“A LONGITUDINAL STUDY TO EVALUATE THE EFFECT OF MANUAL SICS SCLEROCORNEAL TUNNEL INCISION PLACED IN THE STEEPEST MERIDIAN ON PRE-EXISTING ASTIGMATISM AND SURGICALLY INDUCED ASTIGMATISM BY THIS INCISION ON EYES UNDERGOING CATARACT SURGERY AT KLES HOSPITAL, BELAGAVI”

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This is to certify that the dissertation entitled **"A LONGITUDINAL STUDY TO EVALUATE THE EFFECT OF MANUAL SICS SCLEROCORNEAL TUNNEL INCISION PLACED IN THE STEEPEST MERIDIAN ON PRE-EXISTING ASTIGMATISM AND SURGICALLY INDUCED ASTIGMATISM BY THIS INCISION ON EYES UNDERGOING CATARACT SURGERY AT KLES HOSPITAL, BELAGAVI"** is a bonafide research work done by **REGISTRATION NO. BK0115001**

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ABSTRACT

BACKGROUND

Cataract (47.9%) remains the leading cause of visual impairment in all areas of the world, except for developed countries. The spectrum of cataract surgery has evolved greatly from the days to Extra-Capsular Cataract Extraction (ECCE) to phacoemulsification and Manual SICS now-a-days. Phacoemulsification is predominantly done in developed countries, but is difficult to perform in developing countries due to the constraints of higher cost and the need for high-end machines. Manual SICS is the hence the affordable and better alternative in such conditions. In the older cataract population about 66.9% of the eyes have astigmatism equal to or >1.00D, and 6.12% had astigmatism >3.00D. An incision on the steeper meridian of the cornea helps to reduce astigmatism by inducing flattening along that axis and steepening along the axis perpendicular to it. Hence pre and post-operative astigmatism can be reduced by placement of site of the incision along the steeper meridian. The purpose of this study is to see the beneficiary effect of an incision placed on the steepest meridian in controlling the astigmatic outcome in eyes with pre-existing astigmatism and to lower the amount of surgically induced astigmatism induced.

OBJECTIVES OF THE STUDY

Primary Objective

To evaluate the effect of postoperative Surgically Induced Astigmatism (SIA) caused due to sclerocorneal tunnel incision in SICS which is placed along the steepest

meridian either superior or temporal which is determined pre-operatively by keratometry.

Secondary Objective

To compare the amount of Surgically Induced Astigmatism (SIA) caused by Superior and Temporal incisions in Manual SICS.

MATERIALS AND METHODS

This study was carried out on 60 eyes of 60 patients undergoing Cataract surgery by Manual SICS method at KLES Dr. Prabhakar Kore Charitable Hospital, Belagavi. The study was carried out over one year during the time period of 1st January 2016 to 31st December 2016.

The patients underwent Manual SICS with the incision placed along the steeper meridian which was determined pre-operatively. The patients were followed up on post-operative days 1, 7, 21 and 6 weeks for reduction in the pre-operative astigmatism and the amount of surgically induced astigmatism post-operatively.

RESULTS

The average age of the patients was 63.7±9.73 years with range being from 35 years to 81 years. The maximum numbers of patients were in the age group of 61-70 years which was 23 (38%).

In the study, about 47% of the patients were male while about 53% of the patients were female.

Maximum number of patients (21 patients) had pre-operative astigmatism between 0.6D – 1.0D (35%). The range of pre-operative astigmatism was from 0.25D to 2.5D. 52% of patients had post-operative astigmatism of 0.5D – 1.0D. 38% of

patients post-operative astigmatism of about 0 - 0.5D. 10% had post-operative astigmatism of 1.1D – 2.0D.

The average SIA was 1.12D $\pm$ 0.6D with p value < 0.001 (Statistically significant). The average SIA with Superior incision was 1.33D $\pm$ 0.45D. The average SIA with the Temporal incision was 0.84D $\pm$ 0.67D. The difference between the SIA caused by both the Superior and Temporal incisions was Very Significant with a p value of 0.0011.

With Temporal Incision, the keratometric reading in the steeper meridian was reduced from 44.63D $\pm$ 1.52D pre-operatively to 44.05D $\pm$ 1.40D post-operatively with p value of 0.003.

With Superior Incision, the keratometric reading in the steeper meridian was reduced from 44.57D $\pm$ 1.57D pre-operatively to 43.87D $\pm$ 1.44D post-operatively with p value of 0.0016.

On the post-operative follow-up of 6 weeks, about 67% of the patients were seen to have visual acuity from 6/6 – 6/12 and 31% had visual acuity of 6/18 – 6/24.

INTERPRETATION AND CONCLUSION

The study clearly indicates that taking the incision on the steeper meridian during cataract surgery in eyes of patients with pre-existing astigmatism helps to reduce the astigmatism significantly.

The surgically induced astigmatism with temporal incision was much less than the surgically induced astigmatism with superior incision and the difference between the two was statistically significant.

Key words: Manual Small Incision Cataract Surgery, Surgically induced astigmatism, pre-existing astigmatism, Incision, Superior, Temporal.

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INTRODUCTION

"The altering eye; alters all in life."

- William Blake.

Cataract is an age related change in the eyes and is the major cause of blindness in the elderly population worldwide. Cataract is defined to be degeneration and opacification of the lens fibres already formed, the formation of aberrant fibres and deposition of other material in their place.[1] Cataract (47.9%) remains the leading cause of visual impairment in the world, except for developed countries; followed by glaucoma (12.3%), age-related macular degeneration (AMD) (8.7%), corneal opacities (5.1%), diabetic retinopathy (4.8%), childhood blindness (3.9%), trachoma (3.6%), and onchocerciasis (0.8%).[2]

Cataract can be managed by removal of the opacified cataractous lens. The spectrum of cataract surgery has evolved greatly from the days of Extra-Capsular Cataract Extraction (ECCE) to Manual SICS and Phacoemulsification. Phacoemulsification is predominantly done in developed countries, but is difficult to perform in developing countries due to the constraints of higher cost and the need for high-end machines. [3],[4] Manual SICS as a High Volume, High Quality cataract surgery can be employed as a standard procedure in developing countries with a large cataract backlog due to its wider applicability and lower costs.

The evolution of cataract surgery is going towards achieving emetropia. Attempting to correct pre-existing astigmatism is the final frontier in this journey. To achieve emetropia post cataract surgery, we need to not only correct the spherical component but also reduce the amount of Pre-existing Astigmatism, which may affect the quality of vision post-operatively. [5], [6] In the older cataract population about 66.9% of the eyes have pre-existing astigmatism equal to or greater than 1.00D, and 6.12% had pre-existing astigmatism of greater than 3.00D.[7] The spherical component can be managed by proper A-Scan of the eye. The astigmatic component can be reduced by managing the surgically induced astigmatism as well as reducing the pre-existing astigmatism in the eyes.

Astigmatic correction during cataract surgery can be done by modifying either of the following parameters - the site, shape or size of the incision; by putting Toric IOL and/or by limbal relaxing incisions. [8] An incision on the steeper meridian of the cornea helps to reduce astigmatism by inducing flattening along that axis and steepening along the axis perpendicular to it. [9] Hence pre and post-operative astigmatism can be reduced by placement of site of the incision on the steeper meridian.

The purpose of this study is to see the beneficial effect of an incision placed on the steepest meridian in reducing the amount of pre-existing astigmatism and to lower the amount of surgically induced astigmatism.

OBJECTIVES

Primary Objective

To evaluate the effect on Postoperative Astigmatism of Sclerocorneal Tunnel Incision in SICS placed on the steepest meridian either Superior or Temporal which is determined pre-operatively by keratometry in patients with pre-existing astigmatism.

Secondary Objective

To compare the amount of surgically induced astigmatism (SIA) caused by Superior (S) and Temporal (T) incisions in Manual SICS.

REVIEW OF LITERATURE

HISTORICAL REVIEW

Cataract is one of the major causes of blindness not only in India but also worldwide and is also one of the major causes of morbidity in the elderly age group.

Cataract is defined simply as opacity in the lens. [10] Management of cataract is done by removal of the cataractous lens. [11]

Martin A I et al conducted an extensive review of the evolution of Cataract Surgery where it was seen to have evolved to a huge degree from Couching which was done until the middle of 18th century to Femtosecond Laser cataract surgery (FLCS) which is the new developing modality in the field of cataract surgery. [12] Couching is the oldest traditional technique documented to treat cataracts. It was the only method of cataract treatment until the 19th century and was seen to still be used to a large degree in developing countries in the African continent in a study done by Schrader et al. [13] It was first documented and practised in the 6th century B.C. by the Hindu surgeon Sushrutha and was later adopted from India by the Greeks and Romans as well as the Egyptians, Arabs and Europeans.

The first written records of couching come from Sushrutha an ancient Indian surgeon which was translated to English by Sayegh R et al as follows:

"He (the surgeon) scratches the eyeball (lens) with the point of a lancet which has been wrapped in hemp (a marker to determine how deep to plunge the lancet into the eye)... If the patient recognizes forms, the lancet is slowly withdrawn and molten butter is put on the eye..." [14]

Couching involves depressing an occluded crystalline lens to the bottom of the vitreous chamber. Before about 1700, cataracts were generally thought to be opaque concretions arising in front of the crystalline lens; it was not believed to involve depressing the lens itself, but rather removing this separate concretion to allow light and colour to enter once again the crystalline lens. Thus there was widespread recognition that cataract couching could restore sight (to some degree, at least). This historical view on couching was brought to light in a study done by Baker T. [15] Thereafter the timeline of cataract surgery evolved as follows: [16]

A French surgeon, Jacques Daviel, first introduced extra-capsular cataract surgery as an alternative to couching in 1745 where he created a limbal incision in the lower half of the eye with a triangular knife and enlarged it with scissors. Von Graefe in 1865 designed a cataract knife and made the section in the upper half of the eye and advocated iridectomy. William in 1867 was the first to use corneal sutures. Sharp, an Englishman, advocated Intracapsular cataract Extraction (ICCE) in 1773 which was modified by Smith in 1910 to include extraction through a corneal section. Barraquer then devised the method of extraction of the lens by using a suction apparatus. In 1951, Sir Harold Ridley revolutionized the world of cataract surgery by successfully placing an acrylic lens behind the pupil of an aphakic eye. In 1961, Krwawicz described the cryoextractor to which a lens capsule will adhere and facilitate the removal of the whole lens. In 1970, Kelmann introduced phacoemulsification of the lens nucleus and aspiration of lens cortex in a closed chamber. Richard Kratz developed the scleral tunnel incision in 1980. In 1982 Kratz and Sanders proved that smaller incisions are better causing less astigmatic shift. Michael McFarland was the one to devise a sutureless incision in 1990. Ernest then discovered the one way action of the upper lip of the corneal incision and hence devised a method to keep it self-sealing. Blumenthal devised the method of hydro-dissection of the nucleus to deliver it outside the AC. [17]

EXTRA-CAPSULAR CATARACT EXTRACTION

Extra-capsular Cataract Extraction (ECCE) is done by making an opening in the capsule (capsulotomy), removing the nucleus and washing out the cortical substance. There are different techniques of performing Extra-Capsular Cataract Extraction. They vary in terms of incision size, shape of capsulotomy, instruments used for capsulotomy, technique of removing the hard lens nucleus and instruments used for removal of the residual lens cortex. The different methods are: (i) Conventional ECCE; (ii) ECCE by small-incision cataract surgery (SICS) or Small-Incision Manual Nucleus Fragmentation; (iii) Lensectomy and (iv) Phacoemulsification. [1]

In a study done by Dean W et al, it was seen that in the early days of Extra - Capsular Cataract Extraction, the removal of the lens without the capsule led to various complications such as uveitis post-operatively due to some amount of lens cortex left behind which lead to formation of pupillary membrane and opacification of the lens capsule which warranted the need for repeat surgery of the eye.[18]

It was also observed in a study done by Dean W [18] et al that during the last 20 years the results of Extra-Capsular Extraction have greatly improved mainly due to

- Use of Modern surgical techniques, and particularly with the use of operating microscopes, the anterior lens capsule and the entire lens cortex could be now removed, leaving only the thin transparent posterior lens capsule in the eye.
- Post-Operative Topical Steroid Treatment has greatly reduced postoperative uveitis which was earlier common following Extra-Capsular Cataract Extraction.

The complication rate of Extra-Capsular Cataract Extraction is now less than that of the Intracapsular method, and is now the recommended method of cataract surgery. The study by Dean W et al [18] also observed that the other great advantage of Extra-Capsular Cataract Extraction was that Intraocular Lens Implants can easily be inserted behind the iris and in front of the posterior lens capsule. This was said in the study to be the safest and most secure place for Intraocular Lens implants to rest within the eye.

PHACOEMULSIFICATION

Technology continues to advance rapidly. Extra-Capsular Cataract Extraction can now be performed using an ultrasonic probe to break up the cataract inside the eye so it is removed through a tiny incision. The operation is called *Phacoemulsification*.

Phacoemulsification is now being introduced in developing countries and is being enthusiastically promoted. However according to the study done by Dean W et al [18] it was said that phacoemulsification is not always an appropriate technique for general use in developing countries for several practical reasons such as:

The equipment is very expensive and needs expert maintenance. There are additional expenses for disposable items for each case. A top quality microscope with good illumination and focusing controls is also essential, so that the surgeon can see exactly what the “phaco” probe is doing inside the lens.

Phacoemulsification is a difficult technique to learn, and a longer period of training is required.

