"CORRECTION OF MODERATE TO SEVERE DEGREE OF PRE-EXISTING CORNEAL ASTIGMATISM BY TORIC INTRAOCULAR LENS IMPLANTATION IN PATIENTS UNDERGOING PHACOEMULSIFICATION SURGERY- A ONE YEAR HOSPITAL BASED PROSPECTIVE INTERVENTIONAL STUDY AT KLES DR. PRABHAKAR KORE CHARITABLE HOSPITAL AND MRC, BELAGAVI"

By

REG. NO. BK0117005

Dissertation

Submitted to the KLE Academy of Higher Education and Research, Belagavi, Karnataka.

In partial fulfillment of the requirements for the degree of

MASTER OF SURGERY
IN
OPHTHALMOLOGY

DEPARTMENT OF OPHTHALMOLOGY,
JAWAHARLAL NEHRU MEDICAL COLLEGE,
BELAGAVI, KARNATAKA.

APRIL 2020

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

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To,

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ABSTRACT

Background and objectives

As physiological astigmatism is practically invariable, up to 95% of eyes have some clinically detectable astigmatism. More than 1 D of pre-operative corneal astigmatism is seen in approximately 40 % of the patients who undergo cataract surgery. There has been tremendous advancement in the technique of cataract surgery, from the ancient technique of couching to modern manual SICS and phacoemulsification. Earlier, ECCE induced more postoperative astigmatism due to longer incision and sutures. With the advent of phacoemulsification through a small clear corneal incision and foldable intraocular lens, the aim has transformed from reduction of surgically induced astigmatism to correction of pre-existing astigmatism.

Various techniques have been described for the correction of astigmatism during cataract surgery like incision on steep meridian, limbal relaxing incisions, toric intraocular lens and laser vision correction. The purpose of this study is:

1. To correct moderate to severe degree of pre-existing corneal astigmatism in patients undergoing phacoemulsification surgery.

2. To assess the safety, efficacy, post-operative refractive outcome and spectacle independence for distance viewing following implantation of toric IOLs in patients undergoing phacoemulsification surgery.

Methodology

The present observational study was conducted at the Department of Ophthalmology, KLES Dr. Prabhakar Kore Hospital and Medical Research Centre,

Belagavi on patients having >1 D (diopter) of pre-existing corneal astigmatism over a period of one year, who underwent phacoemulsification cataract surgery with implantation of toric intraocular lens.

Results

In the present study, the mean age was 61.15 ± 12.08 years. Majority of patients were in the range of 61-70 years. Also, 47.06 % (16) patients were male and 52.94 % (18) patients were female with male : female ratio of 0.89:1.

In this study, 41.18 % (14) of patients had pre-operative visual acuity in the range of 6/36 to 6/18, 14.71 % (5) had pre-operative visual acuity of 6/60 to CF 3M and 44.12 % (15) had pre-operative visual acuity of CF 2M to HMCF.

In this study, range of pre-existing astigmatism between 1 - 1.5 D was seen in 44.12 % (15) patients, 1.5 - 2 D in 32.35 % (10) patients, 2 - 2.5 D in 17.65 % (6) patients and more than 2.5 D in 5.88 % (3) patients.

In the present study, mean pre-operative astigmatism was 1.64 ± 0.80 and residual astigmatism achieved at 6 weeks follow up was -0.13± 0. 39 ($p < 0.0001$) which was highly statistically significant.

In this study, 47.06 % (16) of patients had WTR astigmatism and 52.94 % (18) had ATR astigmatism. A significant reduction in the magnitude, but no variation in the type of astigmatism was seen in cases post operatively.

In the present study, 1 week post-operatively 5.88 % (2) of patients had uncorrected visual acuity ranging from 6/60 – 6/36, 11.76 % (4) had uncorrected visual acuity ranging from 6/24 – 6/18, 82.35 % (28) had visual acuity ranging from

6/12-6/6. Also, uncorrected visual acuity 6 weeks post-operatively was 6/18-6/12 in 5.88 % 2 and 6/9-6/6 in 94.12 % (32) of patients.

In this study, best corrected visual acuity 6 weeks post operatively was 6/9 in 32.35 % (11) and 6/6 in 67.65 % (23) of patients. Spectacle freedom for distance viewing was achieved in 59 % of patients 6 weeks postoperatively and all patients were given near vision correction of + 2.5 to compensate for loss of accommodation seen in pseudophakic eyes.

In the present study, the anticipated residual astigmatism as calculated by the toric nomogram was -0.04 ± 0.14 and the mean residual astigmatism achieved at 1 week and 6 weeks postoperatively was -0.25 ± 0.87 (p value <0.1292) and -0.13 ± 0.39 (p value <0.2179) respectively, both of which are not statistically significant. Establishing that expected amount of residual astigmatism can be achieved using this toric nomogram.

Conclusion and interpretation

Toric intraocular implantation is a effective and satisfactory method for ensuring optimal correction of moderate to severe degree of pre-existing astigmatism and good visual outcome in patients undergoing phacoemulsification surgery.

Keywords: Phacoemulsification, Pre-existing astigmatism, Toric intraocular lens implantation

LIST OF ABBERIIVIATIONS USED

AK	Astigmatic Keratotomy
ATR	Against the rule
BCVA	Best corrected visual acuity
CRI	Corneal relaxing incision
D	Diopters
ECCE	Extracapsular cataract extraction
ICCE	Intracapsular cataract extraction
IOL	Intraocular lens
ISM	Incision on steep meridian
K_H	Horizontal meridian
K_V	Vertical meridian
LASIK	Laser in situ keratomileusis
LRI	Limbal relaxing incision
NAPA	Nichamin age and pachymetry adjusted
OCCI	Opposite clear corneal incision
PMMA	Polymethylmethacrylate
PRK	Phototrefractive keratectomy
SICA	Surgically induced corneal astigmatism
SICS	Small incision cataract surgery
UCVA	Uncorrected visual acuity
WTR	With the rule

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INTRODUCTION

Cataract is defined as an "An opacity, congenital or acquired, in the lens capsule or its substance due to irreversibly coagulated proteins.'' It is among the commonest causes of preventable blindness in the world.[1]

Cataract contributes to 50-80% of the bilaterally blind in India, where vision < 20/200 in the better eye on presentation is defined as blindness. [18]

Cataract surgery has significantly evolved from 600 B C to the present day.

Couching is the oldest technique described to treat cataracts. It resulted in high complication rates of namely, corneal scarring, uveitis, retinal detachment, secondary glaucoma, optic atrophy, and endophthalmitis, even leading to subsequent blindness. Most studies reported a minimum of 50% of couched patients having complete loss of vision – defined as visual acuity less than 3/60 according to WHO Categories of Visual Impairment.

Intracapsular cataract extraction (1745- 1877) - the advent of this procedure overcame the issue of lysing zonular fibers by using muscle hooks through the limbal incision, direct extraction and even the use of toothless forceps and suction cup like devices to remove lens with traction or tumbling. It left the patient aphakic.

Extracapsular cataract extraction (1877-1980) - required an operating microscope, additional microscopic surgical skill and retention of the posterior capsule which lead to opacification. It corrected aphakia but caused a higher amount of post – operative astigmatism owing to its larger incision.

The emergence of phacoemulsification by Kelman in 1967 is regarded as a major milestone in the field of cataract surgery. This procedure employs a smaller sized incision, thus leading to significantly reduced levels of surgically induced astigmatism as compared to ECCE. Due to the tremendous development in phacoemulsification devices, better quality instruments, modifications in operating techniques and mainly the advent of foldable intraocular lenses, the aim of cataract surgery has changed from dealing with post-operative astigmatism to correcting pre-existing astigmatism.[6]

In the current era, cataract surgery is regarded as a kind of refractive surgery, in which the surgical technique has transformed from mere cataract extraction to providing optimum visual outcome aiming pseudophakic emmetropia, with no spectacle dependence.

The spherical component of the refractive errors is corrected by using accurate IOL power calculations while the corneal astigmatism remains uncorrected.

As physiological astigmatism is practically invariable, up to 95 % eyes have some clinically detectable astigmatism. 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.

Over the years, management of astigmatism has become a crucial part of cataract surgery. There are different modalities that deal with pre – existing astigmatism intraoperatively and various approaches that deal with residual or induced astigmatism post – operatively.

These include epikeratophakia , on axis cataract incision, corneal relaxing incision, opposite clear corneal incision, limbal relaxing incision, toric intraocular lenses (IOLs) and piggy back lenses.

Epikeratophakia is a historic refractive procedure undertaken in aphakic patients. Here, after removal of corneal epithelium, a lathed donor lenticule is placed over the recipient cornea and sutured into place until it heals. It has been abandoned due to the advantages of modern laser refractive procedures.

Incision on steepest meridian causes flattening effect along the axis of the incision. Temporal incisions are stable, cause with the rule astigmatism while being farthest away from the visual axis. Superior incisions are safer as they are located under the eyelid and result in a lower post-operative endophthalmitis rate.

Corneal incisions made over the steepest meridian on opposite sides, 180 degrees apart are more effective than a single clear corneal incision made on a steeper axis to correct mild to moderate pre-existing corneal astigmatism. But, they do bear a higher risk of endophthalmitis.

The technique of limbal relaxing incisions consists of placing paired arcuate incisions at the limbus across the steepest meridian causing a flattening effect on that meridian and steepening of the orthogonal meridian due to tissue addition effect. It has gained popularity as it is a cost-effective procedure and has a predictable surgical outcome in correcting up to 3 D of pre-existing corneal astigmatism.

Toric IOLs, introduced in 1992 by Shimzu et al can rectify up to 8 D of pre-existing corneal astigmatism. Immense refinements in IOL material and design,

advancements in toric technology and surgical technique have resulted in significantly better postoperative rotational stability leading to optimal visual outcomes.

One of the foremost challenges of toric IOLs is ensuring appropriate alignment on the patient's astigmatic axis and rotational stability of the IOL after implantation. Toric IOLs are not preferred in patients having zonular instability and lack of a stable capsular bag.

Piggy back toric IOLs are a combination of two toric IOLs used to decrease high amounts of pre-existing astigmatism. The major drawback being the amount of rotation that significantly affects the cylindrical correction.

The purpose of the study is to see the beneficiary effect, safety, efficacy and rotational stability of toric intraocular lens implantation in reducing the astigmatic outcome in eyes with moderate to severe degree of pre-existing astigmatism.

AIM AND OBJECTIVES

1. PRIMARY: To correct pre-existing corneal astigmatism in patients undergoing phacoemulsification surgery by implantation of toric IOLs.

2. SECONDARY: To assess the safety, efficacy, post-operative refractive outcome and spectacle independence for distance viewing following implantation of toric IOLs in patients undergoing phacoemulsification surgery.

REVIEW OF LITERATURE

The word cataract, has been derived from the Greek word kataráktes, which means both an opacity of the lens and a torrent of water. “Any opacity, congenital or acquired in the capsule or substance of the lens due to irreversibly coagulated proteins is called cataract.” Surgical intervention is indicated only if and when opacification interferes with daily activities. Lens opacification occurs due to compression, hardening and chemical modifications in the lens leading to a decrease in visual acuity. [1]

Cataract is the primary cause of preventable blindness in the world. From 1990 to 2010, a remarkable decline in the number of individuals blind due to cataract has been reported, while the rate of cataract surgeries being performed increased more than three times owing to the improvement in surgical techniques and a lower rate of complication.[2]

Evolution of cataract surgery: couching to phacoemulsification

- Era of couching (600 B.C to 18th century)
- Era of Intracapsular cataract extraction (1745 – 1877)
- Era of Extracapsular cataract extraction (1877 – 1980)
- Evolution of modern Extracapsular cataract extraction:
  - Planned ECCE
  - Manual Small Incision Cataract Surgery (MICS)
  - Phacoemulsification [3]

Couching: (600 BC to 18th century)

It is an ancient procedure for reclination of the cataractous lens. Described by "Sushruta Samhita," in 600 BC in India. The word couching derived from the French word ‘couche’ which means ‘to put to bed’ refers to displacement of abnormal material obstructing vision. In this procedure a hole (sclerostomy) is made posterior to the limbus and the cataractous lens is pushed inferiorly using a couching needle having a curved needle. Couching remained the most popular method of cataract surgery until the 18th Century.

However, it is a painful procedure that leaves the patient aphakic. It is associated with high complication rates of namely, corneal scarring, uveitis, secondary glaucoma retinal detachment, optic atrophy and endophthalmitis resulting in subsequent blindness. [4]

Intracapsular cataract extraction (1745 – 1877)

In 1753, Samuel Sharp performed the first documented intracapsular cataract extraction (ICCE) Here, the entire lens, along with the lens capsule, is removed through a large limbal incision. The method by which zonular fibres are fractured has evolved from early use of forceps to cryoextraction.

Potential drawbacks of this procedure are related to removal of the cataractous lens and lens capsule entirely. These include, operative complications of vitreous loss and rupture of lens capsule, postoperative complications of delayed wound healing and anterior chamber formation, iris prolapse , uveitis , secondary glaucoma hyphema formation and even cystoid macular edema. [1]

Extracapsular cataract extraction (1877 – 1980)

Jacques Daviel, a French ophthalmologist performed the first ECCE on a living human eye in 1750 by a limbal incision of 180 degrees in the inferior half of the eye using a triangular knife. In the conventional method, the entire lens nucleus is removed by a 10 to 12 mm incision leaving behind the lens capsule.[5]

In Manual small incision cataract surgery (SICS) the nucleus is prolapsed through a self-sealing scleral tunnel incision measuring 5.5 to 7.5 mm. It is more safe and efficacious as compared to ECCE.

Phacoemulsification introduced by Charles D. Kelman in 1967 uses an ultrasound-driven needle to emulsify and aspirate the lens through a smaller (3 to 4 mm) incision, after which an intraocular lens is implanted into the capsular bag. By 1980 it became more popular and is now regarded as the most remarkable development in cataract surgery.[6]

There is a difference of only 0.3 to 0.5 D of astigmatism between ECCE and phacoemulsification. It has lesser chances of postoperative infections, vitreous loss and cystoid macular edema and corneal complications, resulting in better visual rehabilitation. [4]

From the implantation of the first intraocular lens by Sir Harold Ridley, on 8th February 1950 to the present day where foldable IOLs are being implanted through a 3 mm phacoemulsification incision has undoubtedly been one of the greatest work of many contributors.

Earlier rigid gas permeable PMMA IOLs were implanted through a 5 mm incision, now foldable acrylic hydrophilic acrylic IOLs inserted through a 2.5mm incision are preferred as they cause lesser capsular opacification and astigmatism.

Foldable IOLs cost 8.3 times more than rigid IOLs. Assuming equal proficiency of sclerocorneal tunnel and clear corneal incisions, the postoperative visual acuity with rigid PMMA IOLs after phacoemulsification are consistent with, if not better than, foldable IOLs at a much lower cost. [7]

In 1989 Neuman AC et al compared surgically induced astigmatism (SIA) during phacoemulsification with rigid PMMA IOL and foldable silicone IOL through 6 mm and 10 mm incision respectively. At the end of 3 and 6 months postoperatively , the mean induced astigmatism was less in the foldable IOL group in comparison with the PMMA IOL.[8]

There are different modalities that deal with pre – existing astigmatism intraoperatively and various approaches that deal with residual or induced astigmatism post – operatively.

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Immense refinements in IOL material and design, advancements in toric technology and surgical technique have resulted in significantly better postoperative rotational stability leading to optimal visual outcomes.[9]

THE REFRACTIVIZATION OF CATARACT SURGERY

Astigmatism is commonly found in about 95 % of the eyes. Among patients undergoing cataract surgery 63 % and 37 % have astigmatism of less than 1 D and more than 1D respectively. [10]

Over the past decade, development of cataract surgery techniques and advances in IOLs have obscured the lines between refractive and cataract surgery. It has become imperative to treat postoperative residual refractive error. Leaving the

astigmatic component uncorrected during cataract surgery results in the patient being dependent on spectacle use.

By the end of 2000, cataract surgery was aimed at correction of both pre-existing spherical and cylindrical components of the refraction. Thus, providing good unaided vision postoperatively.

Appropriate IOL power calculation eliminated the spherical component of the refractive error while the cylindrical component remained uncorrected. Despite the advent of innovative technical advancements and surgical developments, astigmatism still remained a problem.

ASTIGMATISM

Astigmatism accounts for about 13per cent of refractive errors of the human eye [11]

The term astigmatism is derived from the Latin word “Stigma” (meaning a point). Thus, astigmatism means “without a point”. “It is a kind of refractive variation in which no point focus is formed due to unequal refraction of incident light by the dioptric system of the eye in different meridians.”

Irwin and Borigh (1970) defined astigmatism as a refractive condition having variation of power in different meridians of the eye

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.” Commonly one meridian exhibits the greatest and the other the least power. These are known as “principal meridians”. [12]

HISTORY AND TIMELINE:

1727 – Sir Isaac Newton , first considered the question of astigmatism

1801 – Thomas Young described ocular astigmatism

1827 – George Airy corrected his own astigmatism using a cylindrical lens

1862 – Knapp and Donders characterized corneal astigmatism

1864 – Donders described regular astigmatism and astigmatism after cataract surgery

1869 – Snellen suggested placing incision on the steep axis to reduce corneal astigmatism [13]

ETIOLOGY:

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 by Grosvenor. [14]
3. Nystagmus – people with nystagmus usually have high degrees of corneal WTR astigmatism. [15]
4. Visual tasks – Certain visual tasks like prolonged reading habit in down gaze have a potential for inducing ATR astigmatism.[16]
5. Surgically induced astigmatism occurs after surgeries for cataract, trabeculectomy, ptosis, scleral buckling, pterygium excision.

CLASSIFICATION OF ASTIGMATISM:

A) Regular Astigmatism

- With the rule
- Against the rule
- Oblique
- 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.

- **With the Rule (Direct) Astigmatism:**

"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 degrees or the meridian of least curvature makes an angle of less than 30 degrees with horizontal plane."

