. There is no compensation or payment for such medical treatment by law. The doctors and the staff will provide facilities and medical attention to you.

**Questions:**

If you need any further information regarding your rights as a study participant contact

1. Dr. GANGA S. PILLI, CHAIRPERSON, JNMC, Belgaum and Chairman of Institutional Ethics Committee. Contact No. 08312471350

**Consent for participation in research trial**

I, Mr./Ms./Mrs \_\_\_\_\_ voluntarily agree for the participation as a subject of study. By signing this consent form I am not giving up any of my legal rights, I may withdraw from the study anytime. I am signing the consent form after having read or been read for me in vernacular language, including the risks and the benefits and having all my questions answered.

Subject Name: \_\_\_\_\_

Signature or the Left Thumb Print of Subject: \_\_\_\_\_

Witness Name: \_\_\_\_\_

Signature of Witness: \_\_\_\_\_

Investigators Name: \_\_\_\_\_

Signature of Investigator: \_\_\_\_\_

Date: \_\_\_\_\_

Place: \_\_\_\_\_



K.L.E.UNIVERSITY'S  
**JAWAHARLAL NEHRU MEDICAL COLLEGE,**  
NEHRU NAGAR, BELAGAVI-590010 (KARNATAKA-INDIA)  
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Ref: MDC/DOME/ 64

Date: 17/10/2016

To,

BELAGAVI.

Sub: Institutional Ethical Clearance for the study.

With reference to the above, we wish to inform you that your proposed research project titled  
“COMPARATIVE STUDY OF CORRECTION OF PRE-EXISTING ASTIGMATISM BY  
INCISION ON THE STEEPEST MERIDIAN AND LIMBAL RELAXING INCISIONS IN  
PHACOEMULSIFICATION SURGERY A ONE YEAR RANDOMIZED CONTROL  
TRIAL AT KLES DR. PRABHAKAR KORE HOSPITAL AND MEDICAL RESEARCH  
CENTRE, BELAGAVI”, is ethical and justifiable. The proposed research project has been  
cleared by the JNMC Institutional Ethics Committee on Human Subjects Research.

(Dr. Arathi Darshan)  
Member Secretary

JNMC Institutional Ethics Committee  
on Human Subjects Research,  
J.N.Medical College, Belagavi.

(Dr. Ganga Pilli)  
Chairman,

JNMC Institutional Ethics Committee  
on Human Subjects Research,  
J.N.Medical College, Belagavi.



DATE:   /

**CHIEF COMPLAINTS:**

DIMINUTION OF VISION

RE 

Duration: \_\_\_\_\_ days/ months/years

LE 

Duration: \_\_\_\_\_ days/ months/years

**HISTORY OF PRESENT ILLNESS:**

1 .DIMINUTION OF VISION

1- Gradual; 2- Sudden 1- Progressive; 2- Static 1- Painless; 2- Painful 1- For distance; 2- For near 

2. DIPLOPIA/POLYOPIA

1- Present; 2- Absent 

3. COLOURED HALOS

1- Present; 2- Absent 

4. BLACK SPOTS BEFORE THE EYES

1- Present; 2 - Absent 

5. WATERING

1- Present; 2 - Absent 

6. REDNESS

1- Present; 2 - Absent 

8. H/O WEARING GLASSES

(1-Distance; 2-Near; 3-Both)

Duration:   months/years**PAST HISTORY:**

TRAUMA TO THE EYE:

1- Present; 2- Absent 

OCULAR SURGERY:

1- Present; 2- Absent 

Type of surgery: \_\_\_\_\_

Duration:   months/years

DIABETES:

1- Present 2- Absent Duration:   months/years

HYPERTENSION:

1- Present 2- Absent

Duration:   months/years

ANY OTHER MEDICAL DISORDERS: \_\_\_\_\_

**PERSONAL HISTORY:**

SMOKING: 1- Present; 2- Absent

Duration:   months/years

ALCOHOLISM: 1- Present; 2- Absent

Duration:   months/years

ANY OTHER ADDICTIONS: \_\_\_\_\_

Duration:   months/years

**GENERAL PHYSICAL EXAMINATION:**

General Appearance:

1- Well built ,2- Moderately built, 3- Poorly built, 4- emaciated

Pallor: 1- Present 2- Absent

If present 1- Mild 2- Moderate 3- Severe

Pulse:    /minute

BP:-    /    mm of hg

Temperature:    degree Fahrenheit

Respiratory rate:   /minute

**SYSTEMIC EXAMINATION:**

CVS: 1- Normal 2- Abnormal   
if 2, specify : \_\_\_\_\_

RS: 1- Normal 2- Abnormal   
if 2, specify: \_\_\_\_\_

CNS: 1- Normal 2- Abnormal   
if 2, specify : \_\_\_\_\_

Per Abdomen: 1- Normal 2- Abnormal   
if 2, specify : \_\_\_\_\_



2. Adnexa (1- Normal; 2-Abnormal)	<input type="checkbox"/>	<input type="checkbox"/>
3. Sclera (1- Normal; 2- Congested)	<input type="checkbox"/>	<input type="checkbox"/>
4. Conjunctiva (1-normal; 2-conjunctival congestion; 3-ciliary congestion; 4-chemosis)	<input type="checkbox"/>	<input type="checkbox"/>
5. Cornea (1- normal; 2-opacity; 3-vascularisation)	<input type="checkbox"/>	<input type="checkbox"/>
6. Anterior chamber (1- normal depth; 2-shallow; 3-deep)	<input type="checkbox"/>	<input type="checkbox"/>
7. Iris (1-normal colour & pattern; 2-Abnormal)	<input type="checkbox"/>	<input type="checkbox"/>
8. Pupil: Size- ____ in mm Shape- 1- Round & Regular; 2-Abnormal Reaction: Direct (1. Present, 2. Absent) Indirect (1. Present, 2. Absent) Near reflex (1. Present, 2. Absent)	<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>

<p>9. Lens            Clarity- 1. Clear, 2. Opaque            Cataract - (1) , PCIOL - (2)            Cataract if present- 1.immature                                              2.mature                                              3. hyper mature             A) CORTICAL- (1.Present, 2. Absent)</p>		<input type="checkbox"/>  <input type="checkbox"/>  <input type="checkbox"/>  <input type="checkbox"/>	<input type="checkbox"/>  <input type="checkbox"/>  <input type="checkbox"/>  <input type="checkbox"/>
<p>B) NUCLEAR SCLEROSIS- 1. PRESENT, 2- ABSENT             If present- 1. Grade-1                              2. Grade-2                              3. Grade-3                              4. Grade-4</p>		<input type="checkbox"/>  <input type="checkbox"/>	<input type="checkbox"/>  <input type="checkbox"/>
<p>(C) POSTERIOR SUBCAPSULAR CATARACT             1. PRESENT, 2. ABSENT</p>		<input type="checkbox"/>	<input type="checkbox"/>

FUNDUS	RE	LE
GLOW		
MEDIA		
DISC		
C:D RATIO		
BLOODVESSELS		
BACKGROUND		
MACULA		

DIAGNOSIS:-

IMPRESSION:-

INVESTIGATIONS:

1. Ocular

A) Lacrimal patency

(1-Patent , 2- regurgitation: 2A- Clear fluid, 2B- Mucopurulent ,  
3- blocked)

RE

LE

2 IOP:

RE:  mm of hg  
LE :  mm of hg

3 Blood sugar: \_\_\_\_\_mg%

4 Blood Pressure:\_\_\_\_\_mm of hg

**PREOPERATIVE KERATOMETRY:**

EYE:  (1-Right eye; 2- Left eye)

KH (Diopters)	Axis (degree)	KV (Diopters)	Axis (degree)	Preoperative astigmatism(A) A= KH-KV	Axis (degree)

**A SCAN BIOMETRY : SRK II FORMULA**

	RE	LE
KH		
AXL		

KV		
AC DEPTH		
PCIOL		

**OPERATIVE PROCEDURE: PHACOEMULSIFICATION CATARACT SURGERY WITH FOLDABLE IOL IMPLANTATION.**

DATE:\_\_\_\_/\_\_\_\_/\_\_\_\_

OPERATING EYE : \_\_\_\_\_

**ANAESTHESIA: PERIBULBAR BLOCK/ TOPICAL**

GROUP A:

GROUP B:

INTRAOCULAR LENS TYPE: \_\_\_\_\_

Operative Complications: 1. Present, 2. Absent

If present- specify

Post- operative complications: 1. Present, 2. Absent

If present- specify

FOLLOW UP PLAN: 3 week post-operatively

1. Conjunctiva (1-normal; 2-conjunctival congestion; 3-ciliary congestion; 4-chemosis)	<input type="checkbox"/>
2.Section/suture site (1-edges opposed; 2- edges gaping)	<input type="checkbox"/>
3.Cornea (1-clear; 2-hazy/descemets fold)	<input type="checkbox"/>
4. Anterior chamber (1- normal depth; 2-shallow; 3-deep)	<input type="checkbox"/>
5. Pupil: Size- ____ in mm Shape- 1- Round & Regular; 2-Abnormal IF 2 (Specify) :	<input type="checkbox"/>
6.Intraocular Lens (1-in situ, 2-decentred)	<input type="checkbox"/>

VISUAL ACUITY	RE	LE
DISTANT		
PINHOLE		

## POSTOPERATIVE KERATOMETRY:

3 weeks

EYE:  (1-Right eye; 2- Left eye)

KH (Diopters)	Axis (degree)	KV (Diopters)	Axis (degree)	Postoperative astigmatism(A) A= KH-KV	Axis (degree)