White, opaque cataracts and advanced cataracts with very dense, brown, hard nuclei are the least suitable cases for phacoemulsification, and these are very common in developing countries. Phacoemulsification is an ideal procedure for removing cataracts which are in their early stages. As the cataract gets harder and more opaque the risk of serious complications from phacoemulsification also increases, and phacoemulsification is less likely to be successful. (However experts like Boughton B in her study states that experts in phacoemulsification can “*Phaco*” nearly all cataracts [19]).

It was stated in a study done by Laxmiprasad G et al. [20] that considering the aforementioned constraints of Phacoemulsification, Manual Small Incision Cataract Surgery was devised in developing countries as an inexpensive alternative to phacoemulsification. It was found to be preferable to Phacoemulsification in terms of speed, cost, and independence from technology in a study done by Gogate P et al. [3]

MANUAL SMALL INCISION CATARACT SURGERY

Manual small-incision cataract surgery (MSICS) is a variant of ECCE used to address the requirement for high-volume surgical output of dense cataracts in less affluent geographical regions. It involves the creation of a small self-sealing Sclero-corneal Tunnel incision, manual one piece expression of the nucleus, manual aspiration of the cortex and IOL implantation.[11]

In the study done by Haldipurkar S S et al, [21] few observations were made about Manual small incision cataract surgery (MSICS). It was noted that Manual SICS was a much later addition after Phacoemulsification became a popular technique. It was also observed that Manual SICS is neither a hi-tech procedure, nor is it practiced in Western countries. For that matter, MSICS remained and still remains a foreign technique to a large section of the ophthalmic fraternity in the modern world. It was developed mainly as a cost-effective alternative to phacoemulsification cataract surgery. The Western world graduated from extra-capsular cataract extraction (ECCE) to phacoemulsification. In the developing countries where cost is a major issue, MSICS was developed after the advent of phacoemulsification, and hence it is a relatively younger technique than the latter. It is a safe, simple, consistent, stable, and cost-effective way of cataract removal. Small incision is a misnomer as small is always bigger than “Smaller.”

In a study done by the National Cataract Coalition, Manual SICS was seen to have the following advantages over Phacoemulsification [22]:

It can be done in all type of cataracts, even in the advanced and hard cataracts.

Continuous Curvilinear Capsulorrhexis (CCC) or Can-Opener's can be done depending upon the ease and comfort of the surgeon. It can be performed easily in poor visibility like in case of hazy corneas or otherwise. In case Phacoemulsification gets complicated, it can be converted into MSICS.

Hence Manual SICS may be preferred to Phacoemulsification in developing countries as a cost effective and efficacious alternative.

ANESTHESIA IN MANUAL SICS

Goel A [23] in his work provided a brief overview of the anesthesia used in Cataract Surgery. He mentioned that Peribulbar / Retrobulbar / Subconjunctival / Subtenon / Topical / Intracameral Preservative free Xylocaine with or without facial block can be used.

The preferred technique was Topical Xylocaine 4%/ Proparacaine 0.5% 4-5 times. 3 cc xylocaine 2 % + 3cc bupivacaine 0.75% was advised to be given as an inferior temporal peribulbar injection. 3 cc to be injected peribulbar, needle is withdrawn, directed lateral to lateral canthus, deep enough to inject the solution around the branches of facial nerve. This one prick anesthesia should take care of every need of SICS.

CATARACT INCISIONS

Self-sealing cataract incisions were mentioned by Kratz *et al.* in his study done in 1980 [24] and by Girard in his studies done in 1984. [25, 26] Kratz thought of scleral tunnel as an astigmatic neutral way of entering the anterior chamber.

TYPES OF INCISIONS IN CATARACT SURGERY:

Haldipurkar S S et al [21] in his study described the various types of incisions used in Cataract Surgery.

Smile: - It is easy to make, but results in increased astigmatism. Smile incision is a curvilinear incision which runs parallel to the limbus. With this incision, there is an increased chance of corneal flattening after surgery in the vertical meridian with increased induced astigmatism.

Straight: - Straight incision, as the name suggests, is a straight line incision about 2 mm away from the limbus. This incision induces moderate flattening and consequently moderate astigmatism after surgery.

Frown: - The 15-G blade that is used to make the initial groove has to be made with one smooth movement of the hand. The base of the curve is about 2 mm from the limbus. There is minimal induced astigmatism with this wound and is the preferred type for majority of the surgeons. Frown incision is difficult to make for a beginner.

Blumenthal side cuts: - Blumenthal side cuts were devised by Dr. Michael Blumenthal. A straight incision with oblique cuts placed at its either ends. This increases the space in the tunnel for an easy delivery of the nucleus. It has minimally induced astigmatism.

Chevron 'v' incision: - The tunnel size in this incision is relatively smaller. Hence, maneuvering a large nucleus through this would be difficult. However, this incision has least/nil induced astigmatism. This incision is difficult to make.

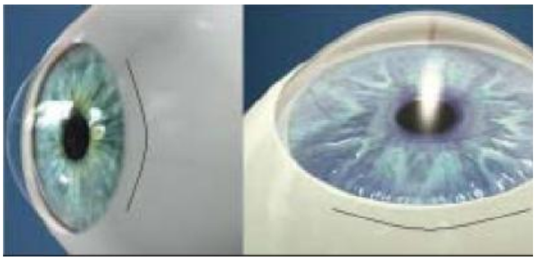


Fig 1a. Smile Incision

Fig 1b. Straight Incision

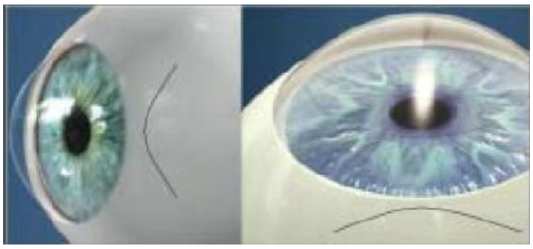


Fig 1c. Frown Incision

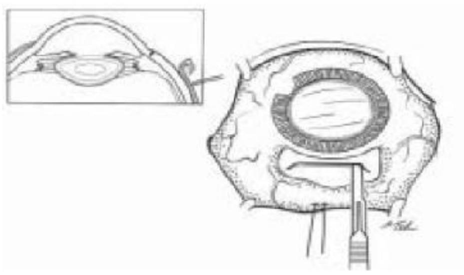


Fig 1d. Blumenthal Side Cuts

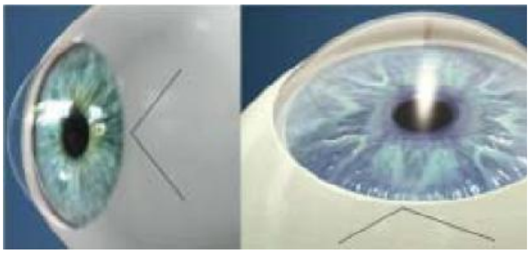


Fig 1e. Chevron 'V' Shaped Incision

INCISION ARCHITECTURE

Haldipurkar et al [21] in his study said the following are the features of incision architecture that affect regression. These include location, depth and length, type, density and tension of suture material, depth and length of suture bites if taken and postoperative steroid dosage.

More the distance from the limbus (on sclera), less is the induced astigmatism although tunnel making and maneuverability are difficult. The ideal distance is around 1–2 mm. [21] In 1984, it was shown in a study done by Thrasher *et al.* that a 9.0-mm posterior scleral incision induces less astigmatism than a 6.0-mm limbal incision. [27]

<u>Advantages of temporal Incision</u> - The temporal location is farthest from the visual axis, and any flattening due to wound is less likely to affect the corneal curvature at the visual axis. When incision is located superiorly, both gravity and the eyelid blink tend to create a drag on the incision. These forces are better neutralized with temporal incision because it is parallel to the vector of the forces.

Haldipurkar et al [21] in his study also observed that With the rule astigmatism induced by a temporal incision is advantageous because most elderly patients have preoperative against the rule astigmatism. It was also in this study that Temporal incision is free from the effect of gravity and eye lid pressure and tends to induce less astigmatism.

As the surgeon is seated on the temporal side of the patient, there is no need for added exposure of the superior part of the eye and hence superior rectus bridle suture is not needed. This position allows greater access to the incision when working over the brow of the patient. The amount of endothelial damage is the least with temporal incision as it is the farthest from the visual axis. Also as the lateral canthus lies directly beneath the incision at the temporal incision position, there is easier and more efficient drainage of fluid.

It was also mentioned in a series of 64 cases where a 5.5mm supero temporal tunnel was constructed in MSICS, the calculated Surgically Induced Astigmatism (SIA) was 0.8 diopter (D) whereas Superior Scleral Incision gave an SIA of 1.2D when the tunnel length was more than 5.5 mm. (Unpublished Data).

Advantages of Superior Incision

Superiorly placed incision is offered protection by the eyelid. Also it is away from the blink of the patient, so it will cause very less foreign body sensation and irritation. It is easier to abandon and convert to larger incision if any complication occurs. It also has lesser incidence of post-operative endophthalmitis.

WOUND HEALING IN CATARACT SURGERY

Collagen Fibres Arrangements in the Corneal Stroma [28]

Vanathi M [28] mentioned in her work that the corneal stroma consists of the lamellae and the ground substance of the cornea containing Keratocytes and Proteoglycans made of Keratan Sulphate, Chondroitin Sulphate and Dermatan Sulphate. The lamellae are arranged in layers parallel to each other and the corneal surface. In the superficial layer, angled less than 90^{o}, they run from limbus to limbus, while in the deeper layers they run orthogonally and form strap-like ribbons which run approximately at right angles to those in the consecutive layers. Also the limbal fibres run tangential to the limbus in an annular area around the limbus. It is about 1.5mm superiorly, 2mm wide inferiorly with maximum thickness midway between Superior and Nasal and Superior and Temporal regions. [29] Each lamella comprises of connective tissue collagen which show typical 64nm periodicity. On Transmission Electron Microscopy and Corneal Collagen Microscopy, corneal collagen fibrils are regular in diameter at all corneal locations and depths and are not significantly altered with ageing. The density of the fibrils is 1.12 times greater in the posterior stroma compared with that of the anterior stroma, in the central cornea. Though the layers are arranged together, they can be easily separated. This forms the basis of lamellar corneal grafting.

<u>Applied anatomy of the cornea as regards to healing</u>

Vanathi M [28] also mentions in her work that the cornea is a tissue highly specialised to refract and transmit light and is essential for ideal visual function. The surface area of cornea is 1.3cm^2 which is about 1/6th of the surface area of the globe. In front the cornea appears elliptical, being 11.7mm in the horizontal meridian and 10.6mm in the vertical meridian. The posterior surface appears more spherical and measures about 11.7mm in diameter. The axial thickness of cornea is 0.52mm with the peripheral thickness being 0.67mm.

The cornea forms a part of what is almost a sphere, but is more curved in vertical axis when compared with the horizontal leading to “With The Rule” astigmatism. The normal cornea is prolate shaped and flattens in the periphery especially in the nasal region. The central optical zone has a radius of curvature measuring about 7.5mm, which equates to average power of 43.5D. However the range of power in the central region is from 39D to 48D. The posterior surface has a smaller radius of curvature, the average being 6.5mm, giving a refractive power of 40-44D.

The cornea contains the following layers

Epithelium - It is stratified squamous and non-keratinized and measures about 50-90µm.

Bowman's Membrane - It is an acellular modified homogeneous region of the anterior stroma measuring about 8-14µm.

Stroma - It has regularly arranged lamellae of collagen bundles with thickness of 500µm. It makes up about 90% of the corneal thickness.

Descemet's Membrane - It is the basal lamina of the endothelium and has a thickness of 10-12µm in a normal adult.

Endothelium - It consists of a single layer of cells attached to the Descemet's membrane by desmosomes.

The epithelium of the cornea continues as the conjunctival epithelium and the corneal stroma continues beyond the limbus as the stroma of the sclera. The stroma is the main supporting tissue of the cornea. Any effect of injury to the cornea is seen mainly in the stroma with the major changes occurring in this region.

Sclero-Corneal Incision Healing – Biomechanics

Koch D D et al [30] mentioned in their works that the subsequent closure of a step or tunnel incision at the end of the surgery depends not on radial compression of the anterior and posterior lips of the incision but rather on the re-approximation of the surfaces of the tunnel flap. For scleral and limbal incisions, active wound healing begins within 48 hours of surgery; the initial phase is the ingrowth of episcleral vascular tissue. Over the next several weeks, this tissue fills the entire incision, creating a fibro vascular plug. Over the ensuing 2 or more years, remodeling occurs, resulting in reorientation of the wound healing collagen so that it becomes parallel to existing scleral collagen. Concurrently, vascularization and cellularity diminish. Rao et al [31] in their study stated the observation that as the cataract wound heals, the meridian along which the wound is centered tends to progressively flatten. This usually occurs till the healing of the tissues is completed and usually continues for up to 3 weeks after surgery. Compared with scleral and limbal wound healing, the wound-healing process of the corneal incision is much slower and ultimately produces a weaker incision, as attested by the relative fragility of corneal graft wounds. For incisions 4mm and longer, one of the most subtle, but perhaps most common, manifestations of wound dehiscence is excessive flattening along the meridian of the incision. This condition can begin at any time in the first 2 years postoperatively and can progress for years thereafter. A precise definition of this condition is difficult to formulate, in part because the determination of excessive flattening along the meridian of the incision depends on incision size. Shifts of unusual magnitude would include flattening of greater than or equal to 1.5diopters (D) for a 5mm or smaller incision, greater than or equal to 2D for 6–7mm incisions, and ≥3D for extra capsular incisions. A predisposition to excessive flattening along the meridian of the incision becomes more prominent with longer wounds and shorter tunnels. This problem certainly is more common in superior incisions and is rarely seen with temporal incisions.