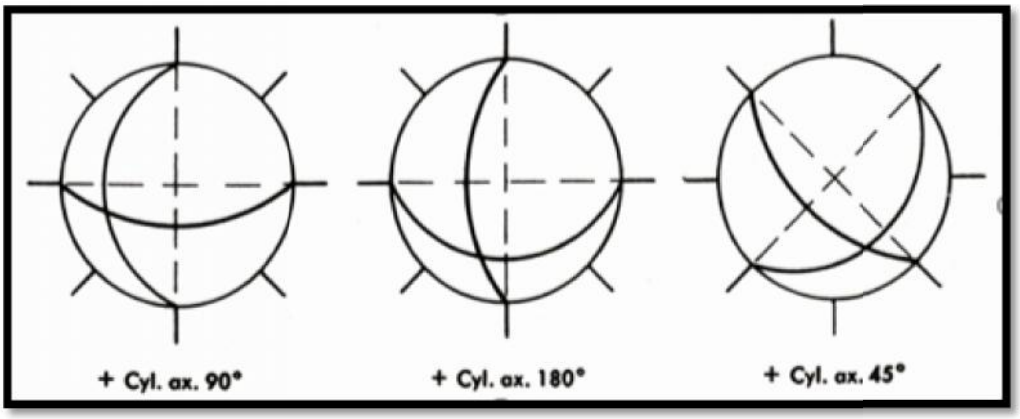
- **Against the Rule:**

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

- **Oblique Astigmatism:**

"The principle meridians are greater than 30 degrees from the vertical or horizontal meridian but still at right angles to each other."

• **Bi-oblique Astigmatism:** **"**The principle meridians are not at right angles to each other."



WITH THE RULE AGAINST THE RULE OBLIQUE

FIGURE 1. CORNEAL ASTIGMATISM

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 and is classified as –

a) Compound hypermetropic astigmatism where both foci are placed behind the retina.

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

Mixed Astigmatism:

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

Irregular Astigmatism:

Refraction in different meridians abides to no geometrical plane and the refracted rays of light bear 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 sphero-cylindrical spectacles.

Types:

• **Macroirregular Astigmatism:** Here the corneal curvature along a given meridian is different for each semi meridian. Eg: keratoconus having steepening of inferotemporal cornea

• **Microirregular Astigmatism**: Here small regions on the corneal surfaces show variable refracting power. Eg: 1 mm as seen in the faceting of contact lens warpage, few epithelial cells seen in keratoconjunctivitis sicca with superficial punctate keratitis. In these conditions mires become irregular and waxy, making crisp superimposition impossible

PREVALENCE OF ASTIGMATISM AND CHANGES WITH AGE:

The prevalence of severe (6D average) ATR astigmatism is more common in early months of life up to 4 years of age. [11]

Pre- term and low birth weight babies have steeper corneas and are more prone to have astigmatism.

Emmetropisation of astigmatism occurs as the child grows. Pressure on the cornea by the eyelids, results in flattening of the cornea, causing a shift to WTR astigmatism by the age of 4 to 5 years.

This persists till 18 years of age, hence children and young adults present with low grades of WTR astigmatism.

As age further advances, corneal curvature remains stable.

Beyond the age of 40 years, higher amount of corneal steepening is seen along the horizontal meridian causing a shift to ATR astigmatism.

Changes in corneal curvature lead to astigmatic alterations as the internal astigmatism remains unchanged across life.

A study conducted by Koch DD et al in 2012, postulated that anterior corneal WTR astigmatism tends to change to ATR astigmatism with age and posterior corneal surface shows ATR astigmatism irrespective of the age. [17]

NEED FOR REFRACTIVE CORRECTION:

The World Health Organization estimated 153 million of the population to be visually impaired due to uncorrected refractive errors.[18]

Refractive power of the eye is based on the cornea and lens. Refraction evaluates the entire optical system of the eye. It includes any aberrations of the lens, posterior cornea, IOL or posterior capsule. Anterior and posterior surfaces of the cornea and lens are the main refracting media of the eye.

As the development of cataract occurs, weight and thickness of a crystalline lens increases and its power of accommodation is lost causing a variation in the refractive status of the eye. Retinoscopy ascertains both magnitude and axis of the cylinder in astigmatism with precision. However, it does not give an accurate refractive status of the eye in patients having cataract and in cases of pseudophakia. [12]

EFFECTS OF ASTIGMATISM ON VISION:

Pre-operative corneal astigmatism of greater than 1.00 D is seen in approximately 40 % of the patients who undergo cataract surgery. Wherein moderate degree of corneal astigmatism from 1.50 D up to 3.00 D is present in 14 % eyes and severe astigmatism of 3.00 D or more present in 2.6 % eyes.

Astigmatism occurs due to toricity of a refractive surface. It produces two principal foci and an area of intermediate focus called the conoid of Sturm.

As a result of contrasting magnification in the two principal meridians, the image formed by an uncorrected astigmatic eye appears distorted as astigmatism causes distortion of images. Each dioptre of astigmatism causes 0.3% image distortion. [19]

A corrected astigmatic eye forms a distorted image due to unequal spectacle magnification along the two principal meridians. Each dioptre of cylindrical correction along the spectacle plane causes an image distortion of 1.6%.

In WTR astigmatism steepest corneal curvature is seen along the vertical meridian and along the horizontal meridian in ATR astigmatism. Thus, in cases of myopic WTR astigmatism it is beneficial to have a better focus in vertical meridian leading to better Snellen's visual acuity. [20]

Also, cylindrical spectacle correction prescribed in cases of WTR astigmatism is lesser as compared to that given in cases of ATR astigmatism of the same magnitude. Myopic ATR astigmatism results in proportionately greater spectacle correction and causes higher amount of distortion. Some amount of myopic astigmatism in pseudophakic patients is beneficial as it may lead to pseudo accommodation.

It has also been recognized that in comparison to ocular astigmatism, cylindric spectacle correction will be lesser in cases of a positive spherical equivalent and greater in cases of a negative spherical equivalent.[20]

The amount of astigmatism produced by contraction of scar post cataract surgery results in flattening of the cornea at an axis perpendicular to the wound. This surgical scar induced astigmatism continues to produce changes in corneal curvature for some weeks after the surgery.

Thus, the final spectacle correction should always be given a minimum of 6 weeks after cataract surgery.

Astigmatic error causes severe form of asthenopic symptoms in the form of headache, eye ache and burring of vision. Patients having preoperative astigmatism may have difficulty adapting to shift in meridian induced by surgery and even after appropriate spectacle correction the meridional magnification may create distortion.

Uncorrected astigmatic error results in symptoms of blurred image, glare and monocular diplopia. These effects cause a dissatisfaction with visual outcome and discomfort for the patient from an otherwise uneventful surgery.[21]

In 2013, Singh et al studied the association between uncorrected astigmatism and visual acuity in pseudophakia. He concluded that uncorrected hyperopic and myopic astigmatism results in deterioration of both near and distance vision in pseudophakic eyes.[22]

Measurement of corneal curvature:

1. Keratoscope :

Placido's disc: Invented by Gode in 1847. 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.

FIGURENO – 2: PLACIDO DISC

Photokeratoscope: Invented by Placido in 1880 and Gullstrand in 1896. 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.

Astigmatometer: 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 (Ophthalmometer) : The first keratometer was devised by Helmholtz in 1854.[13]

In 1881, Javal and Schoitz, restricted the use of the Helmholtz instrument to measurement of corneal curvature along with surface astigmatism. 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 due to 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 has a lamp system that illuminates the mires through a diagonal mirror. As light from the mire strikes the cornea, it produces an image behind it. Radius of curvature of the cornea decides the image size as the mires are of a fixed dimension. The image formed serves as an object for the optical system.

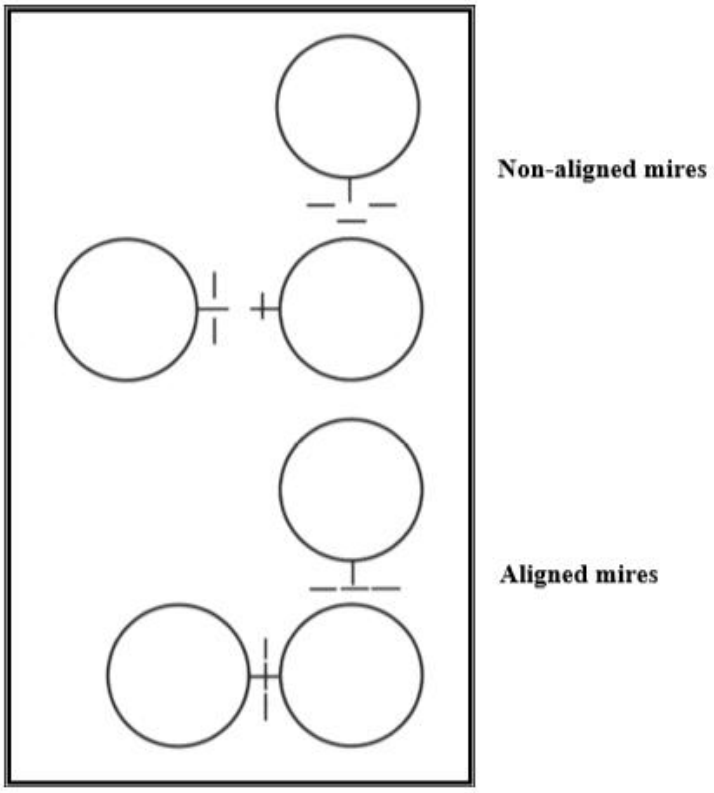


FIGURE NO – 3: MIRES OF KERATOMETER

Light emitted from the object is received by an objective lens and focused to a plane farther over the central axis. A four-aperture diaphragm is placed near the objective lens. Past the diaphragm are two doubling prisms, one with base up and the other with base out. These prisms can be moved parallel to the central axis of the instrument, independently. The base up prism deviates light passing through the left aperture of the diaphragm to form an image above the central axis. The base out prism deviates light passing through the right aperture of the diaphragm forming a second image to the right of the central axis.

Light from the upper and lower apertures produces an image on the axis as it does not pass through either prism. 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. If the instrument is improperly focused over the image of the corneal mires, doubling of the central image occurs as both upper and lower apertures act as a Scheiner's Disc. A magnified view of the double images is seen via the eye piece.

Automated Keratometry:

Here, the reflected image of a target is focused onto a photodetector which measures the image size and the radius of curvature. A photodetector emitting infrared lights illuminates the target mires. The image is measured in many meridians, 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:

The use of keratometers during a surgical procedure was first recommended by Barraquer. Troutman devised a qualitative device that projects a series of dots onto the cornea forming 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, others 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 colour maps, where cooler colours represent flatter areas and warmer colours represent steeper areas.

JAVAL'S RULE OF ASTIGMATISM:

Proposed in 1890 states that total astigmatism of the eye can be ascertained by corneal astigmatism. [11]

$At = k + p(Ac)$

At = total astigmatism

Ac = corneal astigmatism

k and p are constants approximated by 0.5 and 1.25 respectively.

This rule considers residual astigmatism to be constant and ATR in most people

Grosvenor et al by using regression analysis formulated a simplification of Javal's rule of $At = Ac - 0.5$. [11]

A study conducted by Keller et al depicts the relationship between corneal and total astigmatism by using videokeratoscopy to measure corneal astigmatism. [23]

Dunne, Elawad and Barnes calculated the difference between ocular and total astigmatism and determined the residual astigmatism. The average residual astigmatism was estimated to be $-0.46 \times 98.2°$ for right eyes and $-0.50 \times 99.4°$ for left eyes. [24]

Two third of the eyes depicted residual astigmatism along an axis perpendicular to corneal astigmatism axis.

Kelly, Mihashi and Howland postulated that compensation of horizontal/vertical astigmatism is an ongoing process and bears no significant compensation in case of oblique astigmatism. [25]

Several studies have suggested that levels of astigmatism for the posterior cornea range from 0.18–0.31 D. The posterior corneal curvature has a sign opposite to that of the anterior cornea. Thus, Javal's rule suggests that the compensation of corneal astigmatism by the internal optics of the eye is an inactive process. [26 27]

SURGICALLY INDUCED ASTIGMATISM FOLLOWING CATARACT SURGERY :

As first described by Donder in 1894,[28] it is well recognized that the wound performed during cataract surgery produces astigmatism. With the advent of sutured cataract sections and IOL implantation induced astigmatism became more of a concern.

Extra capsular cataract extraction consists of a longer incision and greater number of sutures resulting in greater degree of surgically induced astigmatism.

Small incision sutureless cataract surgery by phacoemulsification, as compared to conventional ECCE enables extraction of a cataractous lens through a smaller incision, resulting in a potentially astigmatically neutral incision with less postoperative against the rule shift.

Surgically induced corneal astigmatism depends on various factors such as dimension, location of the incision, patients age, preoperative corneal astigmatism and

use of sutures. The magnitude of SICA for a 2.2 mm incision has been reported to range from 0.19 D to 0.31 D and 0.19 to 0.40 D for a temporal and superior incision respectively. While, implantation of toric IOL requires a 1.8 to 3.4 mm incision. [29]

In the late 1800s astigmatic keratotomy was performed for surgical correction of astigmatism. On the basis of Gauss' law of elastic domes which states that "for every change in curvature in one meridian there is an equal and comparable change in the opposite meridian." [30]

Snellen suggested that placing a corneal incision perpendicular to the steep axis might cause corneal flattening in that axis. [13]

In 1885, Schiotz performed a penetrating limbal incision in the steep meridian resulting in a reduction in a higher degree of astigmatism following cataract surgery.

Faber performed anterior transverse incisions to reduce idiopathic astigmatism.

In 1886, Lucciola reported non – penetrating incisions to correct astigmatism. In 1894, Bates recognized that relaxing incisions produced flattening of steep meridians;

He postulated basic principles of cataract surgery [21]

- The radius of curvature is lengthened in the meridian perpendicular to the corneal incision and has no effect on any other meridian.
- The astigmatism produced is permanent following a duration of one month after the corneal healing.
- The amount of astigmatism produced is greater near the centre of the cornea

Lans suggested that a transverse incision causes flattening in the axis perpendicular to the incision and steepening along the opposite axis.

In 1940s, Sato concluded that "transverse incisions simultaneously flatten both steep and flatter meridian by investigating radial and astigmatic keratotomy."

Thorton proposed placement of paired arcuate incisions at the 7.0mm and 8.0 mm optical zones, considering age factor and timing after surgery[31]while Chayez et al proposed optical zone sizes of 5.0 mm. [32]

Nichamin devised Intralimbal relaxing incision nomogram for modern phacoemulsification to correct with- the – rule astigmatism and against – the – rule astigmatism.

Shimzu et al In the year 1992 implanted the first toric IOL during cataract removal having a predictable outcome to reduce residual refractive error. [9]

Closure of corneal incisions by sutures:

Sutures usually cause a corneal steepening in the meridian of the suture. However, even if same number of sutures are being used, SIA is greater in a larger wound. In a long wound, a greater number of tissues can be affected by suture tension.

Larger wounds produce greater amount of WTR astigmatism. Astigmatism resulting from these wounds decay faster over a period of time and need a longer duration for stabilization.

Smaller wounds usually have less surgical edge surface area and are more resistant to mechanical forces of sutures.

In 1984 Nakada S, Tanuka M, Nakajima A conducted a study on 137 cases and concluded that with the rule astigmatism for the initial 6 months progressed to against the rule astigmatism 2-4 years after surgery. [33]

In 1996 Masket S and Tennon DG concluded that these incisions skip with the rule phase and show against the rule astigmatism even on the first postoperative day i.e. unsutured and sutured incisions both move in the direction of against the rule astigmatism over time. [34]

Wound compression in superior incisions causes a reduction of vertical circumference of the globe and thus a steepening of the vertical meridian. Wound gape leads to an increase in the vertical circumference of the globe resulting in flattening of the vertical meridian. Gary F. Jaffe concluded that these changes are because of ocular rigidity and shape of the cornea. [19]

Ken Hayashi et al studied long term change in corneal astigmatism after suturless cataract surgery.

They concluded that as age advances corneal astigmatism following sutureless cataract surgery depicts a long term against-the-rule astigmatism and this variation is identical to that of a normal cornea, establishing that ATR change occuring subsequently should be considered during cataract surgery. [35]

SURGICAL CORRECTION OF ASTIGMATISM DURING CATARACT SURGERY:

15%–29% of cataract patients have more than 1.5 dioptres (D) of pre-existing astigmatism.[9]

"Approximately 70% of the general population diagnosed with cataract have at least 1.00 D of astigmatism and 33% of patients undergoing cataract surgery are eligible for management of pre-existing astigmatism." [26 27]

Ferrer-Blasco et al in 2008 conducted a study on prevalence of corneal astigmatism prior to cataract surgery concluding 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.

Thus, surgeons should plan correction of both spherical and astigmatic components during cataract surgery in order to achieve an outcome close to emmetropia.

In the past few years, two major advances have resulted in a remarkable improvement in visual outcome. First, being the use of smaller incisions and second is intraoperative use of toric IOLs. [9]

METHODS OF SURGICAL CORRECTION:

1. **CORRECTION WITH INCISIONS**
    a. **Clear corneal incisions**
    b. **Opposite clear corneal incisions**
    c. **Limbal relaxing incisions**
    d. **Corneal relaxing incisions**
2. **CORRECTION WITH INTRAOCULAR LENSES**

    Toric intraocular lenses

1. CORRECTION WITH INCISIONS

Postoperative corneal astigmatism:

Astigmatism following 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 right angles to the wound.

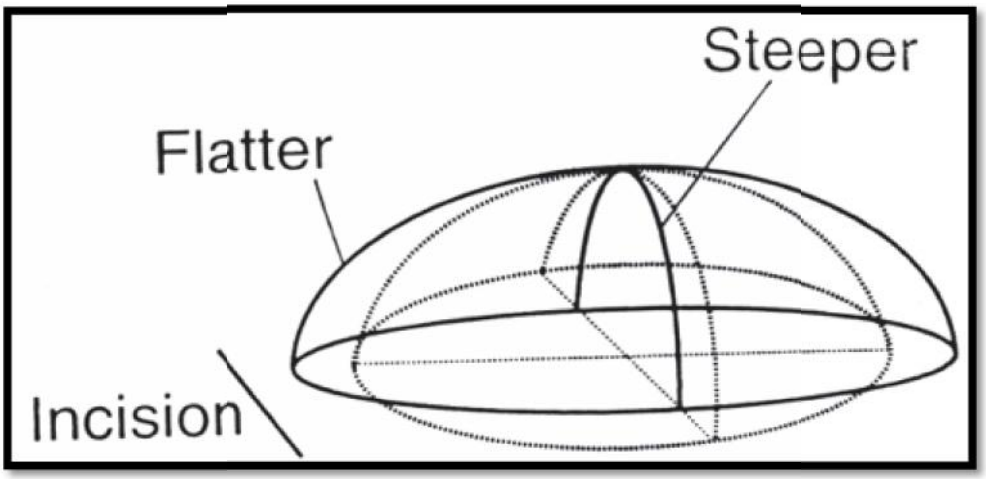


FIGURE NO- 4: POSTOPERATIVE CORNEAL CHANGES

Basic concepts of corneal incisions:

Dimension of arc length of the incision is directly related to the amount of flattening produced.

As a result of coupling, arc lengths of more than 90 degrees are not beneficial.

Incisions made on the cornea or sclera cause flattening along the axis adjacent and perpendicular to it. Due to coupling effect the axis 90 degrees away is steepened.