FOLLOW UP PLAN: 6 week post-operatively

1. Conjunctiva (1-normal; 2-conjunctival congestion; 3-ciliary congestion; 4-chemosis)	<input type="checkbox"/>
2. Section/suture site (1-edges opposed; 2- edges gaping)	<input type="checkbox"/>
3. Cornea (1-clear; 2-hazy/descemets fold)	<input type="checkbox"/>
4. Anterior chamber (1- normal depth; 2-shallow; 3-deep)	<input type="checkbox"/>
5. Pupil: Size- ____ in mm Shape- 1- Round & Regular; 2-Abnormal IF 2(Specify) :	<input type="checkbox"/>
6. Intraocular Lens (1-in situ, 2-decentred)	<input type="checkbox"/>

VISUAL ACUITY	RE	LE
DISTANT		
PINHOLE		

POSTOPERATIVE KERATOMETRY:

6 weeks

EYE:  (1-Right eye; 2- Left eye)

K1 (Diopters)	Axis (degree)	K2 (Diopters)	Axis (degree)	Postoperative astigmatism(A) A= KH-KV	Axis (degree)

Prescription	Spherical	Cylindrical	Axis	BCVA
RE				
LE				

**ANNEXURE III – PHOTOGRAPHS**



**Photograph 1 - Keratometry**



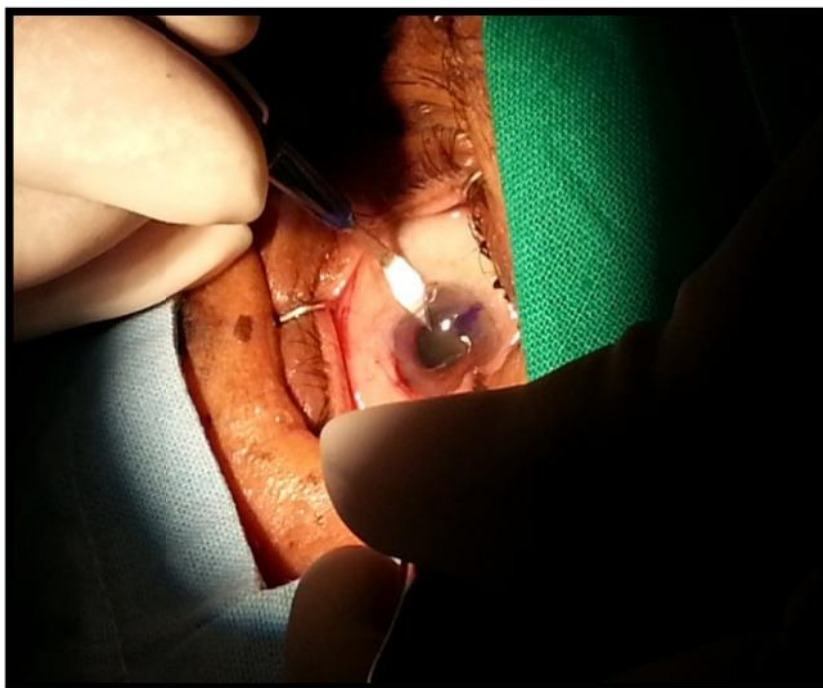
**Photograph 2 – Axis marking with surgical marker**



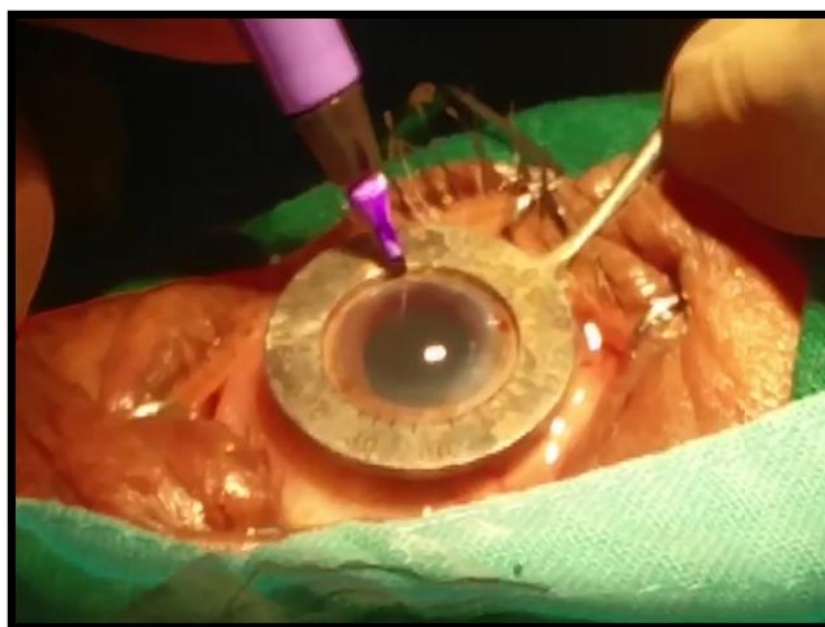
**Photograph 3 – Bausch & Lomb Phacoemulsification machine with OT setup**