PRINCIPLES OF THE CATARACT INCISION

Now-a-days Cataract surgery is viewed as refractive surgery. It was observed in a study done by Koch M J and Kohen T[32] that centering the incision on the steep corneal meridian leads to flattening of the that particular meridian and steepening of the meridian perpendicularly opposite to it; thus decreasing the magnitude of astigmatism and can be further modified by varying the size and design of the incision.

The cataract incision causes flattening of the cornea along the meridian where it is taken and produces a corresponding steepening of the meridian 90^0 away from it. The effect of the incision on the flattening of the visual axis increases as the incision site approaches the visual axis. Hence a sclero-corneal incision will cause lesser Surgically Induced Astigmatism than limbal incisions which will in turn cause lesser Surgically Induced Astigmatism than clear corneal incisions. This is based on Gauss's law for a perfectly elastic dome that if there is any change in one axis, it results in an equal and opposite change in the opposite axis. The degree of change that occur after an incision can be described as a coupling ratio which is an important part of refractive surgery. Coupling is described as the ratio of flattening or steepening of corneal curvature that occurs in the axis of incision to that at 90 degrees away by Chaudhari Z and Vanathi M in their works. [33] According to Euler's Theorem, an axis deviation of 5, 10 or 15 degrees results in 17%, 33% and 50% reduction respectively, in effect of the incision on decrease in the astigmatism reduction as mentioned in the works of Abrams D.[34]

In case sutures are taken to seal the incision, if the sutures are loose then there occurs flattening of the curvature adjacent to the suture site and 180^0 away, and steepening 90^0 away from the site of suturing. If the sutures are tight, then occurs steepening of the corneal curvature adjacent to the site of the suture and 90^0 away and flattening of the corneal curvature 180^0 away from it.

Hence the thumb rule is that sutures steepen the adjacent curvature and incisions flatten it. Hence if the incision is placed along the steeper curvature of the cornea according to the pre-operative readings then there occurs flattening of the steeper curvature and decrease in the amount of the pre-existing astigmatism.

Incisions can be made on the steepest meridian (on-axis) to reduce mild pre-operative astigmatism of 1 D or less as it causes flattening of the meridian in which incision is taken with increase in curvature of the perpendicular meridian. A latest study done by Mohan S et al [35] by making 'on axis' incision, in various locations to correct preoperative astigmatism showed that nasal incision increased preoperative cylinder from 1.13D to 1.83D 6 months after surgery.

Edmund Arthur et al. [36] conducted a study on the post-operative corneal astigmatic changes in about 58 subjects with pre-existing ATR astigmatism undergoing cataract surgery. The study led to the conclusion that there occurred a change in corneal astigmatism from 1.49 ± 1.34D to 2.80 ± 1.40 D post-operatively. ($p < 0.0001$). The centroid preoperative astigmatism was 1.42D × 179 (1.49±1.34 D).This preoperative ATR astigmatism increased postoperatively at 12 weeks to 2.48D × 0 (2.80 ± 1.40 D).The resultant centroid SIA was then recorded as 1.07D × 1 (1.62 ± 0.90 D) showing increase in the pre-existing ATR astigmatism. For patients with ATR astigmatism who have a flatter vertical corneal meridian, it would be expected that a superior approach MSICS would flatten the already flatter vertical meridian leading to high postoperative corneal astigmatism. Hence increase of astigmatism was seen post-operatively than pre-operatively.

In a study done by Haldipurkar S S, Shikari H T, and Gokhale V [21] consisting of series of 64 cases where a 5.5mm superotemporal tunnel in MSICS was constructed, the calculated Surgically Induced Astigmatism (SIA) was 0.8 diopter (D) whereas the superior scleral incision always gave us an SIA of 1.2 D when the tunnel length was more than 5.5 mm. Hence it helped prove that the post-operative astigmatism is more with superior scleral incision than with supero-temporal incision or temporal incisions. Scleral tunnel incisions minimize suture induced astigmatism and provide greater wound healing surface. Hence, it is more stable from the refractive standpoint.

In another study done by Magadum R, Gahlot A, Maheshgauri R D, Patel K[37] Manual SICS surgery was done on 100 cases of senile cataract using Superior and Temporal incision and Surgically Induced Astigmatism was studied. It was seen that the SIA in Superior Incision group was 0.95D ± 0.68D and in Temporal Incision group the mean was 0.62D ± 0.72D at 3 months follow-up visit.

ASTIGMATISM

HISTORY OF ASTIGMATISM

Sir Issac Newton, who himself was apparently astigmatic, first considered the question of astigmatism in 1727.

It was then investigated in depth by Thomas Young in 1801. It was recorded by Abrams [38] in his works that Thomas Young himself had an astigmatic error of 1.7D and since it remained even after he immersed his head in water, thus eliminating the effect of the cornea, replacing the corneal refraction by a suitable convex lens, he attributed the aberration to the lens.

Airy in 1827 was the first to correct it using a cylindrical lens. Donders in 1864 impressed the world with his work on the prevalence and the importance of astigmatism in the world. It included explaining the prevalence of regular astigmatism and the astigmatism induced by the incision of cataract surgery.

Snellen in 1869 explained that placing the incision on the steeper axis in cataract surgery would cause flattening of that meridian as recorded by Abrams. [38]

BASICS AND DEFINITION OF ASTIGMATISM

According to the works of Benjamin W J, [39] the term Astigmatism is derived from '*a*' which means 'lacking' and '*stigma*' meaning 'a point'. Astigmatism is that condition of refraction wherein a point focus of light cannot be formed on the retina. In his works Abrams [38] noted that astigmatism includes those anomalies wherein an appreciable error is caused by the unequal refraction of light in different meridians. Generally one of the meridians shows the greatest power and the other shows the least power. These meridians are known as Principal Meridians.

AETIOLOGY OF ASTIGMATISM

Abrams [38] noted the cause of astigmatism to be due to error either in the Curvature, Centring or Refractive Index.

Curvature Astigmatism usually has its seat in the cornea and is congenital. Its occurrence in small degrees is almost invariable. The most common type of error is Direct Astigmatism where the vertical curvature is greater than the horizontal by about 0.25D. However with age it disappears or may reverse into Inverse Astigmatism. Curvature Astigmatism of the lens also occurs in small amounts and is marked in certain conditions like lenticonus. Decentring of the lens and small inequalities in the refractive index may also lead to astigmatism in a few cases.

CLASSIFICATION OF ASTIGMATISM [39]

Benjamin W J classified astigmatism on the basis of the following properties

1. Regular/ Irregular
2. With respect to contributing ocular component

3. By Orientation
4. With respect to refractive error

Regular and Irregular Astigmatism

In Regular Astigmatism, the meridians having the maximum and minimum refractive powers are 90 degrees apart.

In Irregular Astigmatism, also known as Bi-Oblique Astigmatism, the maximum and minimum powered meridians are separated by an angle other than 90 degrees. It is usually seen in keratoconus/ sclercornea.

Classification with respect to contributing Ocular Component

The Anterior Cornea - Astigmatism is frequently produced by the toricity of the anterior corneal surface.

The Posterior Cornea - It has significant contribution to astigmatism. However as the toricity of the posterior corneal surface is difficult to measure, hence, its relatively small contribution is ignored usually.

The Crystalline lens - It may be produced due to the toricity of the lens surface or tilting of the lens. However the magnitude of the astigmatism is small and is opposite to that of corneal astigmatism.

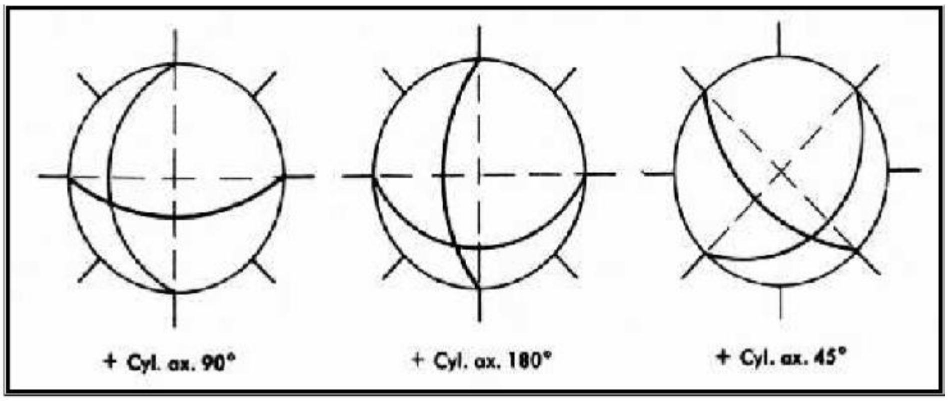
Other Causes - The infero-temporal location of the macula and the angle between the optic and visual axis produces an oblique astigmatism of 0.10D.

Classification by Orientation

If the corneal meridian having the least power is horizontal, i.e. between 160 and 20 degrees, it is said to be *With The Rule Astigmatism*.

If the corneal meridian having the least power is vertical, i.e. between 70 and 110 degrees, it is said to be *Against The Rule Astigmatism*.

If the corneal meridian having the least power is either between 20 and 70 degrees or between 110 and 160 degrees it is said to be *Oblique Astigmatism*.



With the rule **Against the Rule** **Oblique**

Fig. 2 Types of astigmatism

Classification with respect to Refractive error

If the image is in the retinal plane it is known as Simple Astigmatism.

If the any one of the two images is focussed in front of or behind the retina with the other image focussed on the retina, it is known as Simple Hypermetropic or Simple Myopic Astigmatism respectively.

If both the images are formed either in front or behind the retina it is known as Compound Myopic and Compound Hypermetropic Astigmatism respectively

If one image lies in front of the retina and the other lies behind it, it is known as

Mixed Astigmatism.

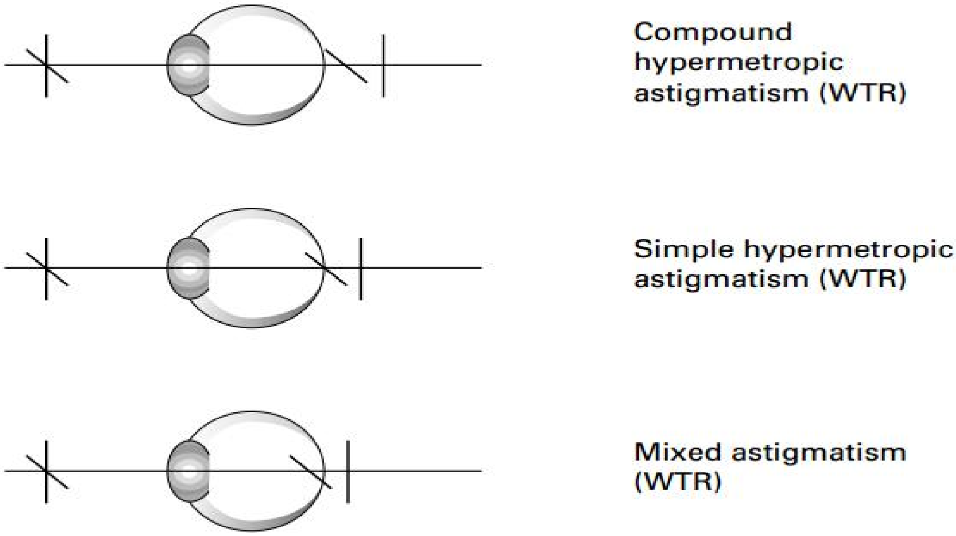


Fig. 3A Types of astigmatism with respect to refractive error

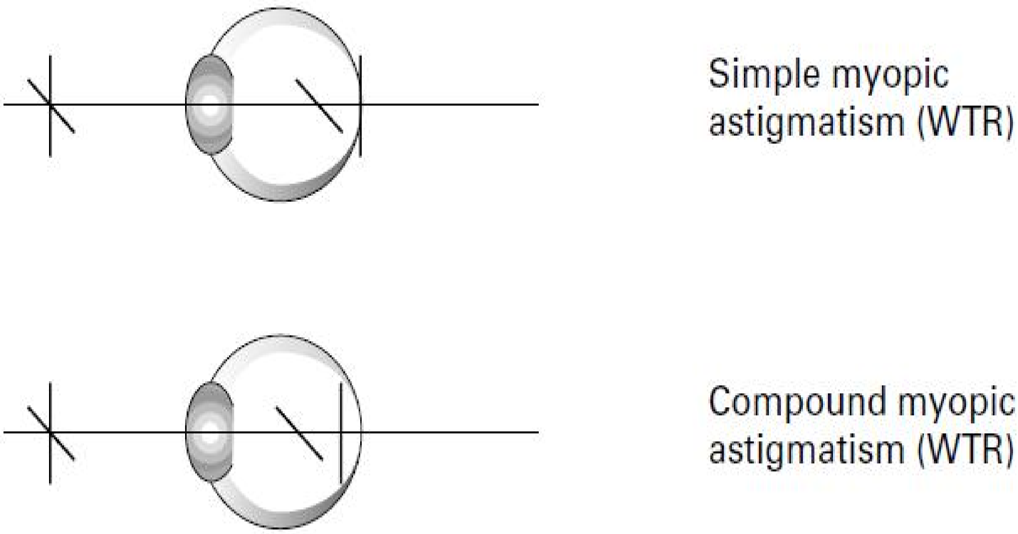


Fig. 3B Types of astigmatism with respect to refractive error

<u>Irregular Astigmatism</u>

Irregular astigmatism is said to occur when the orientation of the principal meridians changes from one point to another across the pupil, or when the amount of astigmatism changes from one point to another. Refraction in different meridians conforms to no geometrical plane and the refracted rays have no planes of symmetry. This is found only in pathological conditions of the cornea i.e. following any injury, inflammation or ulceration.