Incisions closer to the optical centre cause greater flattening.

Depth of the incision is directly proportional to the amount of flattening.

On comparing incisions of the same dimension, scleral incisions cause lesser astigmatism than limbal incisions.

In case of a penetrating incision tunnel length is indirectly proportional to the amount of resultant flattening.

It must be remembered, that incisions above 90 % of the pachymetry cause greater flattening effect but can lead to corneal perforation.

Besides being easier to execute, arcuate incisions cause greater flattening and do not alter the corneal circumference.

a. CLEAR CORNEAL INCISION:

Pre-existing astigmatism can be reduced by altering the dimension, shape, form and location of the incision on the steepest meridian of astigmatism. The flattening effect is seen along the axis of the incision which can be either superior,

temporal or oblique. Superior incisions have against the rule astigmatism while temporal incisions have with the rule astigmatism.[28]

Biomechanics of wound healing in clear corneal incisions:

Once the wound is created, fluid imbibition by the layers of the cornea makes the wound edged quite edematous and opaque. Anterior and posterior apices are formed corresponding to the superficial and deep edges of the wound respectively.

Mechanics involved in healing of the anterior triangle: There is an increase in the activity of epithelial cells and migration of epithelial cells from the surrounding to cover the defect. Mechanics involved in healing of the posterior triangle: Endothelial cells rearrange themselves by sliding, mitosis and thinning to fill the defect. Gradual increase in collagen formation occurs resulting in an increase in the tensile strength leading to stromal healing. The newly formed connective tissue pushes out the epithelial plug outwards and fills in the posterior triangle. Thus, restoring the normal corneal layers. The effect of burn wound created by hard / brown cataract slows down healing process and induces more postoperative astigmatism. Clear corneal incision made over the steepest axis causes flattening of the cornea in that axis and steepening of the opposite axis. [36]

Roman S et al analysed surgically induced astigmatism in superior and temporal incisions with foldable IOLs. Postoperative SIA was 0.90 D with superior incision in WTR astigmatism and 0.58 D with temporal incision in ATR astigmatism.[37]

James Tejedor et al studied the preferred site of clear corneal incisions in phacoemulsification, on the basis of pre-existing astigmatism. They concluded that in

cases with astigmatism of atleast 1.5 D at a steep axis of 90 degrees, superior incision is preferred. While temporal incision is preferred at astigmatism of lower than 1.5 D and lower than 0.75 D with steep axis at 90 and 180 degrees respectively.[38]

Oshima Y et al studied results of implantation of foldable IOL through 3 mm temporal clear corneal and 3 mm superior scleral tunnel incision in 78 patients having pre – existing ATR astigmatism. Decrease in pre – existing astigmatism at 3rd postoperative month was 0. 56 D and 0.65 D in temporal clear corneal group and superior scleral tunnel group respectively proving that greater decrease was seen in the temporal clear corneal group in comparison with the superior scleral tunnel group.[39]

Pistarini Fernando Gonsalves et al concluded that knowledge about the pre-existing astigmatic axis helps to effectively diminish surgically induced astigmatism.[40]

Thus, pre-operative marking of the steep axis is mandatory to ensure that the surgical incision is taken at the appropriate keratometric axis in order to flatten the cornea. This technique is used effectively to correct cases of mild astigmatism of up to 1 D by modifying the length , depth and distance of the corneal incision from the centre. [40]

Advantages of temporal clear corneal incision:

As the surgeon is positioned on the side working temporally, Bridle sutures are not required.

This location allows better access as compared to working over the brow.

Intraocular structures are better seen with an improved red reflex as the iris plane is parallel to the light of the microscope.

The irrigation fluid is naturally drained as the lateral canthus is directly below the incision.

Temporal incisions are more stable and flattening caused at the wound site has less probability to affect the corneal curvature along the visual axis.

Effects of tug created on the incision by eyelid blink and gravity when placed superiorly are neutralized by a temporal incision.

In elderly patients having against the rule astigmatism preoperatively, temporal incisions induce with the rule astigmatism.

As temporal incisions are farthest away from the visual axis, they cause lesser endothelial damage postoperatively than superiorly placed incisions.

Advantages of superior clear corneal incision:

Safer as it located under the eyelid.

Superior incisions theoretically reduce postoperative discomfort and foreign body sensation.

Patients having WTR astigmatism and deep set are taken up for superior incision.

Superior incisions can be easily be converted into larger incisions if needed.

Lower rate of post- operative endophthalmitis.

b. OPPOSITE SIDE CLEAR CORNEAL INCISIONS:

Here, the corneal incisions are made along the steepest corneal meridian on either side, 180 degrees apart. It is based on the hypothesis that during the process of wound healing, tissue adding effect due to the formation of tissue between these incisions causes corneal flattening. The incisions are aided by creating two biplanar 3.2 mm incisions 180 degrees apart along the steep corneal axis 1.5 to 2 mm within the edge of the limbal vessels.

However, risk of endophthalmitis is higher as it consists of penetrating incisions thereby limiting the use of this technique.

In this technique introduced by Lever and Dahan, an incision identical to clear corneal incision is made on the opposite side 180 degrees away from the main corneal incision. Their study included 33 eyes, showing changes in mean corneal astigmatism from 2.80 D pre operatively to 0.75 D post operatively. [41]

In 2005 J S Bhalla et al compared the effect of single clear corneal incision (CCI) along the steep meridian with opposite clear corneal incisions (OCCIs) on pre – existing regular corneal astigmatism in patients undergoing phacoemulsification surgery and concluded that OCCIs on the steep meridian were more effective than single CCI in correcting mild to moderate pre-existing corneal astigmatism.[42]

Similar studies conducted by Khokhar et al and Nemeth et al documented a mean astigmatic correction of 1.66 D and 1 D at the end of 3 months and 9 weeks respectively with OCCIs.[43 44]

Limbal relaxing incisions:

In 1898, L. J . Lans , a Dutch ophthalmologist , was the first to demonstrate the effect of non- penetrating incisions placed at the limbus across the steepest meridian to treat astigmatism. [45]

LRI's as an adjunctive procedure with phacoemulsification to correct pre-existing astigmatism has gained popularity over the past years as it is cost effective and has a predictable surgical outcome.[46]

The technique consists of paired arcuate incisions placed at the limbus across the steepest meridian leading to flattening of that meridian as an effect of tissue addition effect and steepening along the orthogonal meridian.

Various authors have reported that LRI technique reduces mean astigmatism by 25 to 52 %.

Advantages of LRI:

Easy, cost effective technique, quick to perform with use of low technology.

Causes minimal irregularity and distortion on corneal topography due to limbal placement of incisions.

Less variability of refraction.

Symptoms of glare and patient discomfort are less postoperatively.

Early postoperative visual recovery.

Risk of overcorrection of astigmatism and corneal perforation are lesser.

Principle of coupling:

Coupling is described as the variation in corneal power at the incision site in comparison to the variation in corneal power 90 degrees away. Coupling ratio is the amount of flattening produced by an incision relative to flattening or steepening 90 degrees away. This flattening causes a hyperopic shift while steepening produces a myopic shift. Thus, maximum coupling signifies a low coupling ratio.

Shorter incisions need to be placed more centrally, within a 15-degree arc and have a lower coupling ratio and have less impact on the postoperative spherical equivalent. Two different procedures can correct the same amount of astigmatism while producing a different coupling ratio.

For example, a single long LRI causes a greater hyperopic shift (higher coupling ratio) as compared to 2 shorter CRIs (lower coupling ratio).[47]

Depth of LRI incision:

As the corneal thickness varies from center to periphery and in different meridia, Measuement of corneal thickness using pachymetry at the incision site has become a cardinal part of preoperative evaluation. The depth of LRIs around the limbus should be around 90 % of the minimum corneal thickness as postulated by Nichamin et al. They designed a 600 micron cutting depth blade which is preferred by most surgeons empirically. Reduction in mean astigmatism has been reported to be between 25-52 % by various authors.[26 47 48 49 50]

Kim et al suggested, that since patients have variable corneal thickness, the cutting depth should be ascertained based on the preoperative pachymetry value of

corneal thickness. He also demonstrated that an acceptable amount of astigmatism can be corrected by using less than 90 % cutting depth.[51]

LRI Nomograms:

A nomogram is designed to calculate the arc length of the incisions on computing the amount of astigmatism to be corrected. 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.

The arc length of the incisions is calculated after corelating the patient's age and the quantity of pre- existing cylinder to be corrected.

Paired incisions expressed in degrees of arc are commonly used to achieve symmetric corneal flattening. The incision length and its resultant effect depends on the corneal diameter. Thus, over- correction or under – correction can be reduced by presenting in degrees of arc mostly for cases of small or large corneas.[52 53]

Commonly used nomograms are as follows:

- The NAPA Nomogram :
- The DONO Nomogram :
- The Gills LRI Nomogram
- The Wallace LRI Nomogram

Corneal relaxing incisions:

These single or paired, straight or arcuate incisions, run collateral to the limbus along the steepest corneal axis and can correct astigmatism of 1-3 D like LRIs implemented during surgery or post operatively. They may be mandatory during

implantation of multifocal intraocular lenses in eyes having greater than 1 D astigmatism.[54]

Wang et al performed peripheral corneal relaxing incisions in 115 eyes using a modified nomogram. As a result 4 months postoperatively, significant reduction in pre-existing astigmatism was seen in WTR and ATR astigmatism.[55]

2. Correction with intraocular lenses

Although corneal or limbal relaxing incisions still remain popular alternatives in patients having low to moderate degree of astigmatism, toric IOLs are gaining superiority in terms of visual outcome.

In 2015 , Kessel L et al conducted a systemic review and meta-analysis assessing the pros and cons of toric versus non – toric implantation with or without relaxing incisions. They concluded on the basis of significant evidence that toric IOL implantation gives better UCVA, lesser residual astigmatism and higher spectacle independence for distance vision without increased risk of complications as opposed to any other method.[56]

TORIC INTRAOCULAR LENSES :

Since their introduction Toric IOLs have become a useful tool for rectifying pre – existing astigmatism in cataract surgery. In patients having regular corneal astigmatism they enhance uncorrected distance visual acuity. [57]

Historical overview:

In 1992, Shimzu et al introduced the first toric IOL which was a non foldable 3 piece posterior chamber lens inserted through a 5.7mm incision, available in cylinder powers of either 2.0 D or 3.0 D.[58]

77 % eyes had CDVA of 20/25 or better. Significant rotation was noted postoperatively, 20% of the IOLs rotated 30 degrees or more and 10 degrees or more was seen in almost 50% of IOLs. The results were promising.[58]

In 1994, the first foldable one piece toric IOL made of silicone was implanted through a smaller incision of 3.2mm. [59 60]

23 % of patients had UDVA of 20/25 or better on being implanted a toric IOL in comparison to the 4 % of patients having a standard IOL. The limitation of this IOL still remained a relatively greater rotation rate during the postoperative period. 20 to 30 % of eyes showed a rotation rate of over 10 degrees, which resulted in a 35 % residual astigmatic error.[61]

Since 1994, there have been numerous developments in IOL material and design, advancements in toric technology and surgical technique. These advances have led to a significantly better rotational stability and improved visual outcomes in the postoperative period.

Owing to their enhanced safety and predictability, toric IOL implantation is now considered the procedure of choice to rectify significant corneal astigmatism in cases having cataract surgery.[62]

One third of cases undergoing cataract extraction have preoperative corneal astigmatism of more than 1D. 22 % and 8 % have more than 1.5 D and 2 D astigmatism respectively. In such cases of moderate to severe degree of astigmatism toric IOLs provide optimal patient satisfaction and postoperative spectacle independence.[63]

IOL material:

Toric IOLs are available as monofocal and multifocal models made of either hydrophobic acrylic, hydrophilic acrylic, silicone or PMMA biomaterial. IOL biomaterial affects the postoperative rotational stability of the IOL. Rotation of the IOL is prevented by strong adhesions between the IOL and the capsular bag and fusion of the anterior and posterior capsules.[64]

Many in vitro studies have been conducted to assess the associations of different IOL biomaterials with the capsular bag. Lombardo et al. concluded that hydrophobic acrylic IOLs depicted the highest adhesive properties, followed by hydrophilic acrylic IOL, PMMA IOLs and silicone IOLs which showed the least adhesive properties by making use of atomic force microscopy. [65]

Linnola et al. postulated that IOL biomaterials show variation in IOL adhesion as an effect of difference in affinity to proteins in the capsular bag. Extracellular matrix proteins such as fibronectin, vitreonectin and type IV collagen are present in the aqueous humour postoperatively and these could be responsible for IOL adhesion to the capsular bag.

Acrylic IOLs explanted from human autopsy eyes had significantly more fibronectin in comparison to silicone or PMMA eyes indicating that acrylic IOLs have the highest amount of adhesions with the capsular bag.[66]

IOL design:

The overall IOL diameter and haptic design are major factors leading to a stable capsular bag and preventing postoperative IOL rotation.[67 68 69]

Chang et al. compared two toric IOLs made of the same silicone material having different sizes which included a smaller model having a diameter of 10.8 mm and a longer model with a diameter of 11.2 mm. Over 10 degrees of rotation was seen in 10% of the longer IOLs and 45% of the smaller IOLs. Presently toric IOLs of diameter ranging from 11.0 mm to 13.0 mm are available.[68]

Currently two IOL haptics designs are available in toric IOLs: plate haptic and loop haptic. Patel et al postulated higher chance of rotation in loop haptic IOLs as a result of their asymmetric fusion with the capsular bag.[67] However, Prinz et al. found no significant variation in the rate of postoperative rotation on comparing plate and loop haptic acrylic IOLs postulating that plate and loop haptics acrylic IOL show similar magnitude of rotational stability.[70]

Need for toric IOL implantation:

A recent study conducted by Khan MI et al showed that among patients presenting for cataract surgery, 40.41 % , 20.5 % and 4.61 % had more than 1 D , more than 1.5 D and more than 2.5 D of astigmatism respectively.[71]

Corneal astigmatism of more than 1.2 D cannot be corrected by limbal relaxing incisions alone, in such scenarios implantations of a toric IOL or additional incisions would be required.[72]Toric IOLs have gained popularity for correcting moderate to severe degree of astigmatism.[73 74]

Net corneal astigmatic power:

In 2012 , Koch evaluated 715 corneas of 435 patients laying emphasis on the role of posterior corneal astigmatism in calculating the net corneal astigmatism in toric IOL calculations.[17]

Selecting toric IOls based upon anterior corneal measurement causes an overcorrection in eyes having with- the – rule astigmatism and an under correction in eyes having against – the – rule astigmatism. Thus concluded that posterior corneal astigmatism is related to WTR astigmatism and not with ATR astigmatism.[75]

In 2011, Goggin et al first described the need to include both effective lens position (ELP) and spherical power when making toric IOL calculations as the cylinder at the corneal plane varies with the spherical power of the IOL implanted. [76]

Toric IOL calculation:

Various techniques can be employed preoperatively to measure corneal astigmatism in order to achieve optimal visual outcome.[77 78 79]

Devices used are – automated keratometry

manual keratometry

corneal topography

Scheimpflug imaging

Calculations performed by manual or automated keratometry show comparable results in measuring astigmatism.[80]

Scheimpflug imaging considers both the anterior and posterior corneal surfaces defining true refractive indices for cornea and aqueous humor resulting in remarkably distinct values as compared to keratometry or topography.[81 82]

"Cylindrical power of a toric IOL depends upon the amount of corneal astigmatism. Effective cylinder power of the IOL at the corneal plane depends on both estimated lens position and spheroequivalent power of the IOL." Cylindrical and spherical power of the IOL should initially be translated into the two principal lens powers, then both lens powers are calculated in relation to the corneal plane using a standard vertex formula. The variation between both lens powers along the corneal plane is employed to choose the ideal IOL cylinder power. Therefore, the association of cylinder power at the IOL plane and at the corneal plane is variable.[83 84]

Goggin et al compared a fixed corneal plane cylinder power with a calculated corneal cylinder power that includes both the estimated lens position (ELP) and IOL spheroequivalent power. This study suggested that "for a hydrophobic acrylic toric IOL, the fixed IOL cylinder power at the corneal plane varied from the calculated value." [76]

Recently, a new toric IOL calculator became available which considers the estimated lens position and predicts posterior corneal astigmatism based on anterior corneal astigmatism. [85]

Nomograms /online toric calculators:

Alcon toric calculator – uses a fixed ratio to calculate toric power at corneal plane

Holladay toric calculator – uses effective lens position (ELP)

Barrett toric calculator – uses ELP of the Barrett Universal II formula and the mathematical model of posterior cornea

In 2013, Koch et al in 2013 described Baylor toric nomogram which can be used along with any toric calculator as it takes into consideration the influence of posterior cornea in the presence of WTR and ATR astigmatism.[17]

Types of astigmatic markers:

Popp et al evaluated the effects of marking at the slit lamp by 4 different corneal astigmatic marking methods – [86]

Insulin needle marker

Pendular marker

Bubble marker

Tonometer marker

All markers showed a minimal deviation to the horizontal reference meridian. Even minute deviations of the meridian cause a relevant reduction in astigmatic correction with toric IOLs. Alteration in the patient position from upright to supine leads to variable cyclotorsion. Thus, accurate corneal marking before surgery is crucial to the visual outcome.[86]

Evaluation of posterior corneal astigmatism:

Considering posterior corneal astigmatism while calculating total corneal astigmatism is ideal to avoid errors in IOL power calculation. The posterior corneal serves as a minus (myopic) lens having against the rule astigmatism which remains

stable over the years. With advancement of age, anterior corneal astigmatism shifts from with-the-rule to against-the-rule.

Basing toric IOL power calculations on the anterior corneal curvature measurements alone results in residual astigmatism after toric IOL implantation. Leading to an overcorrection by a factor of 1.38 in eyes having with-the-rule astigmatism and an under correcting by a factor of 0.65 in the eyes with against-the-rule astigmatism.[63]

Residual refractive error:

Despite the proven efficacy of toric IOLs 28 to 47 % and 6 to 16 % of eyes have more than 0.50 D and 1 D of residual refractive astigmatism respectively. [29 87]

Residual astigmatism after toric IOL implantation ranges from 0.00 to 2.25 D. [88]

Drawbacks of Toric IOL implantation:

Generally , good visual outcome occurs over a period of 6 months with modern hydrophobic and hydrophilic acrylic toric IOLs but even after accurate preoperative biometry ,IOL calculation and optimum IOL alignment, some amount of postoperative IOL rotation might prevent an ideal refractive outcome.[89 88 90 91 92]

Risk factors for postoperative IOL rotation : [69 89 93 61]

Axial length more than 25 mm

WTR astigmatism

Large diameter of capsular bag

Compression of IOL from capsule shrinkage

Incomplete removal of OVD causes decreased friction between haptics and capsular bag

Postoperative intraocular pressure fluctuations

Inadequate size of continuous curvilinear capsulorhexis

Insufficient extension of IOL haptics [94 68 95 96]

Rotation of toric IOL:

The rotational stability of toric IOL decides the stability and effectiveness of the surgical outcomes. One of the primary challenges of toric IOLs is enabling appropriate alignment on the axis of corneal astigmatism and rotational stability following implantation. Minimal amount of variation in alignment will result in postoperative astigmatism on an axis different from that of the pre-operative astigmatism.