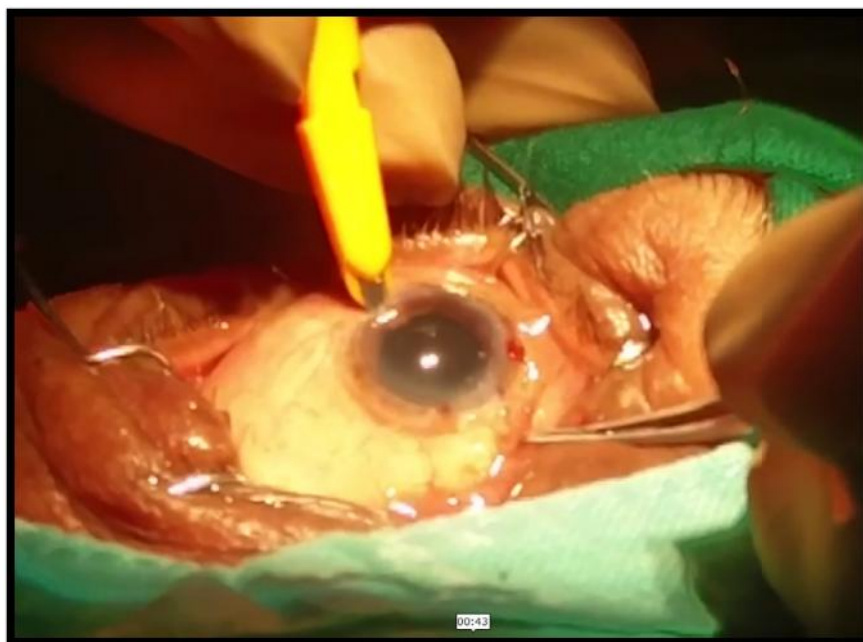
**Photograph 4 – Superior clear corneal incision**



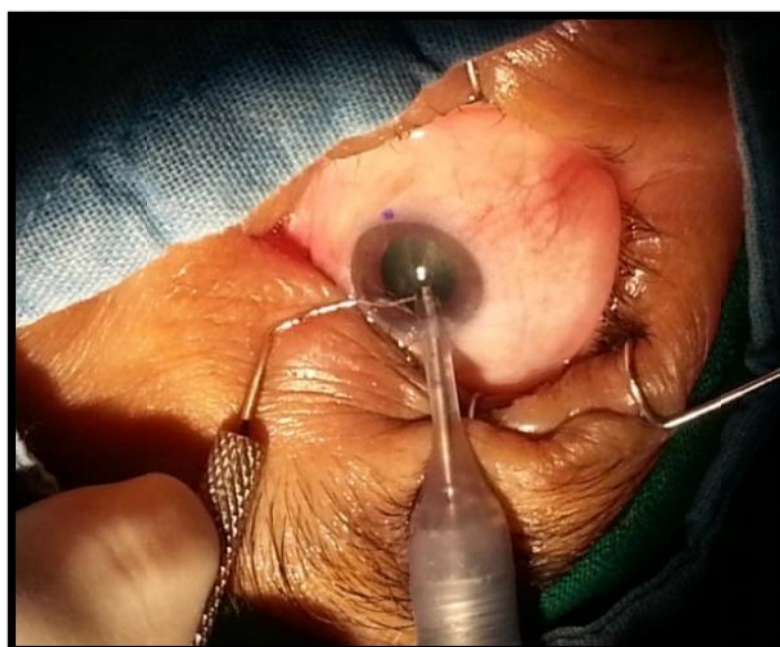
**Photograph 5 - Temporal clear corneal incision**