This usually exists when distribution of the refracting power over the cornea is irregular and prevents the cornea from forming a single point focus. Instead it forms a line focus. This refractive error cannot be corrected with sphero-cylindrical spectacles.

Types:

Macro Irregular Astigmatism: It occurs when the corneal curvature along a given meridian is different for each semi-meridian. A common example is keratoconus in which the inferotemporal corneal steepening occurs.

Micro Irregular Astigmatism : It exists when small regions on the corneal surface show variable refracting power i.e. 1mm as seen in the faceting of contact lens warpage or as small as a few epithelial cells seen in Keratoconjunctivitis Sicca with Superficial Punctate Keratitis. This can be easily detected where in mires become wavy and irregular due to which crisp superimposition is impossible.

Astigmatism is particularly necessary to correct since it is liable to cause the worst form of asthenopic symptoms. It leads to symptoms like headache, eyeache due to blurring of vision due to the strain caused on accommodation.

Observations reveal that the dioptric power of lesser curvature of cornea rises while the steeper curvature decreases in the post-operative period due to the flattening of the same. It is believed that the post-operative changes in astigmatism are probably due to healing of the wound and contraction of scar resulting in flattening of the cornea in the steeper meridian. It has also been observed in a study done by Lamba P A and Sood N N [40] that the spherical refraction and the astigmatism showed a progressive rise and decline respectively till the 40th postoperative day after which it becomes stable and hence accurate prescription of glasses may be given to the patient 6 weeks post cataract surgery.

PREVALENCE OF ASTIGMATISM AND CHANGES WITH AGE

Tsz-Wing Leung, Lam Kwok-Cheung et al [41] conducted a study on the prevalence of astigmatism in a clinical population. They observed that the overall prevalence of astigmatism is 28.4%. The prevalence of astigmatism increases from 17.8% in the 3 to 10 years age group to 31.4% in the 11 to 20 years age group. It then drops from 38.1% in the 21 to 30 years age group to 29% in 31 to 40 years age group. The prevalence of astigmatism then remains relatively constant (26%) before 60 years of age but climbing up to 41.8% again at 60 years of age. The risk of having ATR astigmatism for 60 years age compared to 3 to 10 years age is as high as 128-fold. Ametropia increases the risk of astigmatism, and the risk is highest in patients with high myopia but lower in patients with hyperopia. WTR astigmatism is highly dominant in 3 to 10 years age group but gradually reduces around 60 years age. In contrast, the proportion of ATR astigmatism increases from 3 to 10 years age group to 60 years age. The increase in with-the-rule astigmatism would produce greater flattening of the cornea in the horizontal meridian, since maintained pressure must be greater along the horizontal. The proportion of oblique astigmatism changes less dramatically across the age cohorts compared with those of ATR and WTR astigmatism. It increases with a peak at 41 to 50 years of age and later reduces at around 60 years age. It is seen that age and refractive-error status, but not gender are associated with WTR/ATR astigmatism.

CAUSES OF ASTIGMATISM

Kaimbo D, Kaimbo W [42] in their study evaluated the causes of astigmatism and indicated through their study that some degree of heritability of astigmatism and also tend to favour an autosomal dominant mode of inheritance. Other studies favour a stronger environmental influence. Other possible causes suggested by Kaimbo D, Kaimbo W [42] include mechanical interactions between the cornea and the eyelids and/or the extraocular muscles or a visual feedback model in which astigmatism develops in response to visual cues.

Natural causes by this study by Kaimbo D and Kaimbo W [42] were seen to include Primary Irregular Astigmatism and Secondary Irregular Astigmatism caused by various corneal pathologies associated with elevated lesions, such as keratoconus or Salzmann’s nodular degeneration.

Surgically Induced Astigmatism examined by Kambo D and Kaimbo W [42] included Pterygium Removal, Cataract Extraction, Lamellar and Penetrating Keratoplasty, Myopic Keratomileusis, Radial and Astigmatic Keratectomy, PRK and Laser In Situ Keratomileusis (LASIK).

EFFECT OF ASTIGMATISM ON VISION

Distortion or blurring of images at all distances is one of the most common symptoms. Blurring may happen vertically, horizontally, or diagonally. Indistinctness of objects, circles elongated into ovals and tailing off of a point of light are seen. Symptoms of eye strain such as headaches, photophobia, and fatigue are also commonly seen in the study conducted by Kaimbo W and Kaimbo D [42]. Reading small print is also difficult. Other symptoms seen in the study by Kaimbo W and Kaimbo D [42] included: squinting, eye discomfort, irritation, sore or tired eyes, distortion in the visual field, monocular diplopia, glare, difficulty driving at night.

It is common to observe constricted pupils to reduce aberration; narrowed palpebral fissure to secure stenopeic slit effect; constricted brow/wrinkling and furrowing of the brows; and assumption of unnatural ocular postures in cases of oblique astigmatism patients. Consequently, uncorrected astigmatism has been found to limit educational pursuits in a study done by Emerole C G et al [43] to determine the prevalence, distribution and determinants of Astigmatism.

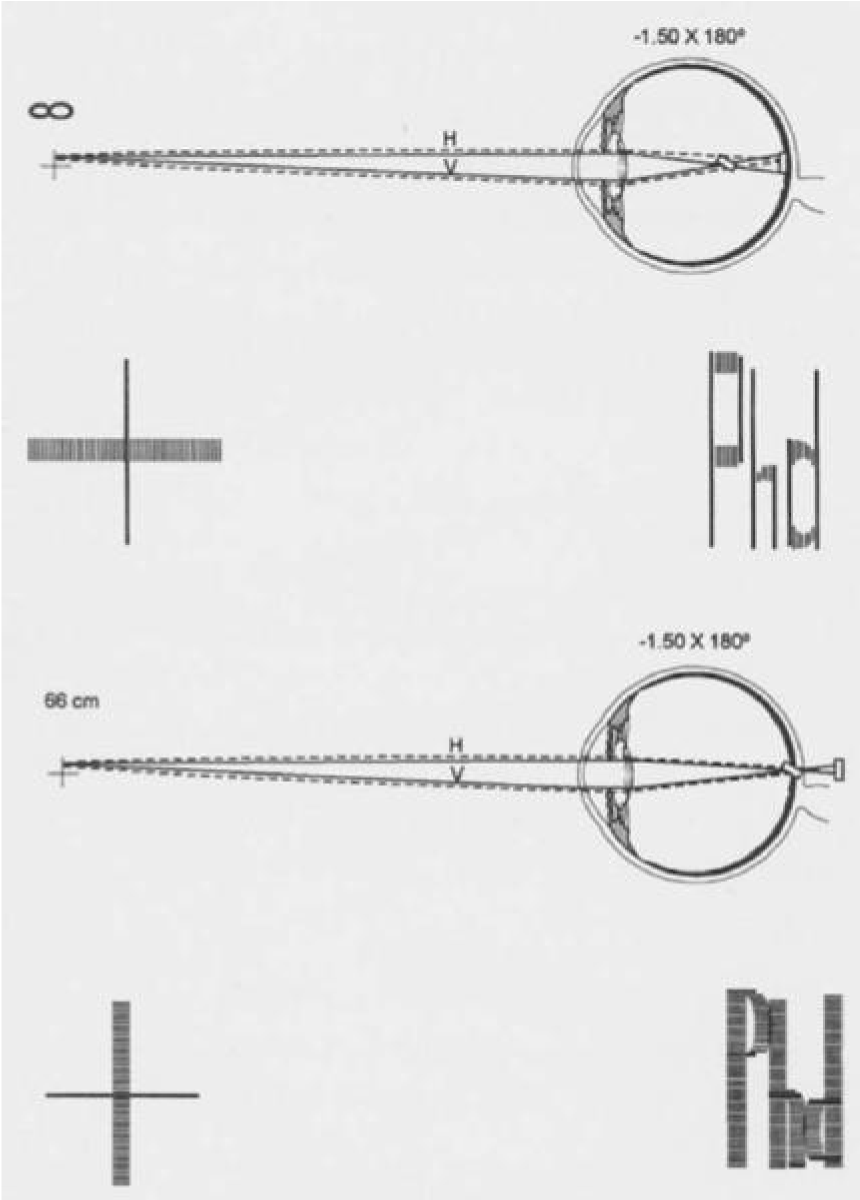


Fig. 4a Effect of WTR and ATR astigmatism on vision

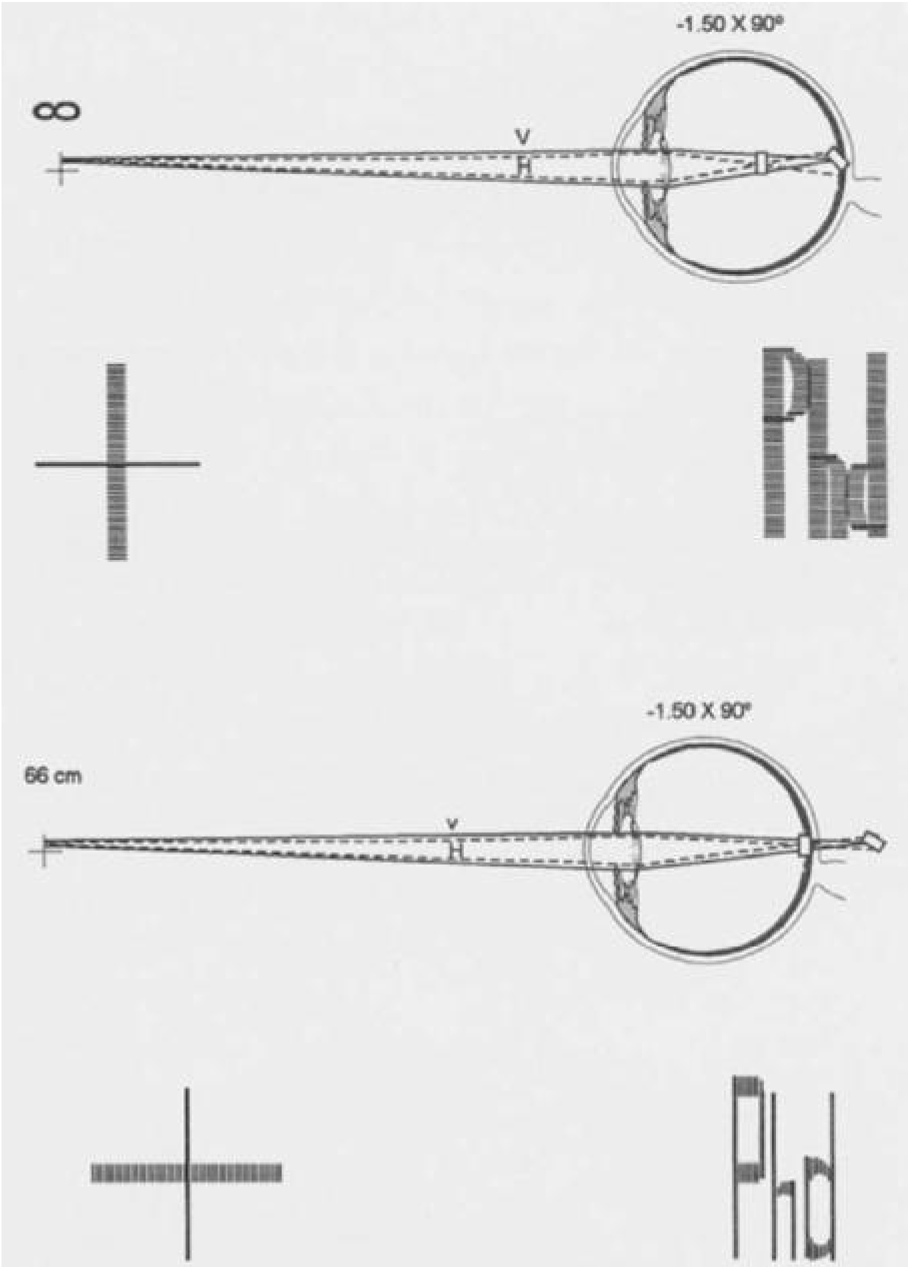


Fig. 4b Effect of WTR and ATR astigmatism on vision

The need for certain amount of post-operative astigmatism was dealt with in a study done by Nagpal K M [44] and the benefit of post-operative ATR astigmatism was explained by a study done by Tinidade F et al [45].

In a study done by Trinidade et al [45] it was observed that when a bundle of light rays emanating from a point object strike an astigmatic eye, the resulting image is altered depending on the refractive power of the principal meridians of the eye. An eye with simple myopic WTR astigmatism looking at a distant cross without correction will see the cross vertical arm (ametropic meridian) sharper than the horizontal arm (emmetropic meridian). This is called the *astigmatic paradox* (Fig. 4a). The horizontal meridian (ametropic meridian) looks sharper than the vertical meridian (emmetropic meridian) in simple myopic ATR astigmatism as per the astigmatic paradox. At near, as the rays divergently strike the eye and there is no accommodation, the focal lines dislocate backward, and the opposite occurs. In WTR astigmatism, the vertical meridian becomes the emmetropic focal line and the horizontal meridian becomes the ametropic and vice versa in myopic ATR astigmatism (Fig. 4b). At near, the ametropic meridian (horizontal in WTR and vertical in ATR) looks sharper. This is because in simple myopic astigmatism, each point is seen as a small trace with the same orientation of the ametropic meridian. If the line has the same orientation of the ametropic meridian, there is an overlapping of the various traces, corresponding to the various points, and this line, the ametropic meridian, will look sharper. Thus, in WTR astigmatism vertical lines are sharper for distance and horizontal lines are sharper for near and vice versa for myopic ATR astigmatism.