Several studies have been conducted on the rotational stability of monofocal toric IOLs. Misalignment is defined as the difference between preoperatively calculated IOL position and real IOL position right after surgery.

Rotation is defined as differences between real IOL position right after surgery and IOL position at post-operative follow up visits.

Both these effects are critical to the surgical visual outcome.[97]

Within the first hour of implantation all lenses undergo some degree of rotation and remain stable for the first month. The main factors responsible for rotation of lenses within an hour of implantation could be due to poor friction between haptic and capsular bag due to incomplete removal of OVD. Also, a large lens

diameter in relation to the capsule can induce distortion of the capsular bag and zonules and even lead to greater friction and minimize risk of rotation.[98]

In 2015, Garzon N et al conducted a prospective interventional study comparing monofocal and multifocal toric IOLs. They found that postoperative UDVA was 0.1 logMAR or better in 64.6 % eyes and 46.4 % eyes implanted with monofocal and multifocal toric IOLS respectively. Lower than 5 degrees misalignment was seen in 69.6% of monofocal IOLS and 67.9 % of multifocal IOLs. Thus, postulating that at a postoperative period of 1 month, multifocal IOLs had a larger effect on UDVA than monofocal IOLs. [97]

Cylindrical power of a toric IOL is reduced by 1/3rd with 10 degrees of rotation and is further reduced to 2/3rd if the IOL rotates off axis by 20 degrees. [99]

Lens misalignment of more than 30 degrees effectively increases the net astigmatic error. [100]

Thus, an accurate complete curvilinear capsulorhexis, stable IOL fixation in the capsular bag and removal of the entire OVD are imperative to avoid IOL rotation.[61]

Patel et al proved that the plate haptic design rotates more than the loop haptic deign in the early post-operative period. Also, loop haptic turn anti – clockwise after a duration of 2 weeks. [67]

Complications of toric IOL implantation:

During surgery any complication such as zonular damage, loss of vitreous, capsulorrhexis tear or posterior capsular rupture, which might lead to a compromise in

the rotational stability of the IOL may warrant the modification to a standard non-toric IOL implantation. [63]

Contraindications of toric IOL implantation :

Although toric IOLs are highly efficacious in correcting regular astigmatism, they have been shown to be useful in cases of irregular corneal astigmatism due to conditions like keratoconus, pellucid marginal degeneration , corneal scars and post keratoplasty. However. they should be considered only in patients having mild to moderate amounts of irregular astigmatism who would need further spectacle correction for an optimal visual outcome. Toric IOLs are an unsuitable option for patients requiring rigid gas permeable contact lenses to correct severe amounts of irregular astigmatism. [60 77 79]

Patients having corneal dystrophy are not ideal candidates for toric IOL implantation as they might have to undergo keratoplasty subsequently. [101]

Toric IOLs should not be implanted in patients having zonular instability, trauma induced zonulolysis, pseudoexfoliation syndrome and posterior capsular dehiscence as they lack a stable capsular bag - IOL complex is essential to ensure rotational stability of the IOL. [102]

Poor pupillary dilatation is also a relative contraindication as it may hamper visibility of alignment marks located in periphery of toric IOL. [87]

Patients having history of previous vitreo retinal procedures , scleral buckling and glaucoma drainage surgeries might not get optimal results from toric IOL implantation owing to the primary pathology and surgically induced changes in the

anatomical configuration. Surgeons are now routinely considering the refractive result of surgery when in planning stages. [99]

Piggy back toric IOLs:

These are a combination of two toric IOLs. They can be used to reduce high degrees of pre existing astigmatism. The major drawback being the amount of rotation that significantly affects the cylindrical correction. [100]

ENHANCEMENT TECHNIQUES:

Although current methods to reduce pre-existing astigmatism such as limbal relaxing incisions (LRIs) and toric IOLs can effectively decrease corneal astigmatism during cataract surgery, the patient may still have postoperative residual spherical or astigmatic refractive error that causes symptoms warranting further correction.[101]

Spectacles and contact lenses:

The simplest way to manage residual refractive error is by using spectacles or contact lenses. Some patients might find it difficult to adapt to spectacle correction as it causes meridional anisokinesia causing a problem with binocular vision. Contact lenses are a better alternative. However horizontal steepening and superior wound gaping can cause inferior riding of lens.[102]

Laser vision correction:

Residual refractive error can be optimally managed through laser vision correction as most patients achieve excellent uncorrected visual acuity. Photorefractive keratectomy (PRK) and laser in situ keratomileusis (LASIK) are both

highly accepted procedures for correcting different degrees and types of ametropia including astigmatism. [103]

Laser vision enhancement techniques can be done 3 months after primary surgery even though refractive stability occurs one month postoperatively without any concern about wound dehiscence.

LASIK enables a quick visual recovery compared to PRK. However, PRK can be considered in cases having thin corneas , anterior basement membrane dystrophy and suspicious topographic patterns.

Baharozian CJ et al concluded that arcuate incisions made using transepithelial femtosecond laser using Donnefield nomogram showed potential for management of mild to moderate corneal astigmatism. They made a 9.0 mm optical zone having 80% depth, over the limbus. They also modified the manual Donnenfeld limbal relaxing incision nomogram to 70% for with-the-rule (WTR), 80% for oblique (OBL), and 100% for against-the-rule (ATR) astigmatism. To further improve refractive accuracy, a reduction in the size of the optical zone or an increase in the magnitude can be implemented for the treatment of WTR and ATR astigmatism using this nomogram. [102]

Management of astigmatism by step ladder approach:

Arzu Taskiran Comez et al described the various techniques available for correction of astigmatism during cataract surgery and concluded that either one or a combination of procedures can be selected according to the patient requirement to correct preexisting astigmatism. [103]

Mukesh Taneja reviewed methods for management of astigmatism in cataract surgery and concluded that the technique should be selected depending on the magnitude of preexisting astigmatism, skill and familiarity of the surgeon regarding the procedure. [104]

Eric C, Amesbury and Kevin M. Miller reviewed the various options to correct astigmatism during phacoemulsification and found incision on steep meridian is sufficient to correct small amount of astigmatism and higher amounts of astigmatism require relaxing incisions on the cornea or at the limbus. On the other hand, toric IOLs are a safe an effective method for correction of more than 1 D of astigmatism. [105]

Amount of corneal astigmatism	Treatment
<1 D	Phaco incision on steep axis
1 – 1.5 D	Paired opposite clear corneal incision
1 – 3 D	Limbal relaxing incision
1 – 4 D	Toric IOLs
4 – 7 D	High powered Toric IOLs or combination of toric IOLs with LRI or bioptics

FIGURE NO – 5: STEP LADDER APPROACH TO ASTIGMATISM

METHODOLOGY

The present study was conducted at the Department of Ophthalmology, KLES Dr. Prabhakar Kore Hospital and Medical Research Centre, Belagavi on patients who underwent phacoemulsification cataract surgery with implantation of toric intraocular lens for correction of moderate to severe degree of pre-existing corneal astigmatism.

Source of Data: All the patients with cataract and pre-existing astigmatism of 1D or more undergoing phacoemulsification with foldable IOL at KLES Dr. Prabhakar Kore Hospital and Medical Research Centre, Belagavi.

METHOD OF DATA COLLECTION:

STUDY DESIGN: A one-year prospective interventional study

STUDY PERIOD: One year – January 2018 – December 2018

SAMPLE SIZE: A sample size of 34 cases

SAMPLING PROCEDURE: The minimum sample size formula based on mean and standard deviation is

$$n = \frac{(z_\alpha + z_\beta)^2 (s_1^2 + s_2^2)}{(\bar{x}_1 - \bar{x}_2)^2}$$

where

$z\alpha$ is linked with the level of significance

$z\beta$ is linked with the power of the test

For 5% level of the significance $z\alpha = 1.96$ and $z\beta = 0.84$ for 80% power of the test

$\bar{x}_1$ is the mean of the first group (1.6) and

$\bar{x}_2$ is the mean of the second group (0.9).

s1 is the standard deviation of the first group (0.75)

s2 is the standard deviation of the second group (0.65).

With these values the sample size obtained is 16.

Selection criteria:

Inclusion criteria

- Patients with pre-senile / senile cataract with pre-existing astigmatism of 1 D or more undergoing phacoemulsification surgery with foldable posterior chamber IOL implantation at KLES Dr. Prabhakar Kore Charitable Hospital and MRC, Belagavi.
- Age group between 40 to 80 years
- Patients with cataract from grade 1 to grade 3 nuclear sclerosis
- Pre-existing corneal astigmatism of 1 D or more
- 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:

Ethical clearance was obtained from 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 their written informed consent was taken by the investigator.

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

Detailed history of the following symptoms was noted:

H/O Diminution of vision in 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 spectacle use

- H/o hypertension / diabetes / cardiac illness

History taking was followed by ocular examination which included:

- Visual acuity testing using Snellen's chart
- Ocular examination proper (Adnexa, conjunctiva, cornea, Anterior chamber, iris. pupil and lens)
- Detailed slit lamp bio microscopy for grading of cataract as:

  Cortical cataract

  Nuclear cataract

  Posterior Subcapsular cataract
- Schiotz 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 lab investigations included were:

- Routine hemogram
- Diabetic status

The study included 34 patients, all underwent phacoemulsification surgery with implantation of toric IOL, performed by a single surgeon using the same standard technique.

All the cases were operated under local anesthesia following aseptic precautions.

Surgical technique:

- Preoperative measures such as consent for surgery, antibiotic eye drops, dilatation of pupil was done.
- The axis of toric IOL alignment is marked using desired astigmatic marker before anesthesia with the patient sitting upright at the slit lamp.
- Peribulbar block was given
- The eye was painted and draped
- Eyelids retracted using universal eye speculum
- Side ports made using 1.2 mm side – port blade depending on the incision site
- Anterior chamber was filled with viscoelastic material
- Continuous curvilinear capsulorrhexis was done using a modified cystitome
- A clear corneal self-sealing incision was made using a 3.2 mm keratome on the meridian predecided based on the toric nomogram
- Hydrodissection and hydrodelination was done to separate the capsule and nucleus and free rotation of the nucleus was ensured
- Phacoemulsification was done by chip and flip or by stop and chop procedure

- Epinuclear plate was removed
- Bimanual irrigation and aspiration was done to remove the cortex
- Following this, capsular polishing was done
- Astigmatic ring is placed over the cornea
- Depending upon the desired alignment of toric IOL the axis is marked
- A hydrophobic aspheric square edge acrylic foldable toric IOL (ACRIOL EC TORIC LENS) of desired power based on nomogram calculations is inserted through the incision
- The marks on the toric IOL indicate the flat meridian or plus cylinder axis of the toric IOL and were aligned with the marked alignment axis.
- First, gross alignment was achieved by rotating the IOL clockwise while it was unfolding, until approximately 5 to10 degrees short of the desired position.
- After the ophthalmic viscosurgical device was completely removed, the IOL was rotated to its final position by exact alignment of the reference marks on the toric IOL with the alignment axis marks.
- The clear corneal wound was sealed by hydration
- Eye was padded and bandaged after intracameral antibiotic injection
- Postoperatively all patients received:
- Topical antibiotic and steroid combination 6 times / day for 1 week tapering the dose every week for one month
- Systemic antibiotics ie : Oral Levofloxacin 500 mg OD given for 3 days
- Postoperative assessment of the patient was done on 1st day, 1 week and 6 weeks postoperatively.

Ocular examination during follow- up involved assessing:

- Visual acuity
- Wound sealing
- Corneal clarity
- Intraocular lens placement
- Fundus visibility
- Refraction was done at 1 week and 6 weeks postoperative visit

Statistical analysis: Paired ‘t’ test was used for calculation of the results

RESULTS

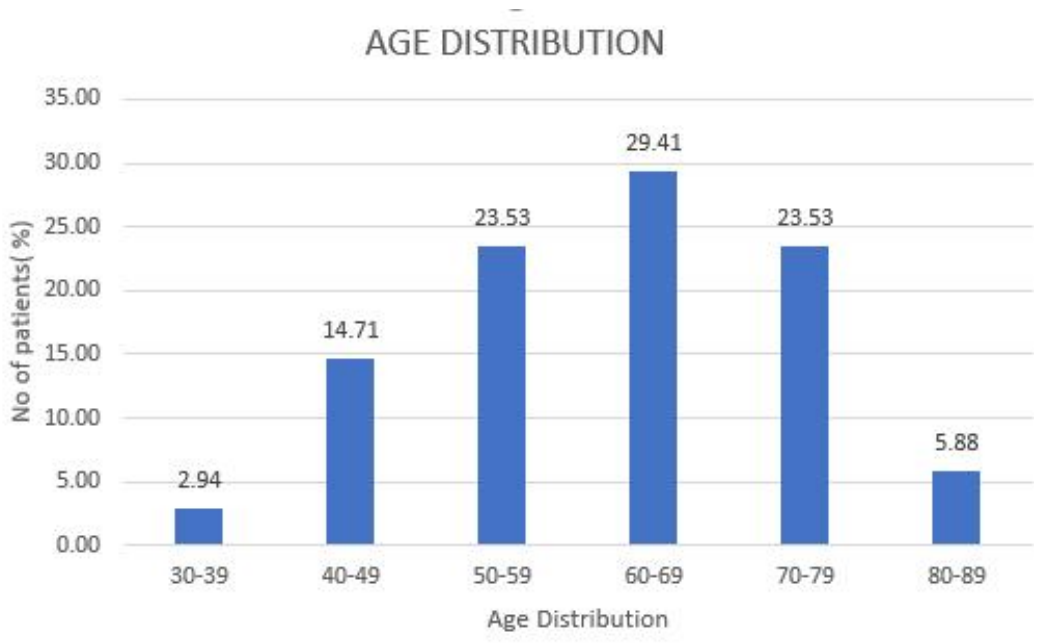
The present study was conducted on 34 eyes that underwent phacoemulsification at the Department of Ophthalmology, KLES Dr. Prabhakar Kore Charitable Hospital and Medical Research Centre, Belagavi during the study period. It included patients having > 1 Diopters (D) of pre-existing corneal astigmatism who were implanted a toric intraocular lens during phacoemulsification.

Pre – 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 Alpins method of vector analysis.

Table No 1: Age Distribution

AGE IN YEARS	NUMBER OF PATIENTS	PERCENTAGE (%)
30-39	1	2.94
40-49	5	14.71
50-59	8	23.53
60-69	10	29.41
70-79	8	23.53
80-89	2	5.88
TOTAL	34	100

Graph no 1: Age Distribution

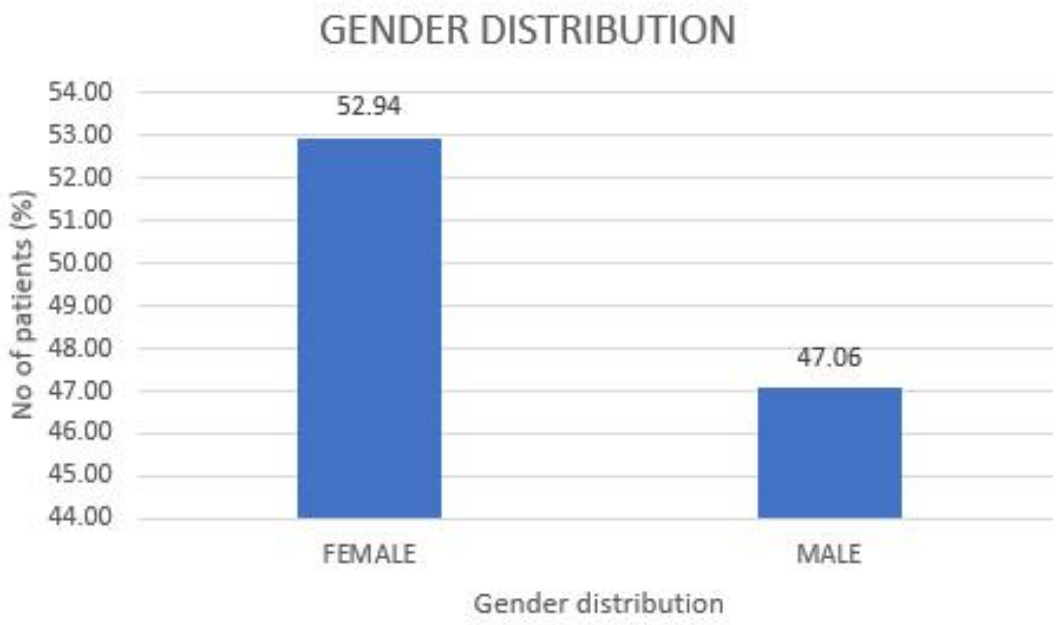


In the present study, the mean age was 61.15 ± 12.08 years. Most patients belonged to the range of 61-70 years.

Table no 2: Gender Distribution

GENDER	NUMBER OF PATIENTS	PERCENTAGE (%)
MALE	**18**	**52.94**
FEMALE	**16**	**47.06**
TOTAL	**34**	**100**

Graph no 2: Gender Distribution

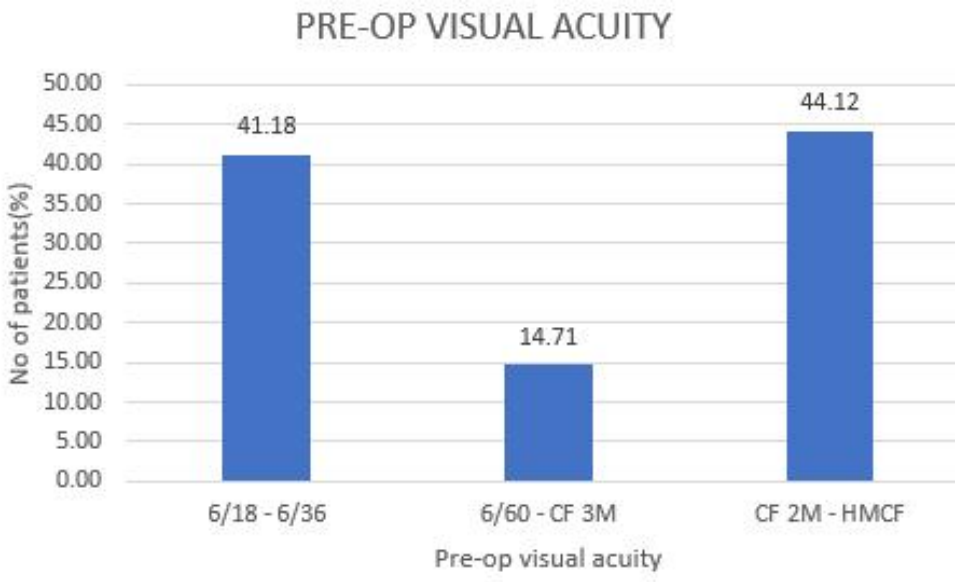


In the present study, 47.06 % (16) patients were male and 52.94 % (18) patients were female with male : female ratio of 0.89:1.