**Photograph 6 - Mendez protractor for axis**



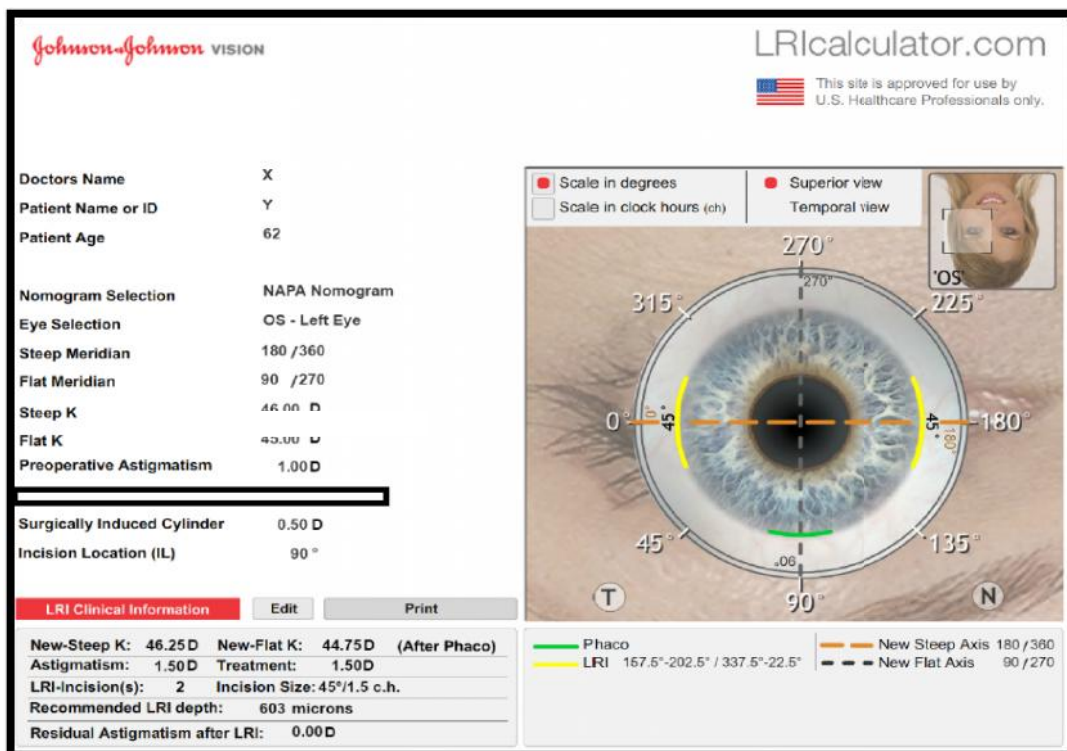
**Photograph 7 - Limbal relaxing incisions**



**Photograph 8 - ongoing phacoemulsification**

DATA INTEGRITY REPORTS										INDIVIDUAL CASE RESULTS (You may change the format in 'SetUp')		
default										plus		
no										Cylinder format		
Postoperative data					Comments					SURGICALLY INDUCED ASTIGMATISM		
Refractive intervention	k1	axis	k2	axis	Preop data	Surgical data	Postop data	Is this case included in subset analysis?	Name (For reference only)	Serial No.	Magnitude (D)	Axis (Degree)
	44.50	180	44.00	90	Valid	Centripetal length Missing	Valid	No	GANGAPPA	38	0.75	90
	45.00	180	44.75	90	Valid	Centripetal length Missing	Valid	No	PARUBAI	39	0.50	90
	46.50	180	46.00	90	Valid	Centripetal length Missing	Valid	No	DATTATREYA	40	2.00	90
	41.00	180	41.00	90	Valid	Centripetal length Missing	Valid	No	DEVAPPA SANAC	41	0.75	90
	42.25	180	43.00	90	Valid	Centripetal length Missing	Valid	No	BASAVANTH	42	2.50	90
	44.50	180	44.00	90	Valid	Centripetal length Missing	Valid	No	S.S.PATIL	43	1.50	90
	44.50	180	43.75	90	Valid	Centripetal length Missing	Valid	No	VALENTINO	44	0.25	90
	42.00	180	41.75	90	Valid	Centripetal length Missing	Valid	No	RAYANNA	45	1.00	90
	44.50	180	44.25	90	Valid	Centripetal length Missing	Valid	No	MANGAL PARIT	46	0.50	90
	42.25	180	42.50	90	Valid	Centripetal length Missing	Valid	No	MURGESH	47	0.50	90
	43.25	180	43.75	90	Valid	Centripetal length Missing	Valid	No	SHANTABAI	48	0.50	90
	44.75	180	45.50	90	Valid	Centripetal length Missing	Valid	No	DODDABASARGC	49	0.50	90
	44.50	180	45.50	90	Valid	Centripetal length Missing	Valid	No	LAXMIBAI	50	0.50	90
	43.75	180	44.25	90	Valid	Centripetal length Missing	Valid	No	NARAYAN	51	0.50	90
	44.50	180	43.75	90	Valid	Centripetal length Missing	Valid	No	DRAUPADI	52	0.50	90
	45.75	180	46.00	90	Valid	Centripetal length Missing	Valid	No	ULAVAPPA	53	1.25	90