Vertical and horizontal lines predominate in test letters as well as in most objects in our environment. In printed matter, where lower case letters predominate, the ascending vertical strokes of such letters as ‘d’ provide important clues to their recognition, as do the descenders of such letters as *p* and *y.* In addition, in printed matter there is usually less space between the letters on a line than between the lines themselves. Therefore, if horizontal components of the letters are sharper, as in WTR astigmatism for near, the letters run together, becoming less legible. Conversely, when the vertical lines are sharper, as in ATR astigmatism for near, the letters appear more separate and thus more legible. That is why low simple myopic ATR astigmatism provides better uncorrected near visual acuity than simple myopic WTR astigmatism. Thus, the study by Trinidade et al[45] and Nagpal K M et al[44] helped to conclude that low, simple, myopic ATR astigmatism after surgery helps patients read without correction .

In distance vision, vertical lines are sharper in WTR astigmatism and horizontal lines are sharper in ATR astigmatism. However, as there is more space between objects or printed matter in distance, there is lesser tendency for the objects or letters to run together or overlap. This is why distance acuity between the two types of myopic astigmatism is similar.

It was suggested in the study by Trinidade et al [45] that low simple myopic ATR astigmatism post cataract surgery can be a good alternative to multi-focal IOL implantation. However it is interesting to note that it was suggested in the study by Emerole et al [43] that –0.50DC of against-the-rule (ATR) astigmatism produces more asthenopia than 1.00DC of with-the-rule(WTR) astigmatism.

REFRACTION

The process of refraction includes the aberrations of the whole of the eye including the aberrations of the anterior and posterior surfaces of the cornea and IOL and the posterior capsule. Retinoscopy serves a remarkably precise objective tool for assessment of the refractive status of the eye which includes the spherical error and the magnitude of the cylinder and its axis.

Refractions are normally performed at the spectacle plane or in the phoropter and not at the corneal plane. For Surgically Induced Refractive Corrections (SIRC) determined by refraction to be compared with SIRCs determined by keratometry or topography, they must be vertexed to the corneal plane. To vertex spherocylindric refractions to the corneal plane, the spherocylinder must first be converted to the cross cylinder form. When correctly vertexed to the cornea, the astigmatism at the corneal plane is almost one-quarter dioptre less than that at the spectacle plane.

The astigmatism is always less at the corneal plane than at the spectacle plane for compound myopia. For compound hyperopia, the relationship is just the opposite; i.e., the astigmatism is always more at the corneal plane than at the spectacle plane. According to a study done by Holladay J, Dudeja D et al [46] this vertex conversion of the SIRC from spectacle plane to the corneal plane must be performed before keratometric or topographic data are compared. Holladay J, Moran J et al [47] in their study stated that an SEQ of Zero indicates that the circle of least confusion is located on the retina and in such cases the corneal astigmatism will be equal to the cylinder power at spectacle plane.

The refractive surfaces of the eye include mainly the cornea and the lens. It was observed by He J, Lu L et al [48] in their study observed that lens power is not linearly associated with refractive error and is affected by many factors including age, cataracts and other factors. Hence they concluded that retinoscopy will not be able to accurately predict the refractive error in such conditions like cataract.

MEASUREMENT OF THE CORNEAL CURVATURE

Zones of cornea and Importance

Clinically, the cornea may be divided into zones. The central zone is 1-2mm and closely fits the spherical surface. It is surrounded by a paracentral zone, a 3-4mm doughnut zone with an outer diameter of 7-8mm, which progressively flattens from the centre. The central and paracentral zones together form the apical zone and are predominantly responsible for the refractive power of the cornea. The peripheral/transitional zone which lies outside the paracentral zone is the area of greatest flattening and asphericity. It has an outer diameter of approximately 11mm. Outside to it, lies the limbus where the cornea steepens prior to joining the sclera at the limbal sulcus.

The refractive power of the cornea is determined by the shape which is in turn decided by the curvature of the cornea. Hence determination of the corneal curvature is very important to determine the refractive status of the eye.

HISTORY AND BACKGROUND

1619 - A description of corneal curvature given by Christoph Scheiner. (By comparing apparent sizes of images of window viewed by reflections from cornea with relative sizes of the images seen in glass marbles of various sizes held next to eye.)

1796 - Jesse Ramden designed a device exclusively for keratometric measurements to study the possibility of corneal accommodation in aphakia.

1854 - Helmholtz improved Ramden’s design to work on physiological optics.

1881 - Javal and Schiotz devise the first practical keratometer for practical use.

1932 - Bausch and Lomb improved keratometer and improved ease of use of keratometer.

KERATOSCOPY [49]

Keratoscopy refers to evaluation of topographic abnormalities of the corneal surface by direct observation of images of mires reflected from the surface of the cornea. Technique of keratoscopy allows the corneal contour to be assessed more comprehensively than could be done by traditional keratometry. Keratoscopy determines the anterior corneal contour by observation of a reflected image of an object which cannot be assessed by keratometry. The evolution and advances in the field of keratoscopy can be described as follows:

PLACIDO DISC –

It was invented in 1880 by Antonio Placido. It consists of equally placed alternating black and white rings with a hole in the centre to observe the patient’s cornea. The observer looks at their corneal reflection, the first catoptric image. Distortions of the corneal shape and curvature appear as deviations from evenly placed concentric circles. Modern photokeratoscopy is based on this principle. While this method is a simple way to make a gross assessment of any corneal irregularities, it cannot provide a detailed quantifiable assessment of the contour.

PHOTOKERATOSCOPE

It was developed by Wessley and Jensen. A Polaroid photograph is taken of a series of concentric rings and the diameter of each ring is then measured. It is basically a keratoscope attached to a photographic film camera. It was used for quantitative analysis of the corneal topography. In this the keratoscopic image is photographed and the size of the image can be varied to change the size of the corneal image. The corneal curvature is then measured by utilizing the distance of the keratoscopic rings from the cornea, the magnification of the virtual image formed by the anterior surface of the cornea and the focal length of the objective of the camera. These images cover the paracentral area of the cornea, but leave the 2-3mm central optical zone and the peripheral cornea. However corneal cylinders upto 3D can escape detection by photokeratoscopy.

VIDEOKERATOSCOPY

When a television camera is attached to a keratoscope it is known as videokeratoscopy. It has been now-a-days computerised. A portrayal of these images is known as videokeratograph. The data points on the mires can be resolve either with manual/automate digitalization.

COMPUTERIZED CORNEAL MAPPING SYSTEMS

It has now given means of looking at corneal contours with far more accuracy than had previously been possible. Photokeratoscopy uses a computer-imaging system to calculate variations in contours from a series of rings projected on to the cornea. The image from the rings is collected by a camera, which sends the data for processing. The rings and camera are linked to a computer, which shows the results on screen or as a colour print. Computerised photokeratoscopes use between 16 and 25 rings projected onto the cornea and allow more than 6,000 data points across the corneal surface to be analysed.

KERATOMETRY [49]

Keratometry works on the principle of recording the image size reflected from a known-sized object. Given the object size and distance from image to object, the radius of curvature of the cornea can be calculated. The measurement of corneal radius is made using an optical doubling system where the observer has to align the images of the mires reflected from the cornea. The doubling may be fixed or variable.

Types –

Fixed Doubling - In the fixed doubling instrument the distance between the mires is varied mechanically. When these are lined up, the reading is taken from a scale. With fixed doubling instruments K-readings are taken along each meridian in two stages. Eg Javal-Schiotz Keratometer and Helmholtz Keratometer.

a. Helmholtz Keratometer

It is not currently in use. It consists of 2 plates each of which displaces the image through half of its length and the total displacement gives the size of the image. It dispenses with the need of immobilization of the eye. The axis of the telescopes coincides with the plane of separation of glass plates. These plates can be inclined one to the other at known angles, and the angle of incidence of light falling on them from a point in front can be varied and measured.

Javal-Schiotz Keratometer

It works on the principle of variable object size and constant image size. It consists of the object which consists of stepped green filter and rectangular red filter illuminated by small lamps. The image of these mires on the patient's cornea forms the object for the rest of the system. The objective and doubling prism of Wollaston type form the doubled image of the new object and the eyepiece lens enables to observe the magnified view of the doubled image. The mires on the cornea are adjusted to focus on the centre of the cornea. When the control mires just meet, the scales associated with the mire separation indicate the correct corneal radius and dioptric power of the cornea. This is done one meridian at a time; first the 90^0 and then the one perpendicular to it. In astigmatism there occurs overlapping or moving apart of the mires. Each step of the mire corresponds to 1D of astigmatism.

VARIABLE DOUBLING

In a variable doubling instrument the object size remains constant. This is achieved using prisms in the optics of the instrument. The prisms may be arranged simultaneously to produce doubling across the two principle meridians with readings from both taken once the instrument is lined up. Examples are Bausch-Lomb Keratometer.

Bausch- Lomb Keratometer

The Bausch- Lomb Keratometer consists of an object (a circular mire with 2 plus and 2 minus signs), the objective lens (to focus the light from the object along the central axis), Diaphragm and doubling prisms (to split the image of the object) and the eyepiece lens for viewing the image. Light passing through the left aperture of diaphragm is made to deviate above the central optical axis by a base-up prism and that through the right aperture of the prism is deviated to the right of the central optical axis by the base-out prism. The images passing through upper and lower apertures do not pass through any prism and the image is produced in the axis. The total area of the upper and lower apertures is equal to each of the other 2 apertures keeping the brightness of the image equal. The upper and lower apertures also act as the Schiener's Disc; doubling the central image. Due to the image doubling the images are produced side by side as well as at 90^0. Hence it allows the measurement of the 2 meridia at the same time; hence proving its name of One Position Keratometer. After adjusting the instrument and patient position, the mires are focussed and the plus signs are superimposed using horizontal measuring control and the minus signs of the central and upper images are coincided with the help of vertical measuring control and these give the horizontal and vertical corneal curvature readings. For oblique astigmatism the whole machine is rotated until the plus signs align completely. Corneal Curvature is then measured in this meridian and the meridian which lies at 90 degrees to it.

AUTOMATED KERATOMETRY

It is similar to a autokeratometer. In it the reflected image of the target is focused onto photo-detector which measures image size and hence computes the corneal curvature. The target mires are illuminated with infra-red light. It has exceptionally high precision.

LIMITATIONS OF KERATOMETRY

It assumes that the cornea is completely spherical or spherocylindrical structure while actually it is a aspheric structure. It measures the refractive status of only the central part of cornea. (3-4mm). It is not very accurate for measurement in very steep or flat corneas. It can't be used if the cornea has multiple small irregularities. Distance to focal point distance is approximated by distance to image.

TOPOGRAPHY [50]

Corneal topography is used to image the cornea by projecting a series of concentric rings of light on the anterior surface, constituting a Placido image. The reflected light is analysed using computer software to produce a detailed surface map. A major application is the detection and management of corneal ectasia, principally keratoconus; screening for corneal ectasia is especially important prior to refractive surgery. It is used in the management of refractive error with regards to relation to refractive surgery as well as sometimes for contact lens fitting, and can be used to measure corneal thickness. Scheimpflug imaging is a newer technology that may offer advantages in topographic imaging. Anterior segment optical coherence tomography (OCT) and ultrasound biomicroscopy can also be used to image the cornea.

Corneal topography can also be used to show the effects of keratorefractive procedures. Pre- and postoperative maps may be algebraically subtracted to determine whether the desired effect was achieved. Corneal mapping may help to explain unexpected results, including undercorrections, aberrations, induced astigmatism, or glare and halos, by detecting decentered surgery or inadequate surgery, such as shallow incisions in radial keratotomy. Corneal topography is useful in managing congenital and postoperative astigmatism

ASTIGMOMETER [51]

The astigmometer was first described by Amoils S P [51] in his study. The astigmometer is a simple accessory which is attached to a surgical microscope. It is used to to determine intra operative astigmatism and set up the wound to reduce post-operative astigmatism. The light source is a circular arrangement of high-intensity light-emitting diodes attached to the operating microscope body. A self-illuminating ring in the focal plane of one eyepiece is rotated about its axis by means of a dial with a sterilisable cover. The oval produced is matched to that of the reflected light ring produced by the anterior corneal curvature. By means of the principle of concentric or superimposed ovals a reading can be made. When a circular ring of lights is reflected from the surface of the cornea, an estimation of the corneal astigmatism existing at that time can be made. The radius of curvature, if in the vertical meridian is longer than the radius of curvature in the horizontal meridian; causes a 'flattening' of the cornea vertically and results in an against the rule' astigmatism. An elliptical reflex with the longer axis directed vertically demonstrates an 'against the rule' astigmatism. The radius of curvature of the cornea in the vertical meridian becomes shorter than the radius of the curvature in the horizontal meridian. This causes a 'steepening' of the cornea vertically and results in’with the rule' astigmatism. An elliptical reflex with its shorter axis directed vertically shows’with the rule' astigmatism.