Table No 3: Pre – operative Visual Acuity

PRE-OP VISUAL ACUITY	NUMBER OF PATIENTS	PERCENTAGE (%)
6/18-6/36	**14**	**41.18**
6/60-CF 3M	**5**	**14.71**
CF 2M- HMCF	**15**	**44.12**
TOTAL	**34**	**100**

Graph no 3: Pre-operative Visual Acuity

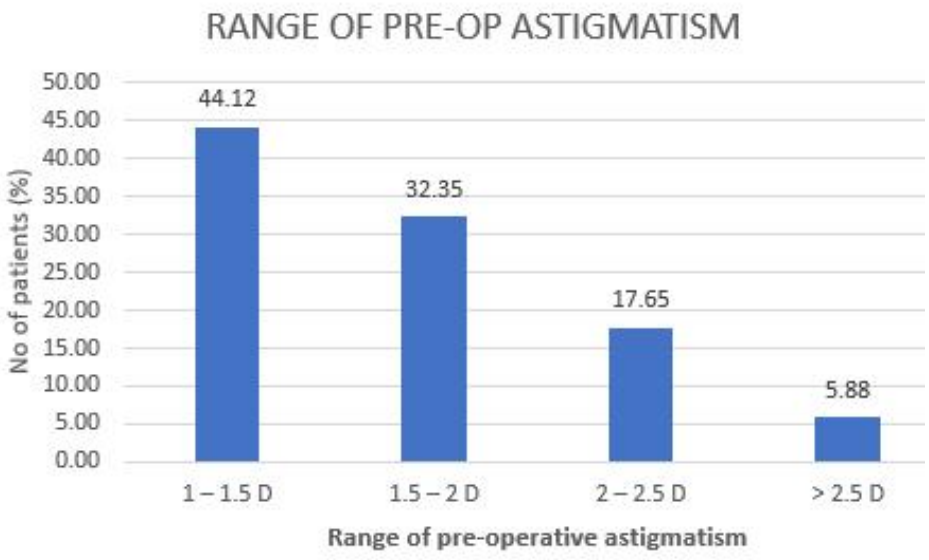


In the present study, pre-operative visual acuity in the range of 6/36 to 6/18 was seen in 41.18 % (14) patients, 6/60 to CF 3M in 14.71 % (5) patients and CF 2M to HMCF in 44.12 % (15) patients.

Table no 4: Range of pre-existing astigmatism

PRE-OP ASTIGMATISM	NUMBER OF PATIENTS	PERCENTAGE (%)
1-1.5 D	**15**	**44.12**
1.5-2 D	**10**	**32.35**
2-2.5 D	**6**	**17.65**
>2.5 D	**3**	**5.88**
TOTAL	**34**	**100**

Graph no 4: Range of pre-existing astigmatism

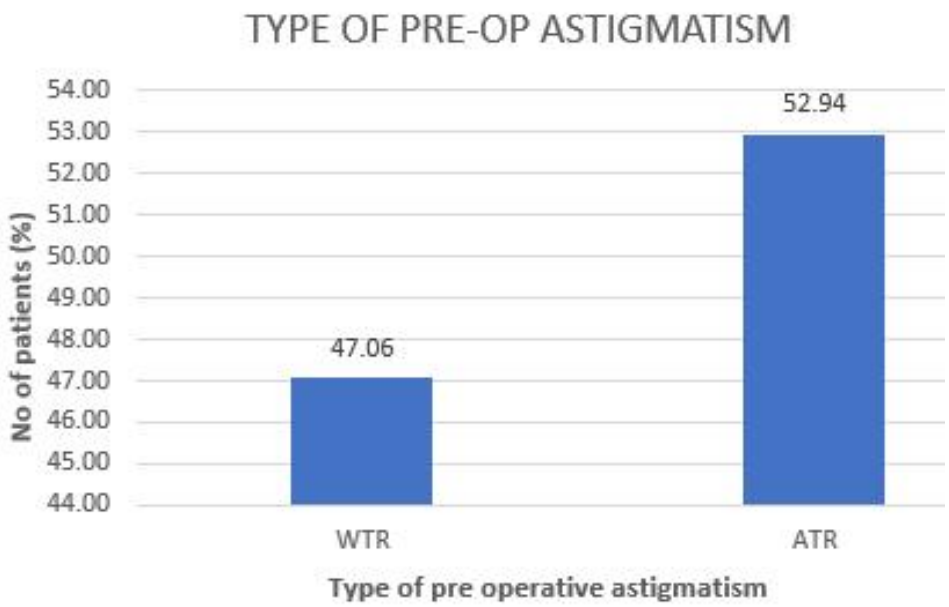


In this study, range of pre-existing astigmatism between 1 - 1.5 D was seen in 44.12 % (15) patients, 1.5 - 2 D in 32.35 % (10) patients, 2 - 2.5 D in 17.65 % (6) patients and more than 2.5 D in 5.88 % (3) patients.

Table no 5: Type of pre-existing astigmatism

TYPE OF ASTIGMATISM	NUMBER OF PATIENTS	PERCENTAGE (%)
WITH THE RULE (WTR)	**16**	**47.06**
AGAINST THE RULE (ATR)	**18**	**52.94**
TOTAL	**34**	**100**

Graph no 5: Type of pre-existing astigmatism



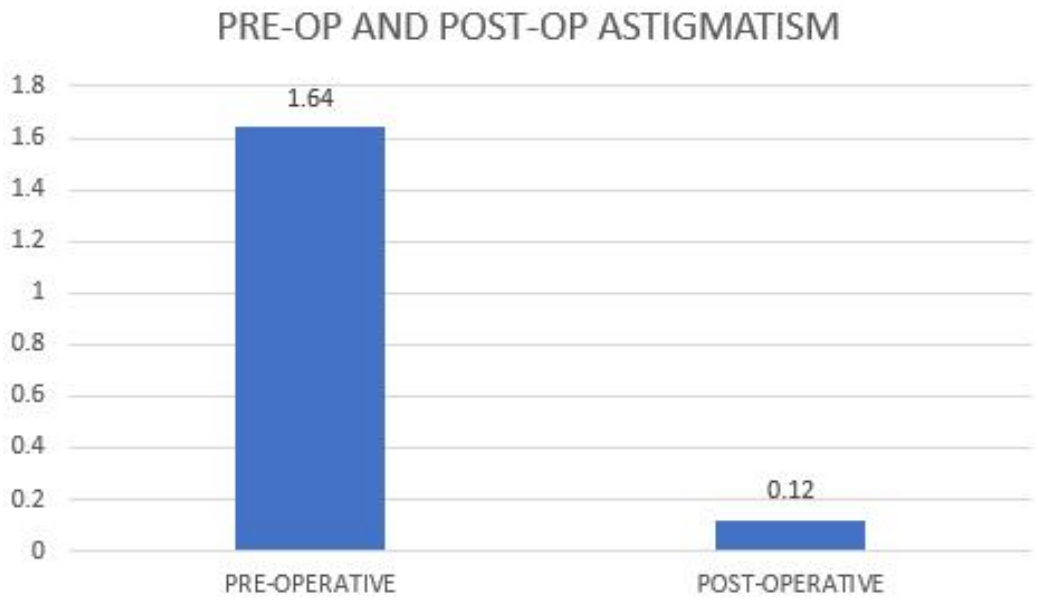
In this study, 47.06 % (16) patients had WTR astigmatism and 52.94 % (18) patients had ATR astigmatism

A significant reduction in the magnitude, but no variation in the type of astigmatism was seen in cases post operatively.

Table no 6: Mean pre-operative and post-operative astigmatism

ASTIGMATISM	MEAN	SD
PRE-OPERATIVE	**1.64**	**0.12**
POST-OPERATIVE	**0.12**	**0.06**

Graph no 6: Mean pre-operative and post-operative astigmatism



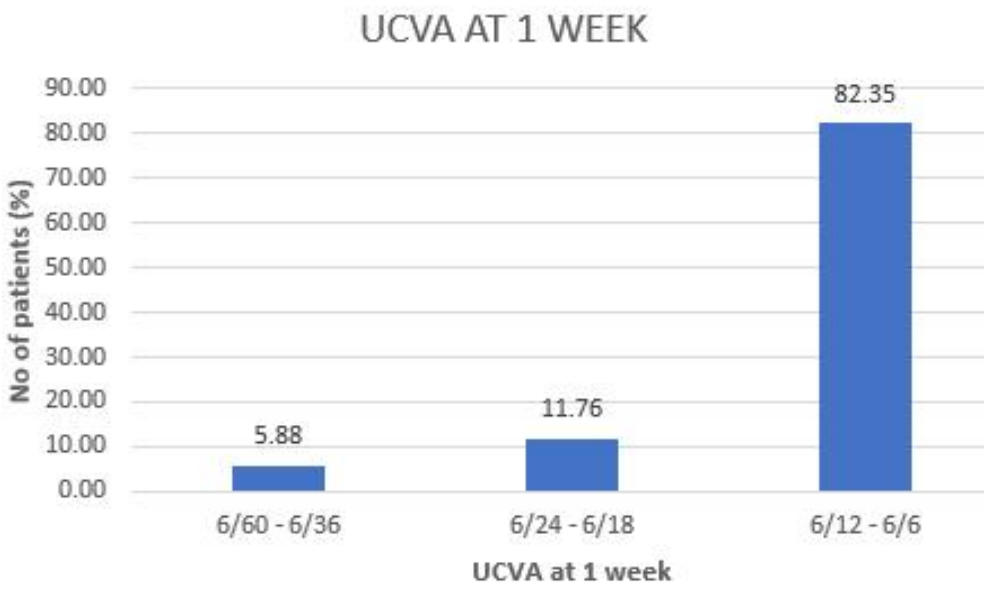
In the present study, mean pre – operative astigmatism was 1.64 ± 0.12 D and post – operative astigmatism was 0.12 ± 0.06 D.

The reduction in astigmatism has p value < 0.0001 which is highly statistically significant.

Table no 7: Post-operative uncorrected visual acuity at 1 week

UCVA	NUMBER OF PATIENTS	PERCENTAGE
6/60-6/36	**2**	**5.88**
6/24-6/18	**4**	**11.76**
6/12-6/6	**28**	**82.35**
TOTAL	**34**	**100**

Graph no 7: Post-operative uncorrected visual acuity at 1 week

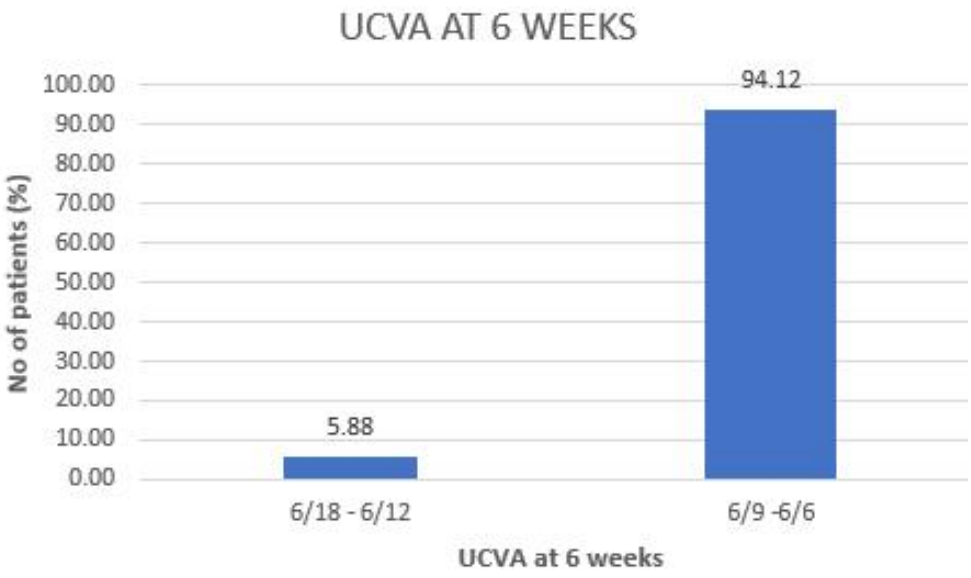


In our study, 1 week post-operatively 5.88 % (2) patients had uncorrected visual acuity ranging from 6/60 – 6/36, 11.76 % (4) patients had uncorrected visual acuity ranging from 6/24 – 6/18, 82.35 % (28) patients had visual acuity ranging from 6/12-6/6.

Table no 8: Post-operative uncorrected visual acuity at 6 weeks

UCVA	NUMBER OF PATIENTS	PERCENTAGE (%)
6/18-6/12	**2**	**5.88**
6/9-6/6	**32**	**94.12**
TOTAL	**34**	**100**

Graph no 8: Post-operative uncorrected visual acuity at 6 weeks

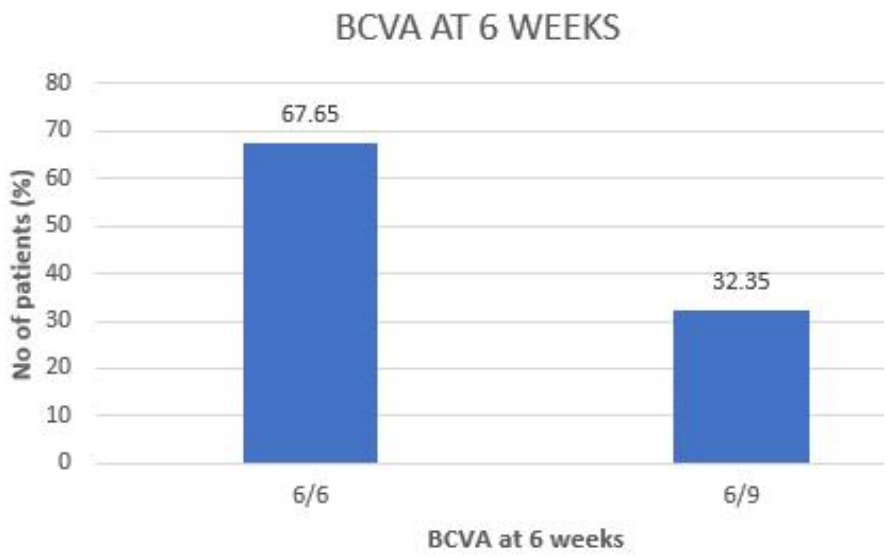


In the present study, uncorrected visual acuity 6 weeks post-operatively was 6/18-6/12 in 5.88 % (2) patients and 6/9-6/6 in 94.12 % (32) patients.

Table no 9: Best corrected visual acuity at 6 weeks

BCVA	NUMBER OF PATIENTS	PERCENTAGE
6/9	**11**	**32.35**
6/6	**23**	**67.65**
TOTAL	**34**	**100**

Graph no 9: Best corrected visual acuity at 6 weeks



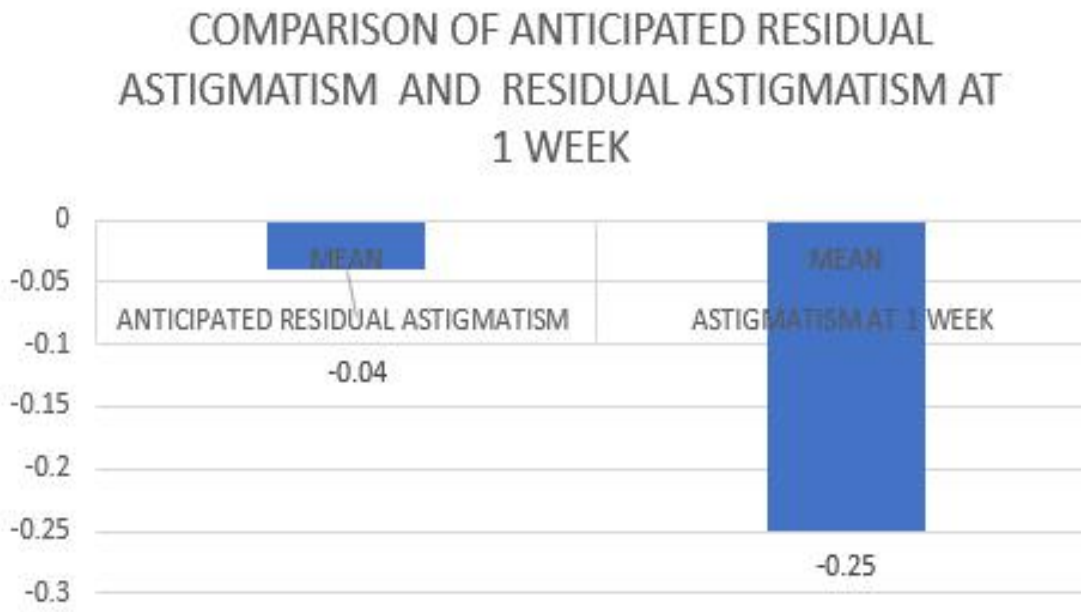
In the present study, best corrected visual acuity 6 weeks post operatively was 6/9 in 32.35 % (11) patients and 6/6 in 67.65 % (23) patients.

Spectacle freedom for distance viewing was achieved in 59 % of patients 6 weeks postoperatively. While, all 34 cases were given near vision correction 6 weeks postoperatively.