Photograph 9 – SIA software 3.1 version



Photograph 10 – LRI calculator

## ANNEXURES IV - MASTER CHART (GROUP A)

SL.NO	IP NO	GENDER	AGE(YEARS)	EYE	PRE-OPERATIVE							POST-OPERATIVE												
					VISUAL ACUITY	KERATOMETRY		PCIOL POWER	ASTIGMATISM			UCVA		ASTIGMATISM			SIA	CI	FE	REFRACTION				BCVA
						KH	KV		DIOPTERS(K1)	AXIS(A1)	TYPE	DAY 21	DAY 45	DIOPTERS(K2)	AXIS(A3)	TYPE				SPHERE	CYLINDER	AXIS	NEAR	
1	781255	M	63	RIGHT	6/36(P)	40.75	41.5	21.5	0.75	90	WTR	6/6	6/6	0	0	NIL	0.75	1	0.75	0			3	6/6
2	788827	M	63	LEFT	CF 3M	42	43.75	20.5	1.75	90	WTR	6/24	6/18	0.75	90	WTR	1.25	1.42	1.25	-0.5	-1	180	3	6/18
3	790216	M	63	LEFT	6/24	44	45	24	1	90	WTR	6/9	6/6	0.5	180	ATR	1	1.5	1		-0.5		3	6/6
4	790151	M	54	LEFT	CF 2M	44.75	43.75	17.5	1	180	ATR	6/9	6/9	0.75	180	ATR	0.25	0.25	0.25	-1	-0.75	180	2.5	6/6
5	797235	M	43	RIGHT	6/18	41.75	42.5	23	0.75	90	WTR	6/6	6/6	0.25	180	ATR	1	1.33	1		-0.25		1	6/6
6	799319	F	48	LEFT	6/24	44.75	44	21.5	0.75	180	ATR	6/9	6/9	0.25	180	ATR	0.5	0.66	0.5	-1			1.5	6/6
7	802005	M	59	RIGHT	6/36	42	42.75	22.5	0.75	90	WTR	6/6	6/6	0.25	90	WTR	0.5	0.66	0.5		-0.5	180	2.5	6/6
8	801941	F	72	RIGHT	6/60	43	44	23	1	90	WTR	6/12	6/9	0.5	90	WTR	0.5	0.5	0.5	-2			3	6/6
9	801873	M	70	LEFT	CFCF	44.5	45.75	21.5	1.25	90	WTR	6/9	6/9	0.75	90	WTR	0.5	0.4	0.5	-0.5	-0.5	90	3	6/6
10	806290	F	68	RIGHT	6/36	44.25	45.75	21.5	1.5	90	WTR	6/18	6/12	1	90	WTR	0.5	0.3	0.5	-2	-1	90	3	6/9
11	813564	M	57	LEFT	CF 2M	43.5	44.5	16	1	90	WTR	6/9	6/6	0.5	90	WTR	0.5	0.5	0.5		-0.5	180	3	6/6
12	816158	F	60	RIGHT	CF 1M	44.75	43.5	23	1.25	180	ATR	6/12	6/9	0.75	180	ATR	0.5	0.4	0.5	-1	-0.5	90	3	6/6

13	816221	M	87	RIGHT	6/36	46.5	45.5	19	1	180	ATR	6/9	6/6	0.25	90	WTR	1.25	1.25	1.25		-0.25	90	3	6/6
14	819632	F	50	LEFT	6/24	43.75	44.75	21.5	1	90	WTR	6/9	6/9	0.25	90	WTR	0.75	0.75	0.75	-1			2.5	6/6
15	822338	M	65	LEFT	6/18	44.5	43.75	21.5	0.75	180	ATR	6/6	6/6	0	0	NIL	0.75	1	0.75	0			3	6/6
16	823063	M	58	RIGHT	6/36	43.25	42.5	22.5	0.75	180	ATR	6/6	6/6	0.25	180	ATR	0.5	0.66	0.5	0			3	6/6
17	823151	M	49	LEFT	6/18	42.25	43.5	21	1.25	90	WTR	6/9	6/6	0.5	90	WTR	0.75	0.6	0.75		-0.5	110	2	6/6
18	824473	F	57	LEFT	CF 1M	45.5	46.5	25	1	90	WTR	6/9	6/6	0.5	90	WTR	0.5	0.5	0.5		-0.25	90	3	6/6
19	826243	F	49	RIGHT	CF 2M	44	42.75	22.5	1.25	180	ATR	6/12	6/9	0.75	180	ATR	0.5	0.4	0.5	-0.5	-0.5	180	2	6/6
20	827055	M	48	LEFT	6/60	43	43.75	21	0.75	90	WTR	6/6	6/6	0.25	90	WTR	0.5	0.66	0.5	0			2	6/6
21	830185	F	65	LEFT	CF 1M	45	44	22.5	1	180	ATR	6/9	6/6	0.5	180	ATR	0.5	0.5	0.5		-1	90	3	6/6
22	831898	M	60	RIGHT	6/36	44.25	43.5	22.5	0.75	180	ATR	6/6	6/6	0	0	NIL	0.75	1	0.75	0			3	6/6
23	836793	M	58	LEFT	6/24	43.5	44.5	22	1	90	WTR	6/6	6/6	0.5	90	WTR	0.5	0.5	0.5		-0.25	180	3	6/6
24	836826	F	67	LEFT	CF 2M	44.75	46	20.5	1.25	90	WTR	6/9	6/9	0.75	90	WTR	0.5	0.4	0.5	-2	-1	90	3	6/6
25	842893	F	57	LEFT	CF 1M	44.75	44	19	0.75	180	ATR	6/6	6/6	0	0	NIL	0.75	1	0.75	0			3	6/6
26	843909	F	70	RIGHT	6/60	43.5	42.5	21.5	1	180	ATR	6/9	6/6	0.5	180	ATR	0.5	0.5	0.5		-0.25	180	3	6/6
27	844362	F	75	RIGHT	6/36	45.25	44.5	21.5	0.75	180	ATR	6/6	6/6	0.25	180	ATR	1	1.33	1		-0.5	90	3	6/6
28	846480	M	73	RIGHT	6/36	42.75	42	20.5	0.75	180	ATR	6/6	6/6	0.5	180	ATR	1.25	1.66	1.25		-0.5	180	3	6/6
29	846682	F	70	RIGHT	CF 1M	44.75	43.25	19.5	1.5	180	ATR	6/24	6/18	1	180	ATR	0.5	0.33	0.5	-1	-0.5	180	3	6/12
30	847974	M	78	LEFT	6/60	45.5	44.5	21.5	1	180	ATR	6/6	6/6	0.5	180	ATR	0.5	0.5	0.5		-0.5		3	6/6