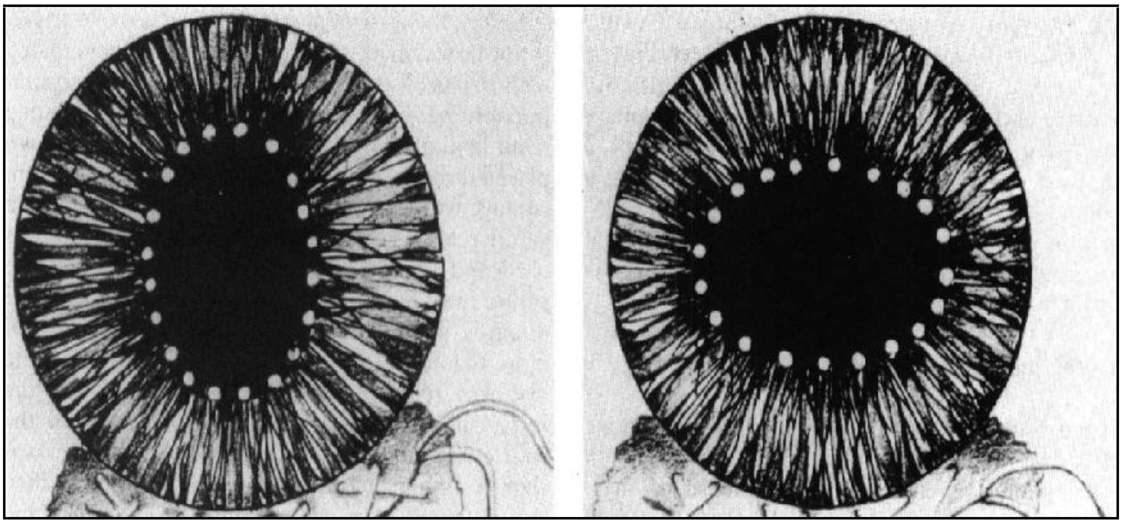


Fig. 5 Astigmometer

SURGICALLY INDUCED ASTIGMATISM AFTER CATARACT SURGERY

Apart from being a procedure that restores vision loss due to the lenticular opacity, Cataract Surgery is changing into a procedure that aims for postoperative emetropia. It was suggested by Rao G N et al [31] in his study to look upon the cataract incision itself as a refractive procedure capable of permanently reducing the astigmatic component of the pre-operative refractive error maintaining sphericity in patients without preoperative astigmatism.

Since first described by Donders, it has been known that incision made during cataract surgery can produce astigmatism. However since the advent of the procedures of suturing the section and IOL implantation, surgically induced astigmatism has become more of a concern.

POST-OPERATIVE CHANGES IN ASTIGMATISM

The astigmatism after cataract surgery is generally Against-The-Rule (ATR). It is so because there occurs flattening of the corneal curvature along the meridian of the incision and steepening along the perpendicularly opposite meridian. Also, usually the incision is placed along the superior aspect of the eyeball.

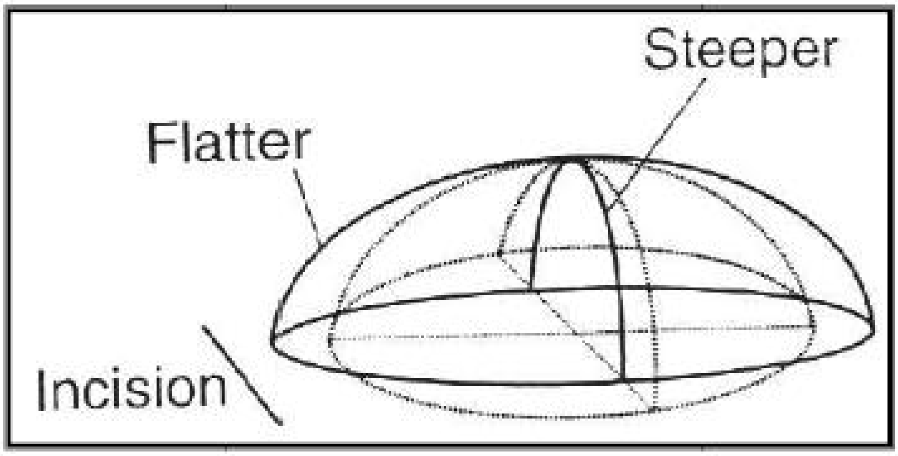


Fig. 6 Post-Operative Corneal Changes

POST-OPERATIVE ASTIGMATISM DUE TO SUTURES PLACED DURING CATARACT SURGERY

Suture is also an important factor for astigmatism. Although the use of different suture materials, suturing techniques, and other suture manipulations may influence the early postoperative outcome, the ultimate astigmatic result was seen to be predominately influenced by wound size and placement in a study done by Morlet N et al. [52]

Suture and tissue adhesive reduce tissue elasticity. Suture at appropriate stretch and localization may reduce SIA. However, in a study done by Reading V [53] on post-operative astigmatism it was seen that stretched and misplaced sutures may flatten the incision site and increase astigmatism in that meridian by steepening in the central optic zone. In the same study it was seen that there is a reduction in the astigmatism from 1.72 D with virgin silk to 0.9 D with monofilament nylon. A small section, a single suture, and minimal tissue handling were seen to reduce the resultant changes in curvature in the study conducted by Reading V [53]. Cases where a larger section is cut (140-160°) and more sutures used superiorly, the curvature in the vertical meridian varied little, but the horizontal steepened and tended to remain steeper than in the preoperative state. These long-term changes on comeal curvature were explained in the study by Reading V [53] on the basis of the process of crimping. When considering a large section, it is as if one were placing the index finger and thumb at 3 o'clock and 9 o'clock respectively on the limbus, and gently pinching. This has the effect of steepening the curvature in the horizontal meridian, with little effect on the vertical. With small section sizes as well as phacoemulsification the pinching effect will have less of a purchase and consequently less effect on corneal curves.

SURGICALLY INDUCED ASTIGMATISM IN MANUAL SMALL INCISION CATARACT SURGERY COMPARED TO CONVENTIONAL EXTRACAPSULAR CATARACT EXTRACTION (ECCE)

Kumar J and Vaish S [54] in their study stated that Manual small incision cataract surgery (MSICS) was similar to the extra-capsular cataract extraction (ECCE) technique but with its suture-less relatively smaller incision, has similar advantages to phacoemulsification and is affordable.

Minimizing incision length effectively decreases surgically induced astigmatism with both scleral and clear-corneal incisions. The incisional length of ECCE is generally 10–11 mm. Dodiya K and Parmar N [55] in their study have demonstrated that smaller incisions induce less astigmatism and achieve stability faster than do larger incisions. Also they observed that radial sutures induce central steepening, or plus cylinder, in the meridian placed, and that longer and tighter sutures generally induce more astigmatism in that meridian, decreasing the size of incision induces less astigmatism.

Postoperatively large incisions are associated with more inflammation and suture induced problems such as astigmatism and irritation. Refraction remains changing for many months postoperatively and induced astigmatism is more, thereby resulting in delayed and unsatisfactory visual rehabilitation.

Induced astigmatism is directly proportional to the cube of incision length and inversely proportional to the distance the incision is placed from the limbus. Burgansky et al [56] with their study, have shown an increase in astigmatism with an increase in incision size. Khanday et al [57] conducted a study to compare the incision characteristics of ECCE and Manual SICS. They observed that the incision in the SICS group is 6mm against the 10-12mm in the ECCE group and is about 1mm away from the limbus compared to the ECCE group where the incision is just on the limbus. It was also seen in the study that sutures cause steepening along the meridian of the incision. Too many sutures, deep bites, excessive tension applied all were seen to predispose to WTR shift and have a direct relation with the magnitude of induced astigmatism. SICS induces less surgically induced astigmatism, less inflammation, less complications influencing the overall visual prognosis and quick stabilization of refraction, hence providing better and rapid visual rehabilitation in the postoperative period as compared to ECCE.

FACTORS RESPONSIBLE FOR POST-OPERATIVE ASTIGMATISM AFTER MANUAL SICS WITH POSTERIOR CHAMBER INTRAOCULAR LENS IMPLANTATION

The procedure of Manual Small Incision Cataract Surgery (SICS) offers the advantages of a small sutureless incision with early visual recovery and better quality of life due to lesser amount of post-operative astigmatism.

Incision

i. Location

ii. Length

iii. Construction

iv. Site of incision depending upon pre-operative astigmatism.

LOCATION

The control of astigmatism is determined by the distance from the visual axis and the meridian in which the incision is taken. Incision in the cornea or the sclera causes the flattening of the cornea adjacent to it and along the perpendicular meridian. The meridian 90^0 away is steepened as a consequence of the coupling effect. Scleral incisions are said to induce lesser astigmatism than limbal incisions of the same size. Horizontal incisions induce lesser drift than vertical incisions. It is since a horizontal incision is placed more away from cornea. Kimura *et al* [58] have shown that surgically induced astigmatism is less with an oblique incision than with a superior incision. It was observed in the study that arrangement of fibers in the sclera makes oblique incision a tight and least astigmatic tunnel.

Astigmatic Neutral Funnel - This concept was described in a study done by Mohan S et al [35] The concept has been derived from two important mathematical equations:

Surgically Induced Astigmatism (SIA) α length of incision

SIA α 1/distance of incision from corneal centre.

Therefore, it was found by the study done by Mohan S et al [35] that incision of 3-3.5 mm at the limbus results in minimal astigmatism of 0.25 – 0.50 D and it can be considered astigmatically neutral for all practical purposes. The funnel's base is at the limbus and as it moves away it widens. The incision which is made within this funnel is astigmatically neutral.

In cataract surgery, the placement of the incision along the steeper meridian of the cornea helps to decrease the amount of pre-existing pre-operative astigmatism.

Superior incisions are said to have twice the impact on post-operative astigmatism than temporal incision. According to Haldipurkar S S et al, [21] this is observed to be due to the fact that the temporal limbus is farther away from the visual axis than the superior limbus.

A study conducted by Dr.K.Sathish [59] done on 130 eyes showed that the mean surgery induced astigmatism was found to be 1.45 ± 0.4 D in superior and 0.70 ± 0.3 D in the temporal incision group. Amount of surgery induced astigmatism was found to be significantly lower among the temporal incision group (t = 11.444, p = 0.000). Thus, SICS through temporal approach provides a better stabilization of refraction with significantly lesser amount of SIA than superior approach.

In another study done by Junsuke Akura, [60] a prospective study was done on 144 eyes, 6 months postoperatively, at 6 months, the mean pre-existing absolute astigmatism of 2.02 D was reduced to 1.07 D in the superior arcuate group, from 1.48 to 0.84D in the temporal arcuate group, from 1.15 to 0.75D in the superior frown group, and from 1.00 to 0.66 D in the temporal frown group. These differences were significant.

In a study done by Malik VK et al [61] on 35 eyes, it was seen that SICS with temporal approach provides better stabilization of refraction with significantly less SIA than superior approach. The pre and postoperative complications are similar in both approaches.

Another study done by Hemlata Yadav and Vaishali Rai, [61] the mean SIA with superior incision was found to be 1.37 ± 0.65 and with temporal incision was 0.67± 0.40. It was found tobe highly significant (P value < 0.001). SIA induced by superior incision was 45.28 % more than temporal incision.

Gokhale N and Sawhney S [63] in their stated that the temporal location is farthest from the visual axis and any flattening due to the wound is less likely to affect the corneal curvature at the visual axis. When the incision is located superiorly, both gravity and eyelid blink tend to create a drag on the incision. These forces were seen to be neutralized better with temporally placed incisions because the incision is parallel to the vector of the forces in the study done by Gokhale N and Sawhney S [63]. They also mentioned that With The Rule Astigmatism induced by a temporal incision is advantageous because most elderly cataract patients have preoperative Against The

Rule astigmatism. The supero-temporal incision also, is probably free from effect of gravity and eyelid pressure and tends to induce less astigmatism. The study done by Gokhale N and Sawhney S [63] also found that induced astigmatism was lower in the temporal and supero-temporal groups compared to that in the superior group. Astigmatism in the supero-temporal and temporal groups was comparable.

LENGTH

Incision length is seen to affect astigmatism after cataract surgery. The amount of post-operative astigmatism varies directly with the length of the incision. Some authors have even suggested varying the length of the incision to regulate the amount of post-operative astigmatism and reducing it. A 3-mm incision is too small to alter the corneal shape appreciably. Such an incision maintains the preoperative cylinder profile. Large incisions cause more cylinder regression. This points towards the greater effect of manual SICS incisions of pre-operative astigmatism and the need for placing the incision on the steeper meridian.

CONSTRUCTION

The shape of the Sclerocorneal incisions was classified in a study done by Mohan S et al. [35] It was classified in terms of the initial cut as

1. Parallel to limbus – convex
2. Antiparallel- frown incision
3. Straight
4. Arrow like- chevron incision
5. ‘J’ shaped

6. Trapezoid shaped

Mohan S et al [35] in their study observed that when the incision is made in the astigmatically neutral funnel with same chord length and with equal distance from the limbus, a convex incision will extend slightly outside the funnel followed by straight and then the concave incision having the least part outside the funnel. Therefore, astigmatism will also be maximum with convex incision. Sagging of the incision leading to wound gape is also maximum with convex incision.