Table no 10: Anticipated residual astigmatism and residual astigmatism at 1 week

ANTICIPATED RESIDUAL ASTIGMATISM		ASTIGMATISM AT 1 WEEK			
MEAN	**S.D.**	**MEAN**	**S.D.**	**pVALUE**	**INFERENCE**
-0.04	**0.14**	**-0.25**	**0.87**	**0.1292**	**NOT SIGNIFICANT**

Graph no 10: Anticipated astigmatism and residual astigmatism at 1 week

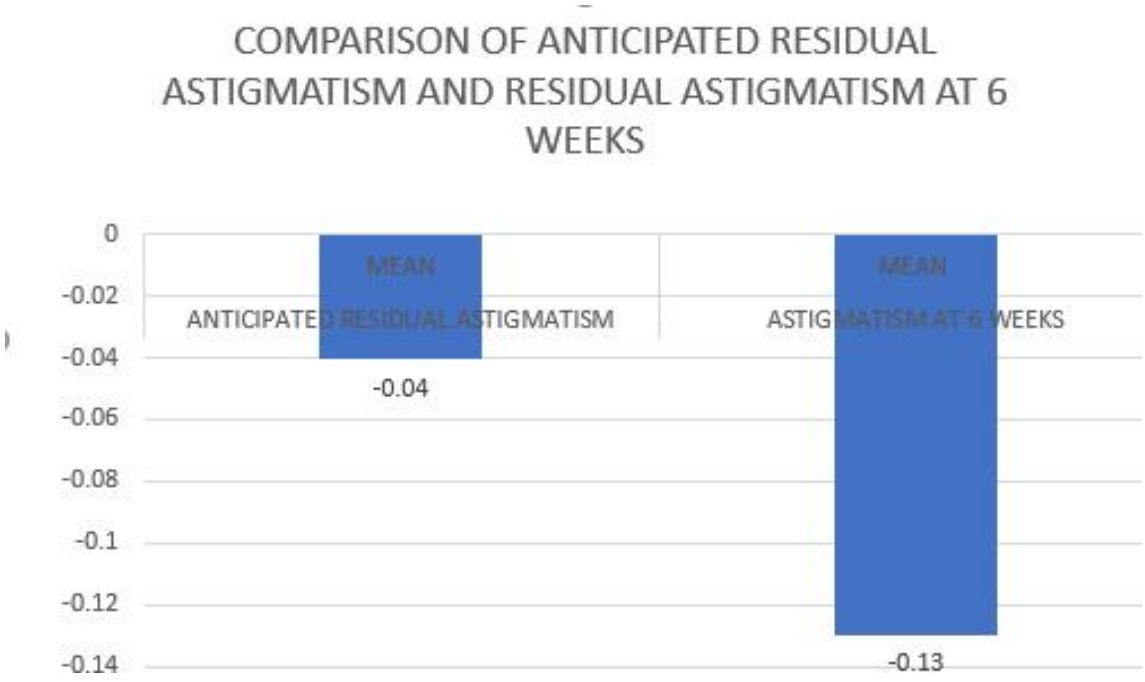


The mean of anticipated astigmatism and astigmatism achieved at 1 week was -0.04 ± 0.14 and -0.25 ± 0.87 respectively, p value < 0.122 which is not statistically significant.

Table no 11: Anticipated residual astigmatism and residual astigmatism at 6 weeks

ANTICIPATED RESIDUAL ASTIGMATISM		ASTIGMATISM AT 6 WEEKS			
MEAN	**S.D.**	**MEAN**	**S.D.**	**pVALUE**	**INFERENCE**
-0.04	**0.14**	**-0.13**	**0.39**	**0.2179**	**NOT SIGNIFICANT**

Graph no 11: Anticipated astigmatism and residual astigmatism at 6 weeks



The mean anticipated residual astigmatism and astigmatism achieved at 6 weeks postoperatively was -0.04 ± 0.14 and -0.13 ± 0.39 respectively, p value < 0.2179 which is not statistically significant.

DISCUSSION

Over the past few decades a paradigm shift has been noted in methods for management of postoperative astigmatism. There has been tremendous development in the field of cataract surgery over the past decades. 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

Following the introduction of phacoemulsification through a small clear corneal incision and foldable intraocular lens, the objective of cataract surgeons has changed from mere cataract extraction to reduction of surgically induced astigmatism and rectification of any pre-existing astigmatism. Thus, cataract surgery today can be modified as a 'Refractive Cataract Surgery'. The correction of corneal astigmatism during cataract surgery has now gained widespread popularity.

Patient satisfaction and early visual rehabilitation of patients who undergo phacoemulsification depends on two factors. The implantation of appropriate IOLs and postoperative astigmatism. After phacoemulsification surgery, corneal astigmatism contributes largely to the residual refractive error. Assessment of corneal curvature and astigmatism pre-operatively aids in choosing the most suitable method for reduction of pre-existing astigmatism.

Pre-existing astigmatism can be reduced through different incisional techniques and implantation of intraocular lenses.

Astigmatism of less than 1D is not considered a significant impediment for achieving emmetropia. Uncorrected corneal astigmatism leads to a corresponding manifest refractive cylinder after surgery

Toric IOL implantation has the following advantages over methods involving incisions over the cornea namely, the ability to reduce induced astigmatism as a result of corneal manipulation and it has the alternative of being reversible.

Ascertaining the ideal meridian for toric IOL alignment is integral to providing the best possible visual outcomes for patients undergoing cataract surgery with implantation of these IOLs. Also, accurate evaluation of IOL power, IOL placement and IOL rotational stability are integral to achieving good results following toric IOL implantation.

The present study was conducted on 34 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 2018 – December 2018. It included patients having ≥ 1 Diopters (D) of pre-existing corneal astigmatism. All patients were implanted a toric intraocular lens after phacoemulsification based on a pre-operative astigmatism evaluation and a nomogram calculation.

In the present study, the mean age was 61.15 ± 12.08 years. Most patients belonged to the range of 61-70 years as cataract is more common at this age group. This was comparable to the study conducted by Farooqui et al [7], Miyake et al[79] and Ferrer-Blasco et al.[80]

Male: Female ratio was 0.89: 1. Even though, gender distribution was co-related between the groups, it did not have any effect on the postoperative results.

In our study 41.18 % (14) patients had pre-operative visual acuity in the range of 6/36 to 6/18 and 14.71 % (5) patients and 44.12 % (15) patients had pre-operative visual acuity in the range of 6/60 to CF 3M and CF2M to HMCF respectively as cases up to grade III nuclear sclerosis were taken excluding hard/brown cataract.

Studies conducted by Leyland et al and Kaur et al included patients presenting with nuclear sclerosis of similar grades and having visual acuity of 6/60 or worse.[62 63]

Also, SIA in all cases was uniform at 0.5 as all cases were performed by a single surgeon.

No cases were lost to follow up in our study.

Pre-operative and postoperative astigmatism:

Our study included patients with pre-existing astigmatism of ≥ 1D who underwent phacoemulsification with toric intraocular lens implantation. In this study range of pre-existing astigmatism between 1 - 1.5 D was seen in 44.12 % (15) patients, 1.5 - 2 D in 32.35 % (10) patients, 2 - 2.5 D in 17.65 % (6) patients, more than 2.5 D in 5.88 % (3) patients.

A study conducted by Ninn Penderson K[19] et al suggested that greater preoperative astigmatism and young age were both essential predisposing factors for rapid changed in postoperative astigmatism.

In our study, mean pre-operative astigmatism of 1.64 ± 0.80 and mean residual astigmatism of -0.13 ± 0.39 ($p < 0.0001$) was achieved at a follow up period of 6

months, this was statistically highly significant. Thereby concluding that toric IOL implantation is an effective method for correction of pre-existing astigmatism.

In a study conducted by Farooqui et al, patients having more than 1.50 D of pre-existing astigmatism were included. The mean preoperative cylinder was 2.54±0.90 and mean residual astigmatism was 0.57±0.28 during the final follow-up of 3 months (p = 0.00) this reduction in astigmatism was statistically significant.[7]

In a similar study conducted by Bauer et al, patients having more than1.50 D of astigmatism preoperatively were included. 74 % of eyes had less than 0.75 D and 91 % eyes had less than 1.00 D of residual astigmatism at a follow up period of 4 months.[7]

Out of the total 34 eyes evaluated in this study, 47.06 % (16) of patients had WTR astigmatism ($K_v > K_H$) and 52.94 %(18) had ATR astigmatism($K_H > K_V$). We compared the change from pre-operative to postoperative astigmatism and concluded that 16 patients having WTR astigmatism, all continued to remain so post-operatively with less magnitude. The other 18 patients having ATR astigmatism. all continued to remain so post-operatively with less magnitude.

Reduction in astigmatism at 1 week and 6 weeks:

In the present study, on implantation of toric IOL, anticipated residual astigmatism as calculated by the toric nomogram was -0.04 ± 0.14 and the mean residual astigmatism achieved at 1 week and 6 weeks postoperatively was -0.25 ± 0.87 (p value <0.1292) and -0.13 ± 0.39 (p value <0.2179) respectively, both of which are not statistically significant.

Thus, concluding that no significant difference was seen between the residual astigmatism devised by the nomogram implemented for the calculations and that reported at 1 and 6 weeks post operatively. Establishing that expected amount of residual astigmatism can be achieved using this toric nomogram. Hence, proving that toric IOL implantation is a highly efficacious method to reduce pre-existing corneal astigmatism during phacoemulsification surgery.

Uncorrected visual acuity and best corrected visual acuity:

In our study, 1 week post-operatively 5.88 % (2) patients had uncorrected visual acuity ranging from 6/60 – 6/36, 11.76 % (4) patients had uncorrected visual acuity ranging from 6/24 – 6/18, 82.35 % (28) patients had visual acuity ranging from 6/12-6/6.

At 6 weeks post operatively, 5.88 % (2) patients had uncorrected visual acuity ranging from 6/18 – 6/12 and 94.12 % (32) patients had uncorrected visual acuity ranging from 6/9 – 6/6. At follow up period of 6 weeks, due to uveitis and corneal edema visual acuity in the range of 6/60 – 6/36 and 6/24 – 6/18 was seen in two and four patients respectively.

Best corrected visual acuity 6 weeks postoperatively was 6/9 in 32.35 % (11) patients and 6/6 in 67.65 % (23) patients respectively.

In a study conducted by Ruhswurm et al, 34 patients (91.9%) a best corrected visual acuity of 0.5 (20/40) 6/12 or better. [49]

In a comparative study conducted by Holland et al, one year postoperatively, uncorrected distance visual acuity of 20/20 (6/6) or better was reported in 40.7% (Toric IOL) versus 19.4% (standard IOL; $p < 0.05$). While, 77 % of Toric IOL group

had best corrected distance visual acuity of ≥ 20/20 versus 6.2 % in standard IOL group.[69]

Ferreria et al implanted toric IOL in patients having 1.00 – 4.50 D of regular astigmatism, 4 months postoperatively, UDVA was 0.3 logMAR (6/12) or better in 50 eyes (98%) and 0.1 logMAR (6/6) or better in 42 eyes (82%).[80]

Farooqui et al implanted toric IOLs in patients having more than 1.50 D of pre-existing corneal astigmatism, on post-op day 1 the mean log MAR UCVA was 0.172 ± 0.02 (6/36), on 7th post-op day was 0.138 ± 0.11(6/24), and on 30th post-op day was 0.081 ± 0.11(6/9). A statistically significant improvement in UCVA was seen between day 1(baseline) and day 7 (p = 0.009)

Also, on comparison of UCVA on day 30 with day 7 and day 1 respectively, reduction of UCVA was statistically significant (p = 0.00) The mean log MAR BCVA at three months was 0.04 ± 0.76 (6/6).[7]

In a prospective study conducted by Ahmad et al, patients having astigmatism in the range of 1.00 – 2.50 D underwent bilateral toric IOL implantation. 6 months postoperatively binocular UDVA was 20/40 (6/12) or better in 99 % of patients and 20/20 (6/6) or better in 63 % of patients.[67]

Thus, postoperative visual outcome among all the studies quoted above correlate with those achieved in our study.

Spectacle independence:

In the present study 59 % patients had spectacle independence.

Holland et al reported 6month spectacle freedom of 61 % patients in Toric IOL group and 36.4 % patients in control IOL group; p <0.0001.[69]

In a study conducted by Ahmad et al, 69 % patients reported never using spectacle correction for distant viewing. Thus, concluding that toric IOL implantation yielded stable visual outcomes resulting in high patient satisfaction.[67]

Limitations of the study:

All cases in the present study were followed up for a duration of 6 weeks, while most other studies have followed up their patients up to 3 months. IOL rotation tends to decrease when anterior and posterior capsule fuses. The capsule fusion starts as early as 2 weeks and IOL rotation is barely seen after 3 months.

Unavailability of Scheimpflug imaging modality at our center was another limitation of our study, as it enhances the accuracy of total corneal astigmatism calculation and efficacy of toric IOL correction by calculating amount of astigmatism of anterior and posterior surface of the cornea. Neglecting posterior corneal astigmatism can lead to overcorrection of WTR astigmatism and under correction of ATR astigmatism.

Rotation or misalignment of toric IOL:

Toric IOL rotation was assessed in all patients, 1 week and 6 weeks postoperatively using a dilated slit lamp examination method. No case had significant IOL rotation within 30 degrees of rotation. Several studies have reported a correlation between capsular bag diameter and increasing axial length, stating that chances of early rotation are more in longer myopic eyes.[103]

No complication was reported in our study, in accordance to studies by Ruhswurm et al[61]and Kaur M et al [63] who reported complete rotational stability and no complications affecting net residual astigmatism using foldable toric IOLs.

The present study concluded that implantation of toric intraocular lens for correction of more than 1 D of pre-existing corneal astigmatism is a safe and highly effective method ensuring optimal visual outcomes and spectacle independence.

CONCLUSION

The present study was conducted on 34 eyes who 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 2018 – December 2018.

It included patients having ≥ 1 Diopters (D) of pre-existing corneal astigmatism. All patients were implanted a toric intraocular lens after phacoemulsification based on a pre-operative astigmatism evaluation and a nomogram calculation.

The following conclusions were drawn from the study:

- The mean pre-operative astigmatism was 1.64 ± 0.80 and residual astigmatism achieved at 6 weeks follow up was -0.13± 0. 39 ($p < 0.0001$) which was highly statistically significant.
- In the present study, the anticipated residual astigmatism as calculated by the toric nomogram was -0.04 ± 0.14 and the mean residual astigmatism achieved at 1 week and 6 weeks postoperatively was -0.25 ± 0.87 (p value <0.1292) and -0.13 ± 0.39 (p value <0.2179) respectively, both of which are not statistically significant.

Thus, concluding that no significant difference was seen between the residual astigmatism devised by the nomogram implemented for the calculations and that reported at 1 and 6 weeks post operatively. Establishing that expected amount of residual astigmatism can be achieved using this toric nomogram. Hence, proving that

toric IOL implantation is a highly efficacious method to reduce pre-existing corneal astigmatism during phacoemulsification surgery.

The number of patients having WTR and ATR astigmatism was 47.06 % and 52.94 % respectively. The type of astigmatism after toric IOL implantation was of less magnitude, but remained of the same type in all the cases.

- The uncorrected visual acuity after toric IOL implantation 1 week postoperatively, in the range of 6/12- 6/6 was seen in 82.35 % of patients and at 6 weeks postoperatively, in the range of 6/9-6/6 was seen in 94.12 % of patients. Thus, there is a significant improvement in visual acuity outcome at 6 weeks.
- On refractive assessment of patients, spectacle freedom for distance viewing was achieved in 59 % of patients. While, all patients were given near vision correction of + 2.5 to compensate for loss of accommodation seen in pseudophakic eyes.
- The best corrected visual acuity of 6/9 was seen in 32.35 % 6 weeks post operatively.
- The best corrected visual acuity of 6/6 was seen in 67.65 % of patients at 6 weeks post operatively.

At the follow up period of 6 weeks, uncorrected visual acuity of 6/6 was seen in 44 % of patients, on performing refractive assessment visual acuity of 6/6 was seen in 67.65 % of patients. Thus, on comparing visual acuity at 1 and 6 weeks, a definite improvement was seen.

In conclusion, toric IOL implantation is a reliable and satisfactory method for ensuring good visual outcome in correction of ≥ 1 D of pre-existing corneal astigmatism in patients undergoing phacoemulsification surgery.

SUMMARY

Cataract surgery has significantly evolved from 600 BC to the present day. From couching in ancient times to modern day manual SICS and phacoemulsification through a small clear corneal incision and foldable intraocular lens implantation, the aim has shifted from reduction of surgically induced astigmatism to correction of pre-existing astigmatism.

Various techniques have been described for the correction of astigmatism during cataract surgery like incision on steep meridian, limbal relaxing incisions, toric intraocular lens and laser vision correction. The purpose of this study is to correct moderate to severe of pre-existing corneal astigmatism and to assess the safety, efficacy, post-operative refractive outcome and spectacle independence for distance viewing following implantation of toric IOLs in patients undergoing phacoemulsification surgery.

The present one year observational study was conducted at the Department of Ophthalmology, KLES Dr. Prabhakar Kore Hospital and Medical Research Centre, Belagavi on patients having >1 D (diopter) of pre-existing corneal astigmatism, who underwent phacoemulsification cataract surgery with implantation of toric intraocular lens during the period of January 2018 – December 2018. They were evaluated at 1 day, 1 week and 6 weeks postoperatively.

In the present study, the mean age was 61.15 ± 12.08 years. Majority of patients were in the range of 61-70 years. Also, 47.06 % patients were male and 52.94 % patients were female with a male : female ratio of 0.89:1.

In this study, majority of patients had pre-operative visual acuity in the range of 6/36 to 6/18 in 41.18 %, 6/60 to CF 3M in 14.71 % and CF2M to HMCF in 44.12 % had pre-operative visual acuity in the range of 6/60 to CF 3M and CF2M to HMCF respectively.

In this study, range of pre-existing astigmatism between 1 - 1.5 D was seen in 44.12 % patients, 1.5 - 2 D in 32.35 % patients, 2 - 2.5 D in 17.65 % patients and more than 2.5 D in 5.88 % patients.

In the present study, mean pre-operative astigmatism of 1.64 ± 0.80 and mean residual astigmatism of -0.13 ± 0.39 ($p < 0.0001$) was achieved at a follow up period of 6 weeks, this was statistically highly significant. Thereby concluding that toric IOL implantation is an effective method for correction of pre-existing astigmatism.

In this study, 47.06 % of patients had WTR astigmatism and 52.94 % had ATR astigmatism. A significant reduction in the magnitude, but no variation in the type of astigmatism was seen in cases post operatively.

In the present study, 1 week post-operatively 5.88 % of patients had uncorrected visual acuity ranging from 6/60 – 6/36, 11.76 % had uncorrected visual acuity ranging from 6/24 – 6/18, 82.35 % had visual acuity ranging from 6/12-6/6. Also, uncorrected visual acuity 6 weeks post-operatively was 6/18-6/12 in 5.88 % and 6/9-6/6 in 94.12 % of patients.

In this study, best corrected visual acuity 6 weeks post operatively was 6/9 in 32.35 % and 6/6 in 67.65 % of patients. Spectacle freedom for distance viewing was achieved in 59 % of patients 6 weeks postoperatively and all patients were given a

near correction of + 2.5 to compensate for loss of accommodation seen in pseudophakic eyes.