**(GROUP B)**

SL.NO	IP NO	GENDER	AGE(YEARS)	EYE	PRE-OPERATIVE							INTRAOPERATIVE		POST-OPERATIVE									
					VISUAL ACUITY	KERATOMETRY		PCIOL POWER	ASTIGMATISM			LRI		UCVA		ASTIGMATISM			REFRACTION				BCVA
						KH	KV		DIOPTERS(K1)	AXIS(A1)	TYPE	INCISION SIZE	AXIS(A2)	DAY 21	DAY 45	DIOPTERS(K2)	AXIS(A3)	TYPE	SPHERE	CYLINDER	AXIS	NEAR	
1	783704	F	74	RIGHT	6/60	44	43.25	20	0.75	180	ATR	35°	180	6/6	6/6	0	0	NIL	0			3	6/6
2	783702	F	66	RIGHT	6/24	44	43.25	24	0.75	180	ATR	40°	180	6/6	6/6	0.25	180	ATR	-0.5	-0.5	180	3	6/6
3	787526	F	61	RIGHT	CF 3M	43	44.5	21	1.5	90	WTR	35°	90	6/9	6/6	0.25	90	WTR	-2	-0.5	90	3	6/6
4	787375	F	65	RIGHT	CF 2M	41.5	43.5	24.5	2	90	WTR	40°	90	6/9	6/6	0.5	90	WTR	-1			3	6/6
5	788765	F	40	RIGHT	CF 1/2M	44.5	42	26.5	2.5	180	ATR	75	180	6/12	6/9	0.75	180	ATR		-1	180	1.5	6/6
6	789514	F	64	LEFT	CFCF	41.75	43.75	23	2	90	WTR	40	90	6/6	6/6	0.5	90	WTR	-0.5	-1	90	3	6/6
7	789724	M	85	LEFT	CF 1/2M	43.75	45	21	1.25	90	WTR	25°	90	6/9	6/6	0.25	90	WTR	-2			3	6/6
8	789856	M	65	LEFT	CF 1M	43.5	45	20.5	1.5	90	WTR	35°	90	6/6	6/6	0.25	90	WTR	-1			3	6/6
9	796984	F	61	RIGHT	CF 1M	43.5	45	21	1.5	90	WTR	35°	90	6/18	6/12	0.25	90	WTR		-0.5	110	3	6/9
10	797859	M	54	RIGHT	6/36	42	41.25	20.5	0.75	180	ATR	45°	180	6/6	6/6	0	0	NIL	0			2.5	6/6
11	798027	M	69	LEFT	6/60	45	44.25	19	0.75	180	ATR	40°	180	6/6	6/6	0	0	NIL	-0.5			3	6/6