In a study done by Jauhari N et al [64], on total of 75 patients aged 40 years and above with senile cataract, it was seen that 5% of patients in Straight incision group, 94.2% in Frown incision group and 95.7% in inverted V group attained BCVA post-operatively in the range of 6/6 to 6/18. Mean SIA was minimum (-0.88 to 0.61D @ 90degrees) with Inverted V Incision which was statistically significant. The conclusion of the study was that inverted V (Chevron) incision gives minimal SIA.

Also conjunctival and scleral dissection which is done may cause bleeding. This may require the usage of cautery which may further lead to increase the amount of post-operative astigmatism.

SITE OF THE INCISION DEPENDING ON PRE-OPERATIVE ASTIGMATISM

These days cataract surgery is seen not only as a routine surgery, but as a refractive surgery. Hence the placement of the incisions along the steeper meridian which is determined on the basis of pre-operative keratometry reading is the need of the hour.

MANAGEMENT AND MODIFICATIONS OF POST-OPERATIVE ASTIGMATISM

In his study Raviv T and Epstein R [65] have mentioned various methods used to modify and reduce the amount of astigmatism which may occur after cataract surgery. They may be classified as non-surgical and surgical which further include the following

Non-Surgical - Glasses and contact lenses are the most common methods to correct astigmatism. They are the simplest strategy and avoid the risk of infection from the use of contact lens. Spherocylindrical lenses combine Spherical and Toric correction, with 2 focal lines formed by the 2 meridians.

Soft Toric contact lenses or Rigid Gas Permeable (RGP) contact lenses also provide correction of astigmatism. Because of the increased risk of infection from inappropriate use, careful instruction on good hygiene and use of daily disposable lenses when possible are recommended. For irregular astigmatism or high astigmatism, RGP lenses provide the best vision, even in comparison with the newest surgical techniques. In fact the worse the spectacle corrected vision, the better the improvement with RGP lenses usually.

SURGICAL MANAGEMENT

Planning prior to cataract surgery

Preoperative evaluation of the astigmatism in the cataract patient includes keratometry, corneal topography, and refraction. In cataract patients only the corneal component of the astigmatism can be accurately assessed. Because the lens is removed during the operation, astigmatism calculation and planning in these patients can be complex and unpredictable. Astigmatism treatment may be indicated if there is an astigmatic difference of greater than 0.50D between the eyes, a significantly different axis, or if the second eye is also scheduled for cataract surgery. There is some debate as to which type of residual astigmatism after cataract surgery. With-the-Rule (WTR) astigmatism gives better depth of vision and is better tolerated visually. Trinidade[44] has shown that low myopic Against-the-rule (ATR) astigmatism provides better near UCVA than an equal amount of WTR astigmatism. Overcorrection with a resultant 90^0 axis shift, is not as well tolerated and should be avoided at all costs.

Incision Parameters

According to Haldipurkar S S, Shikari Hasanain T and Gokhale V[21] broad guidelines that help the cataract surgeon achieve emmetropia are as follows:

1. To centre incision along the steep meridian
2. Longer incisions produce more flattening
3. Posterior incisions decrease against the rule wound drift

4. Straight or frown incisions decrease against the rule drift.

The location of the cataract incision can have a dramatic influence on its astigmatic effect. Both proximity to the visual axis and meridional location are important to control. The placement of the incision in the steep axis whether superiorly, temporally or obliquely can help reduce the astigmatism within that meridian. The incision itself has an AK effect.

Architecture - In cases of less than 1.25D of ATR astigmatism, the use of grooved incisions may be all to control the astigmatism. Incisions are useful in the sense that they allow significant astigmatism control with only slight modification of surgical techniques.

Astigmatic Keratectomy (AK) during cataract surgery - When only incision modifications are not enough for astigmatism reduction, then additional relaxing incisions may be added. This is mostly done at the start of the cataract surgery when the globe is still firm and hydration has not yet affected the tissue. Sometimes it may be done at the end of the case to avoid micro-perforation. AK can be used to enhance the effect of the cataract incision. It is successfully used as an augmentative procedure to enhance the effect of the cataract incision.

Limbal relaxing incision - These relaxing incisions are placed at the limbus anterior to the palisades of Vogt. They have a more conservative effect on astigmatism. They vary in length from 6-10mm and 550-600μm in depth. They have the advantages of lesser foreign body sensation and more rapid recovery of vision. They are also less likely to cause overcorrection but instead under corrections seem to be more common and are ineffective for astigmatism beyond 3D.

Toric IOLs - LRIs and AKs help in correcting astigmatism but they are inherently unpredictable. The Toric IOLs however treat the astigmatism at a lenticular plane and hence maintain the asphericity of the cornea. The main problem with these lenses is the possible misalignment and rotation post-operatively. A 10^0 rotation can decrease the effect of the IOL by 33%. However clinically significant rotation of the lens is seen in less than 5% cases.

Piggyback Toric IOLs - These are used for high amounts of astigmatism. The only problem with these is that even a small amount of rotation can affect the astigmatism correction very seriously. To counter this, plate haptic lenses may be used to prevent rotation of the IOLs.

Toric IOLs with LRIs - This is also used in cases having high amounts of astigmatism. This measure helps by reducing the amount of dependence on incisional correction of astigmatism.

CALCULATION AND ANALYSIS OF SURGICALLY INDUCED ASTIGMATISM

Alpins N and Goggins M [66] in their study mentioned the methods used for the estimation of the Surgically Induced Astigmatism (SIA) which are as follows

SUBTRACTION METHOD

This is the one of the simplest methods to calculate SIA. It involves simple subtraction of the values of post-operative astigmatism from pre-operative values. However it does not take into account the axis of the pre-operative and post-operative readings and hence gives erroneous readings in cases where there is change in the axis post-operatively.

$\Delta M = M_1 + M_2$

Where M_1 - Pre-operative astigmatism

M_2 - Post- Operative Astigmatism

ΔM - Surgically induced astigmatism.

ALGEBRAIC METHOD

This has the following formula - $\Delta M^{alg} = M1^{alg} - M2^{alg}$

where $M1^{alg}$ and $M2^{alg}$ change signs according to direction of the steeper meridian. For a steep meridian between 90^o+/-45^o a plus sign is added. For rest of the meridians a minus sign is to be added. This method does denote the type of astigmatism whether ATR or WTR, but fails to point out the exact degree of the axis of astigmatism.

CRAVY'S METHOD –

The formula is as follows

$\Delta K = \Delta x + \Delta y$

Where $\Delta x = x_1 - x_2$

$x_1 = M_1 cosa_1$

$x_2 = M_2 cosa_2$

$\Delta y = y_1 - y_2$

$y_1 = M_1 sina_1$

$y_2 = M_1 sina_1$

THE VECTOR METHOD –

This method was described first by Jaffe. It is based on the technique where sum of oblique cylinders is obtained by representing the cylinders on a graph in the form of vector. A vector is an entity which has not only magnitude but also direction. The sum of 2 obliquely crossed cylinders can be found by treating the component powers of the 2 vectors as a vector in a vector diagram. However before calculating the astigmatism, the angle has to be doubled than the angle at which it is oriented before the eye. The vector diagram of these entities is then drawn and the SIA is calculated as the line joining the two vectors. A line is then drawn parallel to the baseline to determine the direction of the resultant vector. The resultant angle is then divided into halves to get the resultant vector of the Surgically Induced Astigmatism (SIA). The signs of the result do not matter as they are kept the same during each calculation.

RECTANGULAR COORDINATE (DOUBLE-ANGLE VECTOR DIAGRAM) FORMULAS

The well-recognized formula described by Jaffe for vector analysis is:

$K13 = (K_1^2 + K_3^2 \quad - 2K1K3\text{cosine}2\ [\theta 1 - \theta 3])^{1/2}$

Where

K13 = surgically induced astigmatism vector magnitude

K1 = preoperative astigmatism magnitude

K3 = postoperative astigmatism magnitude

θ1 = preoperative astigmatism steepest meridian

θ3 = postoperative astigmatism steepest meridian

Where K1 and K3 are the dioptric difference between the steepest and flattest curvatures of the cornea or maximum and minimum powers of the correcting spherocylindrical lens. This formula precisely analyzes the magnitude and direction of changes induced by individual incisions or ablations, and is therefore extremely important for analyzing astigmatic change in whichever orientation it occurs.

ALPINS METHOD

It was introduced by Alpins in 1997 and belongs to the rectangular co-ordinates group. It helps to find out the required treatment amount and its direction, is the target induced astigmatism vector (TIA), the surgically induced astigmatism vector (SIA), difference vector (DV) measures the amount and the orientation of the astigmatism treatment required to achieve the initial goal, effectively. The various relationships between the SIA and TIA tell us whether the treatment was on-axis or off-axis, whether too much or too little treatment was applied, and the adjustments required if one had the opportunity to perform the same astigmatic correction again.

POST-OPERATIVE MODIFICATIONS

Raviv T and Epstein R [65] also discussed the post-operative methods for modification of astigmatism in their study. If the predictability of the intra-operative measures may be thought to be variable, post - operative measures may be used to correct the residual astigmatism. AK may be done after cataract surgery, thought the results may be somewhat less predictable. Other options include excimer laser ablation with either LASIK or PRK or wedge resection. This option may have the advantage of reducing the residual spherical refractive error as well.

METHODOLOGY

The study was conducted in the Department of Ophthalmology, KLES Dr. Prabhakar Kore Charitable Hospital, Belagavi to assess the effect of incision placed on the steeper meridian in patients with pre-existing astigmatism undergoing cataract surgery and also the surgically induced astigmatism in those patients.

Source of Data: Patients suffering from cataract and having pre-existing astigmatism of 0.5D-2.0D who are going to be operated for Manual SICS with implantation of Rigid PMMA IOL at KLE'S Prabhakar Kore Hospital and Medical Research Centre, Belagavi.

METHOD OF COLLECTION OF DATA:

Study Design - A Longitudinal Study.

Study Period - 1st January 2016 to 31st December 2016

Sample Size – A sample size of 60 cases.

Sampling Procedure

Sample Size for the study was calculated by the following formula:

$$n = \frac{2(Z_{alpha} + Z_{beta})^2 \quad (SD_1^2 + SD_2^2)}{(mean_1 - mean_2)^2}$$

$Mean_1 = 1.45$

$Mean_2 = 0.75$

$SD_1 = 0.74$

$SD_2 = 0.41$

Type of error is

Power = 80%

Z_{alpha} = 1.96

Z_{beta} = 0.84

Selection Criteria:

Inclusion Criteria

i. Patients between 35-70 years of age undergoing Manual SICS surgery with Rigid PMMA IOL implantation at KLE'S Prabhakar Kore Hospital, Belagavi.

ii. Age between 35 to 85 years.

iii. Pre-existing astigmatism 0.25D to 2.5D.

iv. Cataracts causing significant visual disturbances (Grade II-III and Grade IV NS, PSC, Mature Cataract).

v. Patient giving informed consent.

Exclusion Criteria

a. Cataract with astigmatism >4D.

b. Cataract with Retinal Pathology like Macular, Severe Non-Proliferative Diabetic retinopathy and Proliferative Diabetic retinopathy, Glaucomatous disc cupping.

c. Cataract with pseudo exfoliation syndrome.

d. Cataract with corneal opacity.

e. Posterior Polar cataract.

f. Cataract with keratoconus or any other corneal dystrophy or degeneration.

g. Cataract with pterygium.

h. Any patient who had undergone any ocular surgery in the past. (trabeculectomy, refractive or retinal detachment surgery.)

i. Patient who refused to be a part of the study.

PROCEDURE

Patients who fulfilled the above criteria were enrolled in the study. Written and informed consent was taken from the patients by the investigator and they were taken up for the study. Data regarding the demographic characteristics of the patients were taken and entered into a pre-designed proforma by the investigator at the time of the first visit of the patient pre-operatively.

History of the following complaints was elicited:

H/O Diminution of vision [Right eye/Left eye, Duration of symptomsOnset (Gradual/Sudden), Progressive/static, Vision affected(Distant/Near), Visual improvement with bright light or dim light, Presence/absence of pain.], Coloured haloe, Photophobia, Flashes of light, Diplopia/polypopia, Floaters, Watering, Redness, Discharge, Black spots in front of the eye, C/O Curtain falling in front of the eyes, H/O wearing glasses, H/O Diabetes Mellitus and Hypertension.

Visual examination was then done that comprised of assessment of visual acuity by using the Snellen's visual acuity chart., examination of the ocular adnexa, conjunctiva, sclera, cornea, pupil, and lens. (Ocular Examination.), Slit lamp bio microscopy was done for detailed examination of the anterior segment and in order to grade the cataract. According to the slit lamp findings cataract was graded into the following grades

a) Cortical Cataract

b) Nuclear Sclerosis (Grade I/II/III)

c) Posterior Sub-Capsular Cataract.

Best corrected visual was also assessed. Retinoscopy was done. Fundus details were assessed by ophthalmoscopy. Intra-ocular pressure was measured using schiotz tonometer. Corneal Curvature was measured (Keratometry) using the Bausch-Lomb Manual Keratometer along the horizontal and vertical meridians. This was done by aligning the plus signs of the central and left images for measuring horizontal curvature and aligning the minus signs of the central and upper images to measure the vertical meridian. A-scan Biometry was done to determine the IOL power to be implanted; the IOL power was calculated using the SRK-II formula. Lab investigations were also done for the patient and included Random blood Sugar and Blood pressure measurement and routine haemogram. After the completion of the work-up and investigations of the patient and after informed consent had been taken, 60 patients were posted for Manual SICS surgery with superior or temporal incision based on the steeper meridian.