In the present study, on implantation of toric IOL, anticipated residual astigmatism as calculated by the toric nomogram was -0.04 ± 0.14 and the mean residual astigmatism achieved at 1 week and 6 weeks postoperatively was -0.25 ± 0.87 (p value <0.1292) and -0.13 ± 0.39 (p value <0.2179) respectively, both of which are not statistically significant.

Thus, concluding that no significant difference was seen between the residual astigmatism devised by the nomogram implemented for the calculations and that reported at 1 and 6 weeks post operatively. Establishing that expected amount of residual astigmatism can be achieved using this toric nomogram.

Toric intraocular implantation is a effective and satisfactory method for ensuring optimal correction of moderate to severe degree of pre-existing astigmatism and good visual outcome in patients undergoing phacoemulsification surgery.

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ANNEXURE – I - INFORMED CONSENT

Title Of Research Study: CORRECTION OF MODERATE TO SEVERE DEGREE OF PRE-EXISTING CORNEAL ASTIGMATISM BY TORIC INTRAOCULAR LENS IMPLANTATION IN PATIENTS UNDERGOING PHACOEMULSIFICATION- A ONE YEAR HOSPITAL BASED PROSPECTIVE INTERVENTIONAL STUDY AT DR PRABHAKAR KORE CHARITABLE HOSPITAL AND MRC, BELAGAVI.

Principal Investigator:-

Dr. _____

Post Graduate Student,

Department Of Ophthalmology,

JNMC, Belgaum.

Guide:

Dr. _____

MBBS ,DOMS,DNB

Professor

Department of Ophthalmology,

JNMC, Belagavi.

Introduction and Purpose:- The following prospective observational study is being undertaken to assess the amount of pre-existing astigmatism which can be corrected and visual performance in patients undergoing phacoemulsification surgery for cataract. In order to enable the patient to have better visual outcome toric intraocular

lenses will be implanted. Toric IOLs on being positioned accurately can improve effectively correct pre-existing astigmatism.

Procedure: If you agree to be part of the research study, you will be asked the relevant history and will be subjected to relevant clinical examination and investigations.

Risk and Benefits: The risks associated with phacoemulsification surgery are applicable here. You will have the best possible corrected vision post cataract surgery by implantation of a toric IOl as it is the most preferred technique in correcting pre-existing astigmatism, considered superior even to incisional techniques practised widely.

Alternatives : Taking part in this study is voluntary. You may choose not to take part in this study.

If you decide to take part you can later change your mind and withdraw from the study. Your decision will not change the present or future health care or other services that you receive. The study doctor or sponsor may stop your participation in this study at any time. If you choose not to take part in the study, you will receive the standard treatment for patients with your condition.

Privacy and Confidentiality: All information collected about you during the course of this study will be kept confidential to the extent permitted by law. The code numbers will identify you in this research record. Information from this study may be published but your identity will be confidential in any publication.

Institution / Sponsor's policy: Does not apply to this research

Financial incentives for participation: You will not be paid / offered any gifts /incentives for participating in the study.

Authorization to publish the results: The results of the study would be forwarded to the KAHER, Belgaum as part of requirement towards the completion of MS degree, review and publishing.

In case of the queries during study or in future you may contact following persons,

1. Dr. Roopa Bellad
MBBS MD DCH
Chairman
J.N.M.C. Ethical
Committee
for Human Research
J.N.M.C., Belagavi
9448113403

CONSENT FORM

I voluntarily agree to take part in this study by signing below. I may withdraw at any time. I am not giving up any of my legal rights by signing this form. My signature below indicates that I have read this consent form, or it has been read to me, and I have had all the questions answered.

Signature / Left Thumb print of the Participant or legally authorized representative:

.....

Participant's name: …….....

Signature / Left thumb impression of the participant:

.....……...

Name of the legally authorized representative/guardian:

…….....……...

Signature / Left thumb impression:

.....……...

Witness' name:

.....……

Signature / Left thumb impression:

.....……...

Investigator's name and signature:

.....……...

Date:

Place:

ANNEXURE – II – ETHICAL CLEARANCE CERTIFICATE

K.L.E.UNIVERSITY'S
JAWAHARLAL NEHRU MEDICAL COLLEGE,
NEHRU NAGAR, BELAGAVI-590010 (KARNATAKA-INDIA)
(Accredited 'A' Grade by NAAC)

Website: http//www.jnmc.edu
E-Mail : dome@jnmc.edu

Phone: (+ 91-(0)831 Office : 2471350
Principal: 2471701
Fax No. +91 (0)831 – 2470759

Ref: MDC/DOME/ 32 **Date: 22/11/2017**

To,

PG student in Ophthalmology,
J.N.Medical College,
BELAGAVI.

Sub: Institutional Ethical Clearance for the study.

With reference to the above, we wish to inform you that your proposed research project titled **"CORRELATION OF MODERATE TO SEVERE DEGREE OF PRE-EXISTING CORNEAL ASTIGMASTISM BY TORIC INTRAOCUALR LENS IMPLANTATION IN PATIENTS UNDERGOING PHACOEMULSIFICAITON SURGERY – A ONE YEAR HOSPITAL BASED PROSPECTIVE INTERVENTIONAL STUDY AT KLE'S PRABHAKAR KORE CHARITABLE HOSPITAL AND MRC, 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. Roopa M Bellad)
Chairman,
JNMC Institutional Ethics Committee
on Human Subjects Research,
J.N.Medical College, Belagavi.

ANNEXURE – III - PROFORMA

GENERAL INFORMATION

IP NUMBER: OP NUMBER: PATIENT ID NUMBER:

NAME: _____

AGE: _____ GENDER: F/M CONTACT NUMBER: _____

ADDRESS: _____

_____

_____

DATE OF ADMISSION: _____ DATE OF DISCHARGE:

_____

Is the patient eligible for the study? YES/NO

Has informed consent been given? YES/NO

Final result information:

1. Ineligible
2. Eligible –Refusal
3. Eligible – Participating

CHIEF COMPLAINTS

Diminution of vision: RE/LE/BOTH EYES

Duration: RE: _____ days/months/years

LE: _____ days/months/years

HISTORY OF PRESENTING ILLNESS

Diminution of vision: Gradual/Sudden

Progressive/Static

Painless/Painful

For distance/For near/For both distance and near

Diplopia: Present/Absent

Coloured halos: Present/Absent

Black spots before the eyes: Present/Absent

Watering: Present/Absent

Redness: Present/Absent

Discharge: Present/Absent

Clear/Whitish

Serous/Mucoid

Spectacle use: Distance/Near/Both

Duration: _____ days/months/years

Last refraction done: _____ days/months/years back

PAST HISTORY

Ocular surgery: Yes/No Type of Surgery: _____

Duration: _____ days/months/years

Diabetes: Yes/No

Duration: _____ days/months/years

Hypertension: Yes/No

Duration: _____ days/months/years

Any other medical disorders: _____

PERSONAL HISTORY

Smoking: Yes/No

Duration: _____ days/months/years

Alcoholism: Yes/No

Duration: _____ days/months/years

Other addictions: Yes/No

Duration: _____ days/months/years

GENERAL PHYSICAL EXAMINATION

General appearance: Well-built/Moderately built/Poorly built/Emaciated

Pallor: Present/Absent If present: Mild/Moderate/Severe

Pulse: _____ beats/minute BP: _____ mmHg

Temperature: _____ ^{o}F Respiratory Rate: _____/minute

SYSTEMIC EXAMINATION

CVS: Normal/Abnormal

Specify:

_____

RS: Normal/Abnormal

Specify:

_____

CNS: Normal/Abnormal

Specify:

_____

GIT: Normal/Abnormal

Specify:

_____

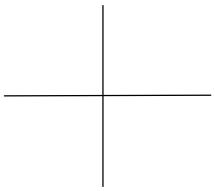
OCULAR EXAMINATION

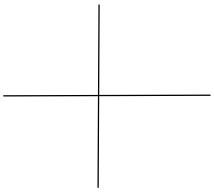
Head posture: Erect/Tilted

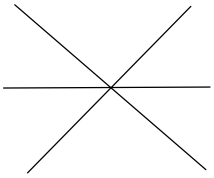
Visual axis: Parallel/Deviated

Facial symmetry: Symmetrical/Asymmetrical

Extra-ocular movements: Normal/Restricted/Partially restricted

RE: 

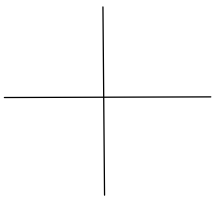
LE: 

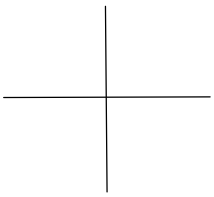
Binocular: 

VISUAL ACUITY:

	RE		LE	
DISTANT				
PINHOLE				
NEAR				
AIDED				

REFRACTION/RETINOSCOPY:

RE: 

LE: 

PRESCRIPTION	SPHERICAL	CYLINDRICAL	AXIS	BCVA
RE				
LE				

	OD	OS
LID		
ADNEXA		
CONJUNCTIVA		
SCLERA		
CORNEA		
ANTERIOR CHAMBER		
IRIS		
PUPIL A. Size B. Shape C. Direct D. Indirect E. Near reflex	 _____ in mm Present/Absent Present/Absent Present/Absent	 _____ in mm Present/Absent Present/Absent Present/Absent
LENS	Clear/Opaque Aphakia/Pseudophakia Immature/Mature/Hypermature NS/CC/PSC Grade – I / II / III / IV	Clear/Opaque Aphakia/Pseudophakia Immature/Mature/Hypermature NS/CC/PSC Grade – I / II / III / IV

Fundus Examination	OD	OS
GLOW		
MEDIA		
DISC		
1. Size		
2. Shape		
3. Colour		
4. NRR		
5. Vessels		
6. Lamellar Dot Sign		
7. Haemorrhagic Spots		
8. Other Signs		
C:D RATIO		
BLOOD VESSELS		
BACKGROUND		
MACULA		

DIAGNOSIS:

_____

_____

INVESTIGATIONS:

1. Lacrimal Patency:

	Patent	Regurgitation		Blocked
		Clear Fluid	Regurgitation	
RE				
LE				

2. IOP:

	By NCT	By Schiotz		
		5.5g	7.5g	10.0g
RE				
LE				

3. Blood Sugar: _____ mg% (RBS/FBS)
4. A-Scan:

   K_H Toric IOL Calculation:

   K_v

   Axl:

   ACD:

   PCIOL:

TREATMENT GIVEN PREOPERATIVELY:

_____

_____

_____

OPERATIVE PROCEDURE:

Surgery: Phacoemulsification with Toric IOL implantation

Date: _____ Eye to be operated: Right/ Left/ Both

ANAESTHESIA: Peribulbar block/ Topical

INCISION: Superior/Temporal/Supero-temporal/Infero-temporal

OPERATIVE COMPLICATIONS: Present/Absent

If present, specify -

_____

_____

POST-OPERATIVE COMPLICATIONS: Present/Absent

If present, specify -

_____

_____

OPERATING SURGEON:

_____

SURGEON'S SIGNATURE:

FOLLOW-UP PLAN: 1 DAY POST-OPERATIVELY

Visual Acuity	RE		LE	
DISTANT				
PINHOLE				
NEAR				
AIDED				

Anterior Segment	OD	OS
LID		
ADNEXA		
CONJUNCTIVA		
SCLERA		
CORNEA		
ANTERIOR CHAMBER		
IRIS		
PUPIL		
LENS		

COMPICATIONS:

Sub-conjunctival hemorrhage	Anterior capsular opacification	Hypaema
Gaping of incision	Intra-ocular infection	Pseudophakic bullous keratopathy
Zonular dehiscence	IOL decentration	After cataract
Cornal edema	IOL dislocation	Vitreous loss
Iris prolapse	Cystoid macular edema	Glaucoma
Nucleus drop	Shallow AC/Flat AC	Iridodialysis
Pupillary capture	Posterior capsular tear	Expulsive choroidal hemorrhage

FOLLOW-UP PLAN: 1 WEEK POST-OPERATIVELY

Visual Acuity	RE		LE	
DISTANT				
PINHOLE				
NEAR				
AIDED				

Anterior Segment	OD	OS
LID		
ADNEXA		
CONJUNCTIVA		
SCLERA		
CORNEA		
ANTERIOR CHAMBER		
IRIS		
PUPIL		
LENS		

COMPICATIONS:

Sub-conjunctival hemorrhage	Anterior capsular opacification	Hypaema
Gaping of incision	Intra-ocular infection	Pseudophakic bullous keratopathy
Zonular dehiscence	IOL decentration	After cataract
Cornal edema	IOL dislocation	Vitreous loss
Iris prolapse	Cystoid macular edema	Glaucoma
Nucleus drop	Shallow AC/Flat AC	Iridodialysis
Pupillary capture	Posterior capsular tear	Expulsive choroidal hemorrhage

FOLLOW-UP PLAN: 6 WEEKS POST-OPERATIVELY

Visual Acuity	RE		LE	
DISTANT				
PINHOLE				
NEAR				
AIDED				

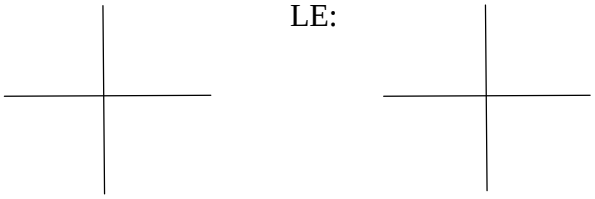
Anterior Segment	OD	OS
LID		
ADNEXA		
CONJUNCTIVA		
SCLERA		
CORNEA		
ANTERIOR CHAMBER		
IRIS		
PUPIL		
LENS		

Fundus Examination	OD	OS
GLOW		
MEDIA		
DISC		
C:D RATIO		
BLOOD VESSELS		
BACKGROUND		
MACULA		

IOP	By NCT	By Schiotz		
		5.5g	7.5g	10.0g
RE				
LE				

REFRACTION/RETINOSCOPY:

RE: LE:



PRESCRIPTION	SPHERICAL	CYLINDRICAL	AXIS	BCVA
RE				
LE				

COMPICATIONS:

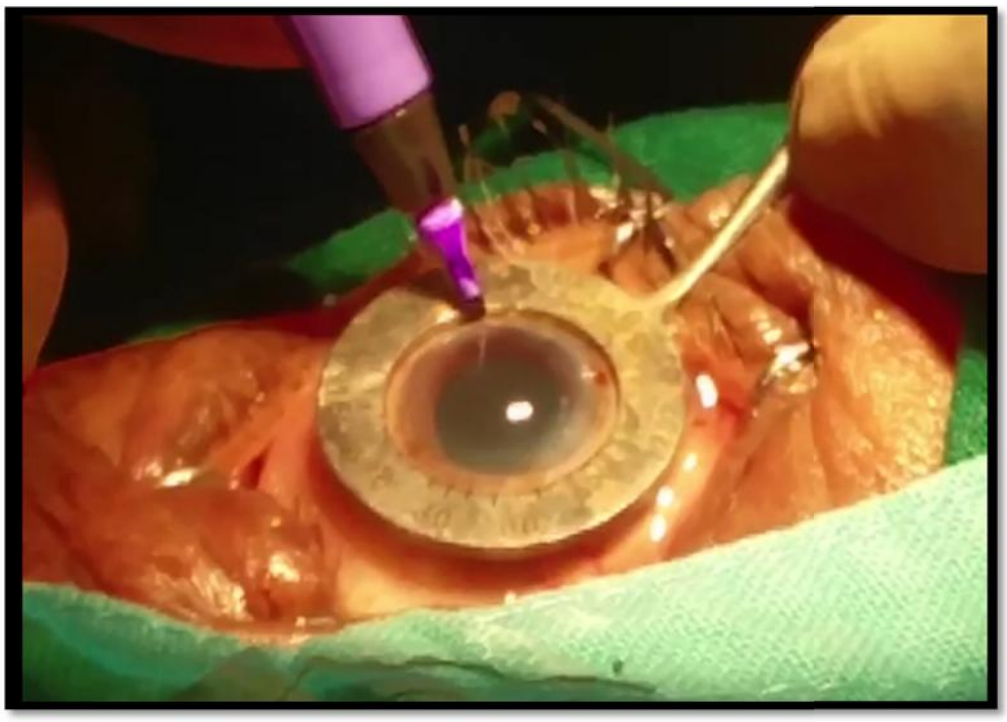
Sub-conjunctival hemorrhage	Anterior capsular opacification	Hypaema
Gaping of incision	Intra-ocular infection	Pseudophakic bullous keratopathy
Zonular dehiscence	IOL decentration	After cataract
Cornal edema	IOL dislocation	Vitreous loss
Iris prolapse	Cystoid macular edema	Glaucoma
Nucleus drop	Shallow AC/Flat AC	Iridodialysis
Pupillary capture	Posterior capsular tear	Expulsive choroidal hemorrhage

ANNEXURE- IV – PHOTOGRAPHS

Photograph I – Keratometry

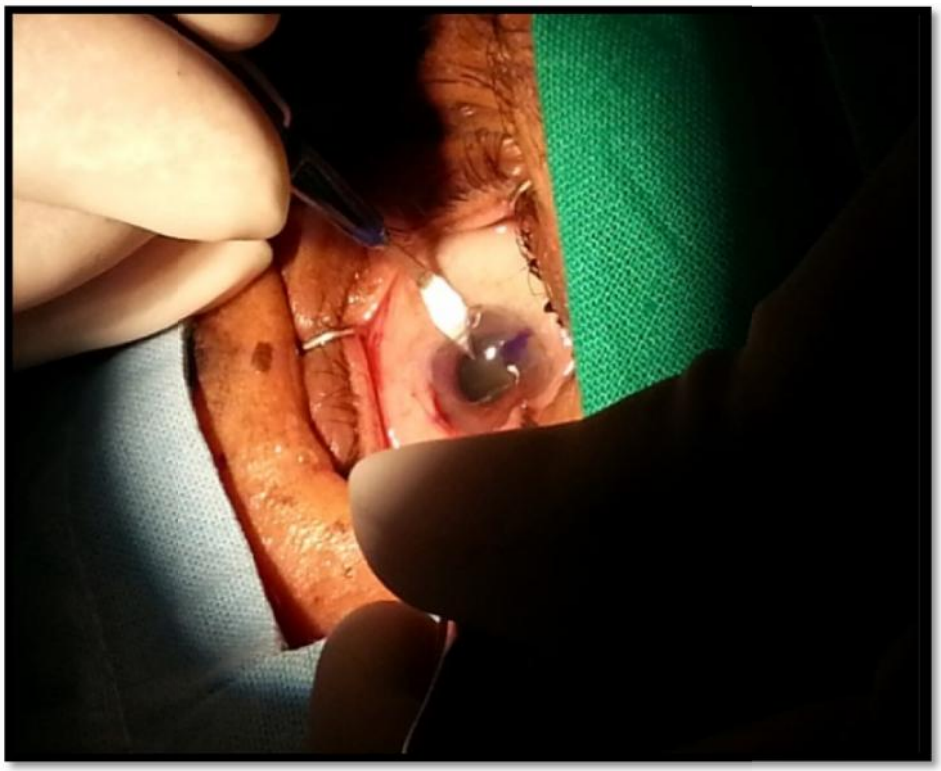
Photograph 2 – Axis marking with surgical marker