12	797761	M	54	LEFT	6/18	46	45	21.5	1	180	ATR	50°	180	6/9	6/6	0.25	90	WTR	-2			2.5	6/6
13	797860	M	54	LEFT	6/24	42.5	41	19	1.5	180	ATR	60°	180	6/9	6/9	0.75	180	ATR	-0.5	-1	70	2.5	6/6
14	797923	M	60	RIGHT	CF 2M	47.25	48.25	18	1	90	WTR	45°	90	6/12	6/9	0.5	90	WTR		-0.5	90	3	6/6
15	797925	M	62	RIGHT	6/60	42	43	20	1	90	WTR	40°	90	6/6	6/6	0.5	90	WTR	-1			3	6/6
16	814763	M	58	RIGHT	6/24	42	43	22.5	1	90	WTR	30°	90	6/6	6/6	0.25	90	WTR	-1.5			3	6/6
17	802564	M	72	RIGHT	6/18	42	43	20	1	90	WTR	25°	90	6/6	6/6	0.5	90	WTR	-0.5	-1	90	3	6/6
18	806578	M	73	LEFT	CF 1M	42.75	43.75	21	1	90	WTR	25°	90	6/6	6/6	0.5	90	WTR	-1			3	6/6
19	816570	F	65	RIGHT	6/60	45	46.25	21.5	1.25	90	WTR	35°	90	6/24	6/18	0.25	180	ATR	-0.5	-0.5	180	3	6/9
20	824470	F	70	RIGHT	6/24	45	46	20	1	90	WTR	30°	90	6/9	6/6	0.25	90	WTR	-1			3	6/6
21	825626	M	65	RIGHT	6/18	44.5	43.5	22.5	1	180	ATR	40°	180	6/6	6/6	0.25	180	ATR	-2			3	6/6
22	826779	M	50	RIGHT	6/36	43	42	18	1	180	ATR	50°	180	6/9	6/6	0.25	90	WTR	-1	-0.5	90	2.5	6/6
23	832476	M	72	LEFT	6/60	42	43	18	1	90	WTR	25°	90	6/6	6/6	0.25	180	ATR	-2.5	-0.5		3	6/6
24	837008	M	70	LEFT	6/12	40.75	41.75	25	1	90	WTR	30°	90	6/6	6/6	0.5	90	WTR	-1.5			3	6/6
25	839568	F	62	LEFT	6/24	49.25	46.75	17.5	2.5	180	ATR	70°	180	6/12	6/9	0.75	180	ATR	-0.5	-1	180	3	6/6
26	843908	M	64	RIGHT	CF 2M	40.5	41.5	20.5	1	90	WTR	30°	90	6/6	6/6	0.25	180	ATR	-1			3	6/6
27	843906	M	84	LEFT	6/18	45	44	21	1	180	ATR	40°	180	6/6	6/6	0.25	90	WTR	-2			3	6/6
28	845323	M	72	LEFT	6/60	45	43.75	16	1.25	180	ATR	45°	180	6/9	6/6	0.5	180	ATR	-0.5	-0.5	180	3	6/6
29	847801	F	78	RIGHT	6/36	45.25	44.5	19.5	0.75	180	ATR	35°	180	6/6	6/6	0	0	NIL	0			3	6/6
30	847825	M	71	LEFT	CF 1M	47.75	45.25	25	2.5	180	ATR	50°	180	6/9	6/6	0.5	180	ATR	-1	-0.5	180	2	6/6

**ANNEXURE-V**

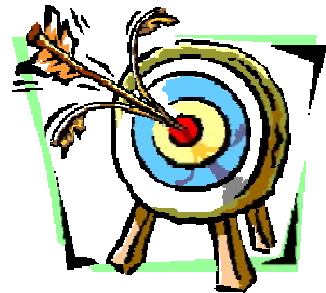
**KEY TO MASTER CHART**

A1	–	Axis of preoperative astigmatism
A2	–	Axis of placement of limbal relaxing incisions
A3	–	Axis of postoperative astigmatism
ATR	–	Against the rule astigmatism
BCVA	–	Best corrected visual acuity
CFCF	–	Counting Fingers close to face
CI	–	Correction index
F	–	Female
FE	–	Flattening effect
K1	–	Preoperative astigmatism in diopters
K2	–	Postoperative astigmatism in diopters
KH	–	Keratometry reading in horizontal meridian
KV	–	Keratometry reading in vertical meridian
M	–	Male
SIA	–	Surgically induced astigmatism
UCVA	–	Uncorrected Visual Acuity
WTR	–	With the rule astigmatism



# *Introduction*

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# *Objectives*

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# *Review of Literature*

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# *Methodology*

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# *Results*

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# *Discussion*

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*Conclusion*

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# *Summary*

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# *Bibliography*

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## *Annexure-I*

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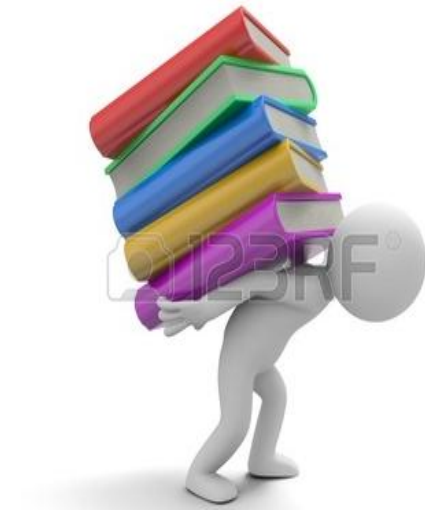
## *Annexure-II*

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## *Annexure-III*

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# *Annexure-IV*

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# *Annexure-V*

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