Photograph 3 – Bausch and Lomb Phacoemulsification machine with OT setup

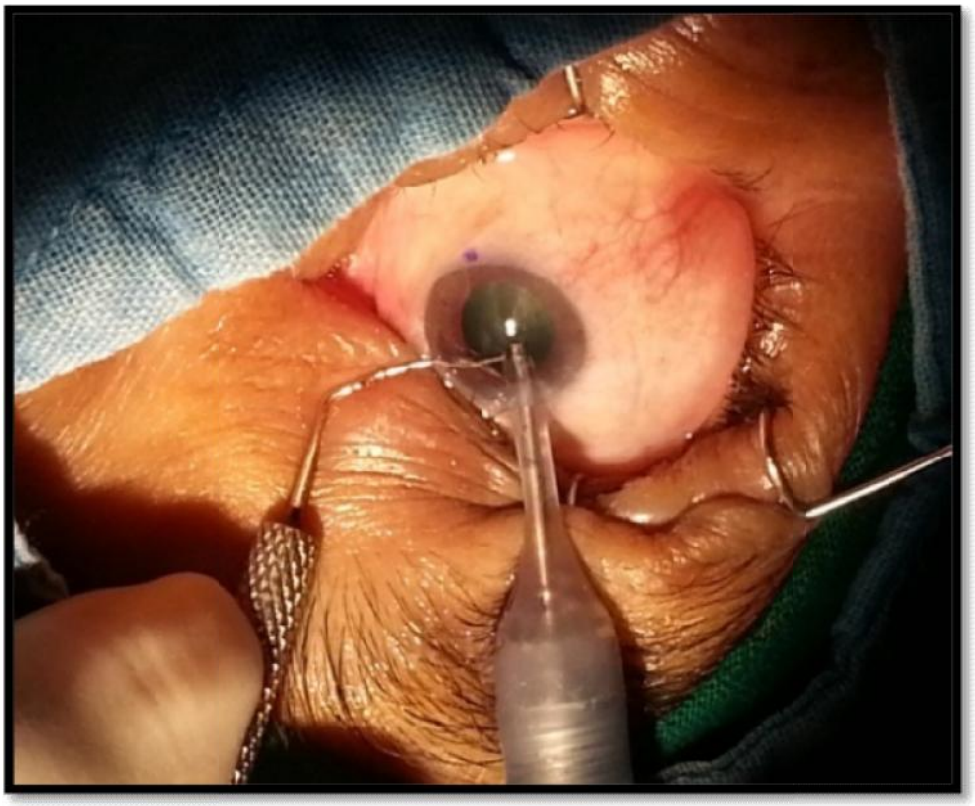


Photograph 4 – Mendez protractor for axis marking

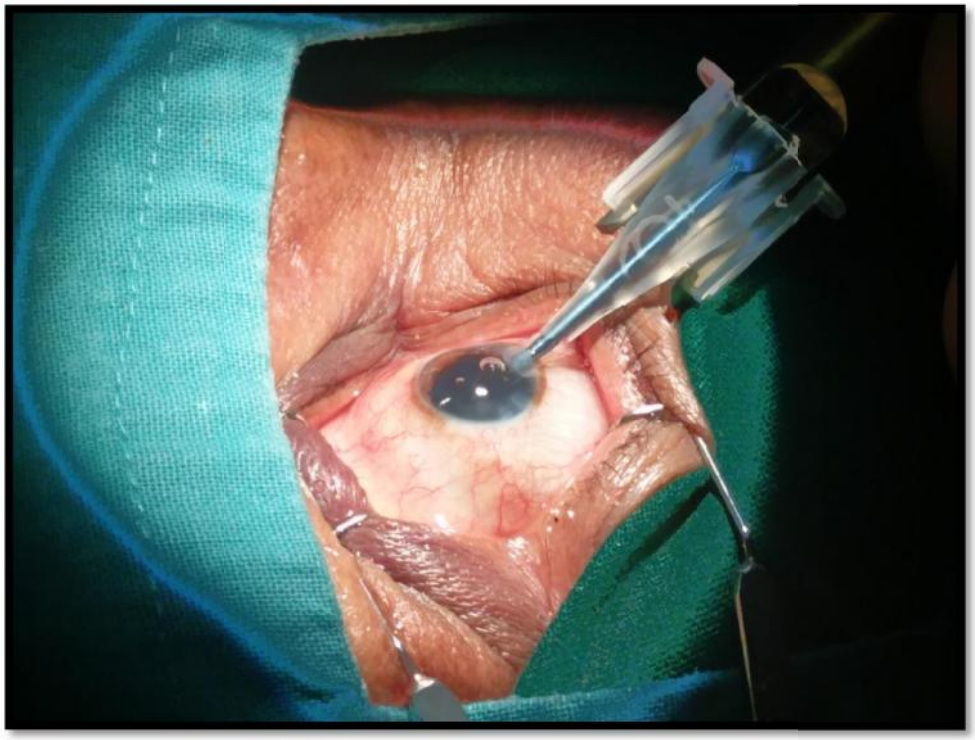
Photograph 5 – Superior clear corneal incision



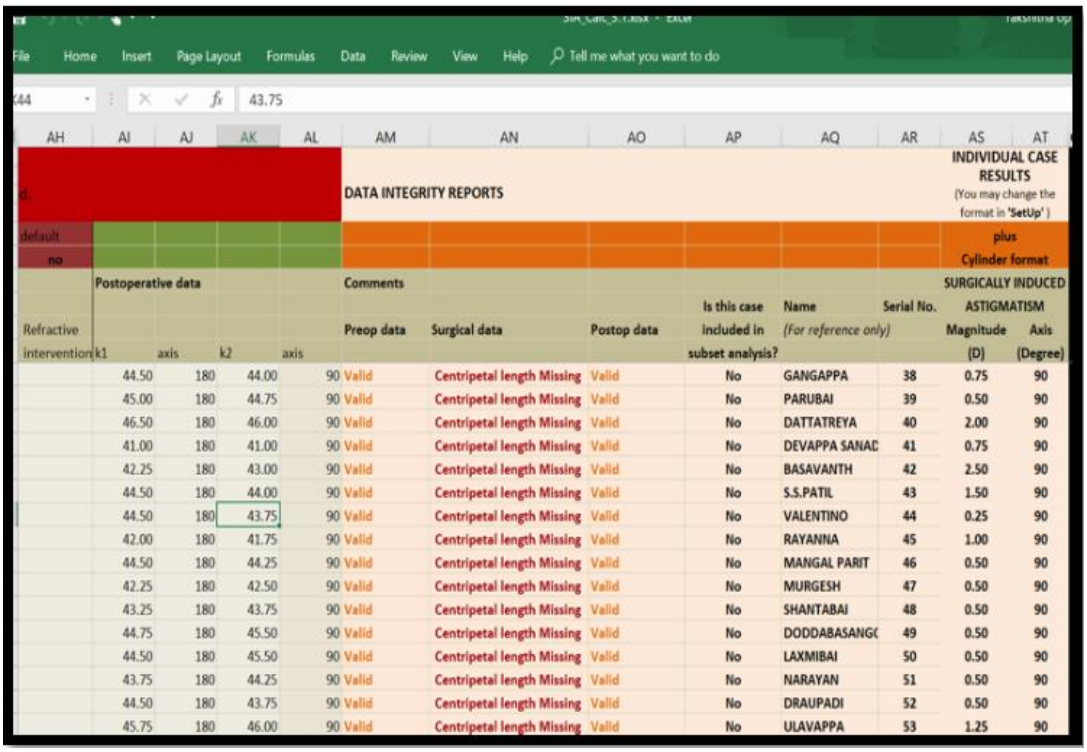
Photograph 6 – Temporal clear corneal incision



Photograph 7 – Ongoing phacoemulsification

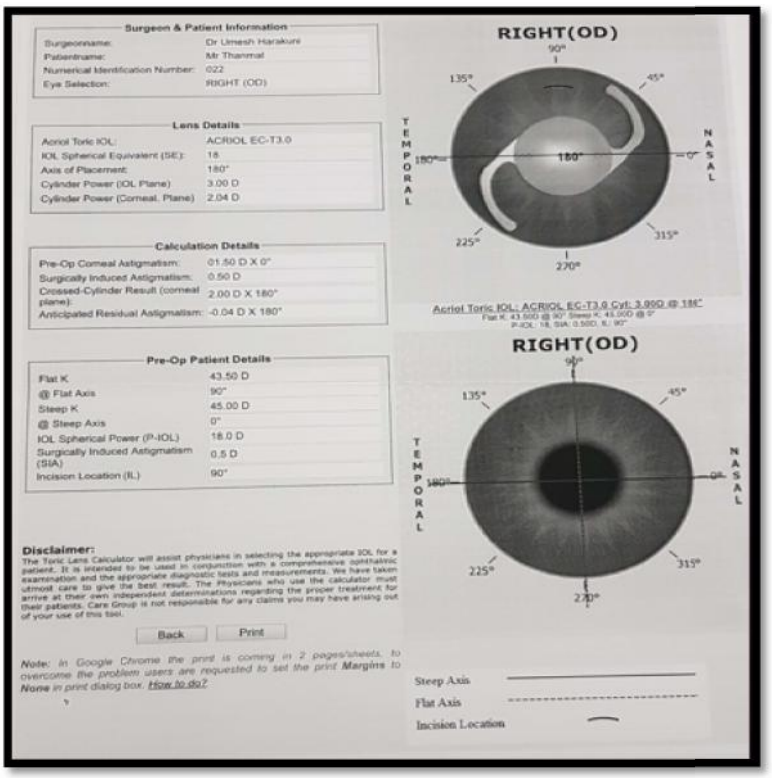


Photograph 8 – Toric IOL implantation



	Postoperative data				Comments							
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 SANAD	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	DODDABASANGC	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 - Toric nomogram used for calculations

ANNEXURE -V - MASTERCHART

SL. NO	IP NO	GENDER	AGE	EYE	PRE-OPERATTIVE								POST - OPERATIVE														
						KERATOMETRY				ASTIGMATISM			UCVA			ASTIGMATISM			REFRACTION-1 WEEK				BCVA	REFRACTION - 6 WEEKS				BCVA
					VISUAL ACUITY	KH	KV	AXIAL LENGTH	PCIOL POWER	DIOPTERS	AXIS	TYPE	DAY 1	1 WEEK	6 WEEKS	RESIDUAL	AXIS	TYPE	SPHERE	CYLINDER	AXIS	NEAR		SPHERE	CYLINDER	AXIS	NEAR	
1	2663880	M	53	LEFT	6 / 3 6	42.5	43.75	23.2	22	1.25	90	WTR	6/12P	6/9P	6/9	-0.16	90	WTR		-0.5	60	2.5	6/12		-0.25	60	2.5	6/6P
2	4695913	F	60	LEFT	CF 1M	45.5	44.5	22.96	19.5	1	180	ATR	6/24P	6/ 1 2	6/9P	-0.13	180	ATR		-1.5	100	2.5	6/9		-0.5	100	2.5	6 9
3	4789264	F	44	RIGHT	6 / 3 6	45.75	47	23	17.5	1.25	90	WTR	6/ 1 2	6 /1 2	6/9	-0.13	90	WTR	2	-0.5	180		6/9	1.5				6 9
4	3662528	F	50	RIGHT	6 / 3 6	44.1	43	22.96	22	1.1	180	ATR	6/ 1 8	6/ 1 2P	6/9	-0.31	0	ATR	1			2.5	6/12	1			2.5	6 9
5	3304264	M	68	LEFT	6/18P	43	44.1	22.6	20.5	1.1	90	WTR	6 9	6/9	6/6P	-0.03	90	WTR		2	90	2.5	6/9		0.5	90	2.5	6/6P
6	4815270	M	54	RIGHT	CFCF	44	45.5	22.66	20	1.5	90	WTR	6/9 P	6/9	6/9	0.11	90	WTR	1	0.5	90	2.5	6/9		0.5	90	2.5	6 9
7	4815685	F	32	LEFT	CF 1 M	47.25	44.25	23.73	18	3	180	ATR	6 / 2 4	6 / 1 2	6/9P	0.12	0	ATR		-0.5	90		6/9	-1				6/9
8	4835618	M	56	RIGHT	CF 2 M	45.75	44	22.82	20	1.75	180	ATR	6 / 1 8	6 / 9 P	6/9	-0.13	180	ATR	1			2.5	6/6P	1			2.5	6/6
9	5045004	F	65	RIGHT	HMCF	46	44.75	23.92	21	1.25	180	ATR	6 / 1 2	6/9	6/9	-0.15	0	ATR				2.5	6/9				2.5	6/9
10	3178563	F	70	RIGHT	6 / 6 0	43	44.25	22.96	18.5	1.25	90	WTR	6/18P	6/ 1 8	6/9P	-0.14	90	WTR		-0.5	180	2.5	6/9P		-0.5	180	2.5	6/9
11	4682610	M	56	RIGHT	CF 2 M	47.5	46.5	22.6	20.5	1	180	ATR	6 / 6 0	6 / 1 8	6/9	-0.12	180	ATR	2			2.5	6/9	0.5			2.5	6/6
12	5162259	F	85	RIGHT	CFCF	46.25	44.25	22.8	20.5	2	180	ATR	6/60	6/12P	6/6	0.12	180	ATR		-0.5	180	2.5	6/9P				2.5	6/6
13	4677891	F	75	RIGHT	CF 1/2M	44	43	23.2	19.5	1	180	ATR	6/60	6/12	6/9	-0.13	180	ATR	0.5	-0.5	90	2.5	6/9				2.5	6/6
14	5009458	M	84	LEFT	HMCF	42.75	41	1.75	20	1.75	180	ATR	6/60	6/12	6/6P	-0.13	0	ATR				2.5	6/9				2.5	6/6P
15	4862285	M	70	RIGHT	6/24P	49	47.75	22.79	17.5	1.25	180	ATR	6/12	6/9	6/6P	-0.13	0	ATR				2.5	6/9				2.5	6/6P
16	883470	M	71	RIGHT	6/36P	43	44.5	24.35	18.5	1.5	90	WTR	6/12	6/9P	6/9	0.11	90	WTR		-0.25	180	2.5	6/9				2.5	6/6P
17	887063	F	70	LEFT	CF 1 M	45.5	44	23.47	19	1.5	180	ATR	CF 1/2M	6/60	6/9	0.11	0	ATR		-1.5	90	2.5	6/12	-0.25	-0.25	90	2.5	6/9
18	4862982	F	48	LEFT	6/36	46.75	45.75	23	22.5	1	180	ATR	6/18P	6/9	6/6P	-0.09	180	ATR		1	180	2.5	6/6P	-0.5			2.5	6/6
19	2598564	F	63	RIGHT	HMCF	45	43.75	22.96	18	1.25	180	ATR	6/36P	6/36	6/12P	-0.14	180	ATR	2			2.5	6/12P	1	0.25	180	2.5	6/6P
20	4815290	M	54	LEFT	CF 1M	45	43.25	22.9	19.5	1.75	180	ATR	6/18	6/9	6/6P	-0.12	0	ATR		0.5	120	2.5	6/9	0.5	0.5	60	2.5	6/6
21	4829137	F	75	LEFT	CF 3M	45.75	47.5	22.92	19	1.75	90	WTR	6/24P	6/12	6/9	-0.12	90	WTR		-0.25	90	3	6/9		-0.25	90	3	6/6
22	4878622	F	53	RIGHT	6/18	44	45	22.48	22.5	1	90	WTR	6/9	6/9	6/6	-0.09	90	WTR	-1			3	6/9				3	6/6
23	18161738	F	68	LEFT	CF 3M	44	46	23.06	20	2	90	WTR	6/18P	6/18	6/9P	0.12	90	WTR		-1.5	180	2.5	6/12	-0.25	-0.25	180	2.5	6/9
24	440222	M	70	RIGHT	CF 1/2M	45	43.5	24.02	18	1.5	180	ATR	6/60	6/24P	6/12P	0.11	0	ATR	1	1	180	2.5	6/9P				2.5	6/9P
25	4927193	M	48	LEFT	6/36	45.25	44	22.98	21	1.25	180	ATR	6/12	6/9	6/6P	-0.15	0	ATR	-0.25	-0.25	90	2.5	6/6P	-0.25	-0.25	90	2.5	6/6
26	4815460	F	67	LEFT	CF 2 1/2M	43.75	42.25	22.51	23.5	1.5	180	ATR	6/12	6/12	6/6P	0.08	0	ATR	0.5	-1	120	2.5	6/6P		-0.5	130	2.5	6/6P
27	925426	F	40	LEFT	6/24	42.3	43.5	23.41	21	1.2	90	WTR	6/12P	6/9	6/9	-0.2	90	WTR		-0.25	180		6/9					6/6P
28	4974420	M	61	LEFT	6/36	47	45.25	22.83	19.5	1.75	180	ATR	6/12P	6/12	6/6P	-0.12	0	ATR	-1.5	-0.25	90	2.5	6/9P		-0.5	140	2.5	6/6P
29	4985319	M	48	LEFT	6/24P	42.75	45	23.1	21	2.25	90	WTR	6/12	6/9	6/6P	0.02	90	WTR	0.5			2.5	6/9				2.5	6/6
30	3002284	F	52	RIGHT	6/24P	44	46	22.65	21	2	90	WTR	6/12P	6/9	6/6P	0.11	90	WTR		-0.5	90	2.5	6/9				2.5	6/6
31	913060	M	63	LEFT	CF 3M	44.25	46.25	23.88	17.5	2	90	WTR	6/24	6/12	6/6P	0.14	90	WTR	1.5			2.5	6/9		-0.25	90	2.5	6/6
32	932076	F	68	LEFT	HMCF	44.5	46	23.01	20	1.5	90	WTR	CF 2M	6/12	6/9P	-0.11	90	WTR				2.5	6/12P				2.5	6/9P
33	937636	M	68	RIGHT	6/24P	38.1	43.45	24.18	21	5.35	90	WTR	6/9P	6/6P	6/6	0.35	90	WTR				2.5	6/6				2.5	6/6
34	4875912	M	70	RIGHT	HMCF	42	44.25	24	22	2.25	90	WTR	6/9P	6/9	6/6	-0.11	90	WTR				2.5	6/6P				2.5	6/6