Based on the keratometric readings if the keratometric reading in the vertical meridian was greater than that of the horizontal meridian, then the patient was said to have pre-operative WTR astigmatism and Manual SICS was planned for the patient with Superior incision. If the keratometric readings in the horizontal meridian was greater than that in the vertical meridian, then the patient was said to have ATR Astigmatism and was planned for Manual SICS with Temporal Incision.

MANUAL SMALL INCISION CATARACT SURGERY:

Preoperatively antibiotic drops and dilatation of the pupils was done alongwith informed consent which was taken. The steepest meridian was marked with surgical marker pen before the administration of ocular anaesthesia with patient in a sitting position. The eye was anesthetized using 2% lignocaine with adrenaline with hyaluronidase dissolved in it by peribulbar block. The operating eye was painted with

Betadine solution and draped. Eyelids were retracted and held in position using wire speculum. Superior rectus muscle suture was put using 4-0 silk suture. Conjunctiva was incised and conjunctiva was then dissected to separate it alongwith the tenon's capsule from the underlying sclera. The remaining Tenon's Capsule was separated from the sclera by using the Tooke's knife. Bleeders were cauterised using bipolar cautery and haemostasis was achieved. The position of seating of the surgeon was determined depending on the site of the incision to be taken. The surgeon sat at the head end of the patient when a superior incision was to be taken and in case of a temporal incision to be taken, the surgeon was seated temporally. The incision was then made either superiorly or temporally based on the pre-operative keratometry readings using the help of the ring axis marker. The incision was then dissected and a tunnel was created into the clear cornea and the tunnel was also extended to both the sides to create a side-pockets. Entry was done in the anterior chamber using a 3.2mm keratome and tryphan blue dye was injected into the anterior chamber through the entry to stain the anterior capsule. After washing off the dye, Viscoelastic was put in the AC and the continuous curvilinear capsulorrhexis (CCC) was done using a cystitome fashioned from a 26-gauge needle. Hydrodissection was then done using a hydrocannula to separate the cortex from the nucleus. The incision was then extended along the entry point into the anterior chamber using the 3.2 keratome. The nucleus was then prolapsed into the AC using a lens dialler. Viscoelastic was then injected below, above and around the nucleus to protect the nucleus from touching the surrounding structures. The nucleus was then delivered out of the AC by the sandwich technique using a lens hook and a wire vectis. Residual lens matter was then thoroughly washed out of the AC using irrigation-aspiration method using the Simcoe's 2-way irrigation-aspiration cannula. Rigid PMMA IOL was then implanted into the capsular bag after the instillation of viscoelastic into the capsular bag and dialled into position. The viscoelastic is then washed out of the AC. Eye was padded and patched after instillation of the antibiotic eyedrops.

Post-operatively all patients received Topical Steroids with Antibiotics 8 times/day for a week with tapering the dose every week for the next one month., Systemic antibiotics ciprofloxacin 500mg BD for 3 days and Topical Tropicamide and phenyephrine eye drops BD for a week.

Post-operative assessment was done on 1st day, 7th day, 3 weeks and 6 weeks post-operative. Post-operative examination of the patient included

a. Visual Acuity.
b. Integrity of the corneoscleral incision.
c. Clarity of the cornea.
d. Position of the IOL.
e. Keratometry readings were taken at each visit post-operative along the horizontal and vertical meridian using the Manual Bosch-Lomb Keratometer.

The amplitude of pre-operative and post-operative astigmatism was calculated by subtracting the steeper meridian keratometric reading from the flatter meridian reading. All the calculations of the keratometric values and Surgically Induced Astigmatism (SIA) were done using Dr. Peyman Astigmatic Vector Analyser, free software which analyses astigmatic vectors and SIA by Alpins Method. [65]

Statiscal Analysis

It was done using the **Paired 't' Test.**

RESULTS

The study was conducted on 60 eyes of 60 patients that underwent cataract surgery by Manual SICS in Dr. Prabhakar Kore Hospital and Medical research Centre, Belagavi from January 2016 to December 2016. The site of incision of the surgery was either superior or temporal which was according to the steeper meridian of the operated eye.

The patient was examined pre-operatively and post-operatively followed up on Days 1, 7, 21 and 45 post surgery. Pre-operatively and at each post-operative visit the visual acuity and the keratometry values were measured. At the follow up period of post-operative 6 weeks, Best corrected visual acuity (BCVA) was recorded which was obtained after refractive correction.

P value was considered statistically significant if p value < 0.05

TABLE No. 1 - Age Group Distribution

Age Group (in Years)	No. of Patients	Percentage (%)
30-40 years	2	3%
41-50 years	2	3%
51-60 years	22	37%
61-70 years	23	38%
71-80 years	10	17%
81-90 years	1	2%
Total	60	100%

The average age of the patients was 63.7 $\pm$ 9.73 years with range being from 35 years to 81 years. The maximum numbers of patients were clustered in the age group of 61-70 years which was 23 (38%). The p value for this variable was $p = 0.5363$. (Not Significant)

TABLE No. 1 - Age Group Distribution

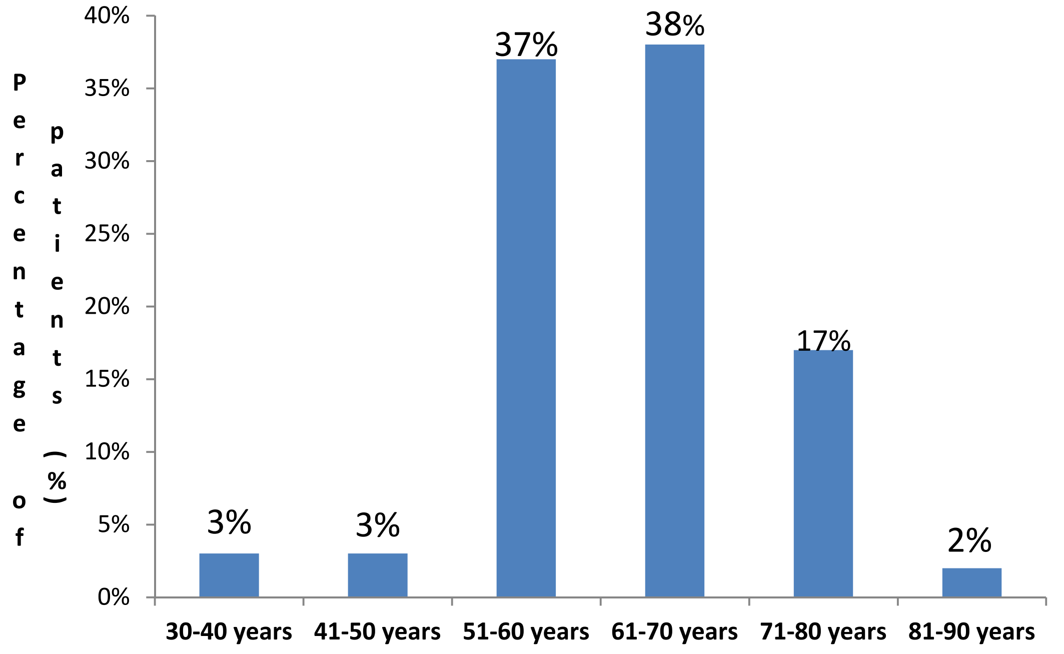


TABLE No.2 - Gender Distribution

Gender	Number	Percentage (%)
Male	25	47
Female	35	53
Total	60	100

In the study, about 47% of the patients were male while about 53% of the sample was female. The female: male ratio is 1.13:1.

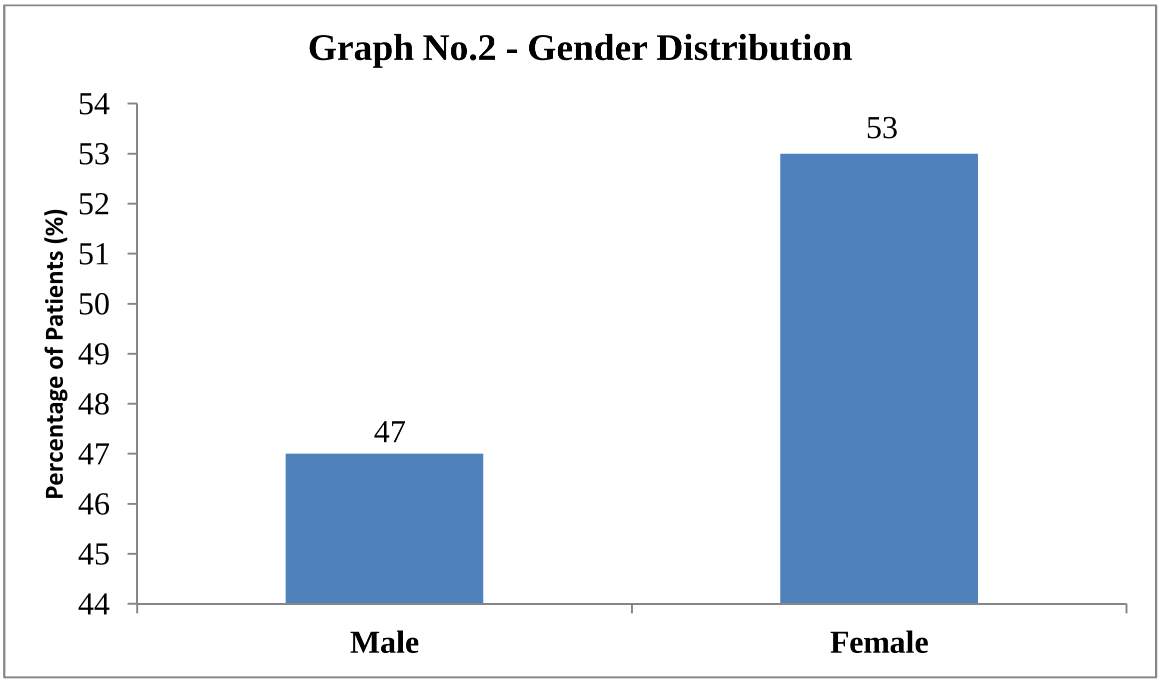


Table No. 3 – Laterality of Operated Eye.

Eye	Number	Percentage (%)
Right	**30**	**50%**
Left	**30**	**50%**
Total	**60**	**100%**

It was seen in our study that about 30 eyes of the operated eyes were Right eyes and 30 eyes of the operated eyes were Left eyes. Hence the number of Right and Left eyes were the same in our study and the difference between the two was seen to be not statistically significant.

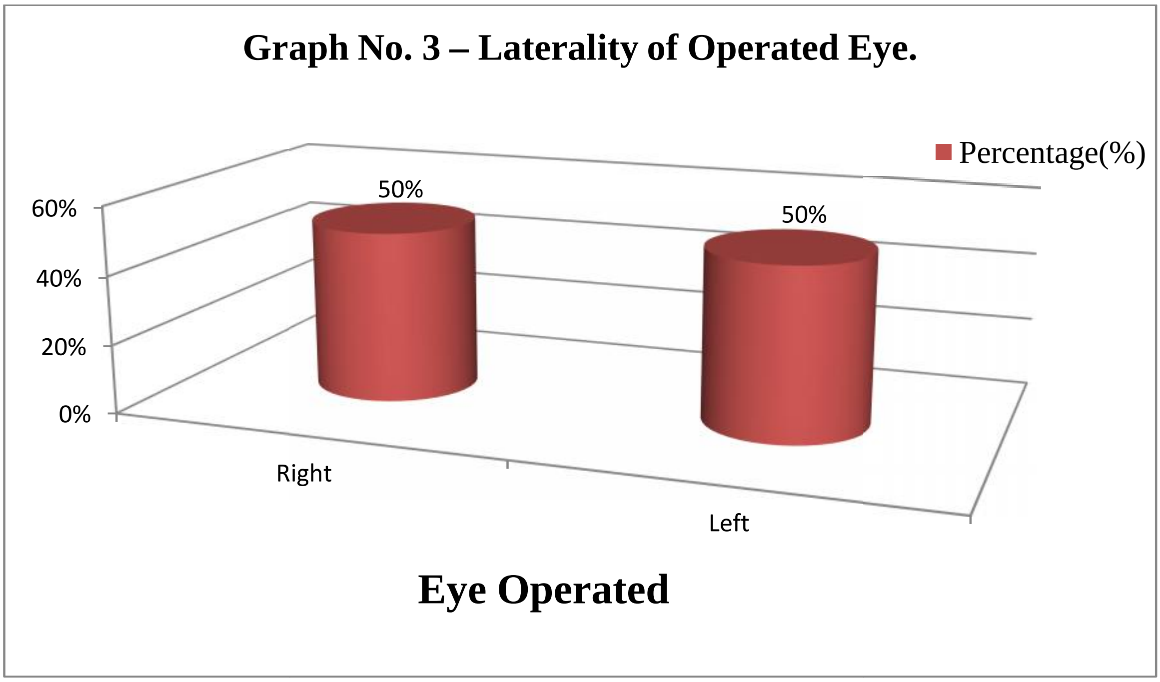


TABLE No.4 - Pre-operative visual acuity

Range of visual Acuity	Number	Percentage (%)
6/12 – 6/18	1	1%
6/24 – 6/36	10	17%
6/60 – CF 3 Mtr	15	25%
CF – PL+, PRacc	34	57%

Patients had pre-operative visual acuity ranging from 6/12 to PL+, PR accurate. The majority of the patients (n = 34) had visual acuity in the range of CF 3mtr to PL+, PR accurate. (57%)

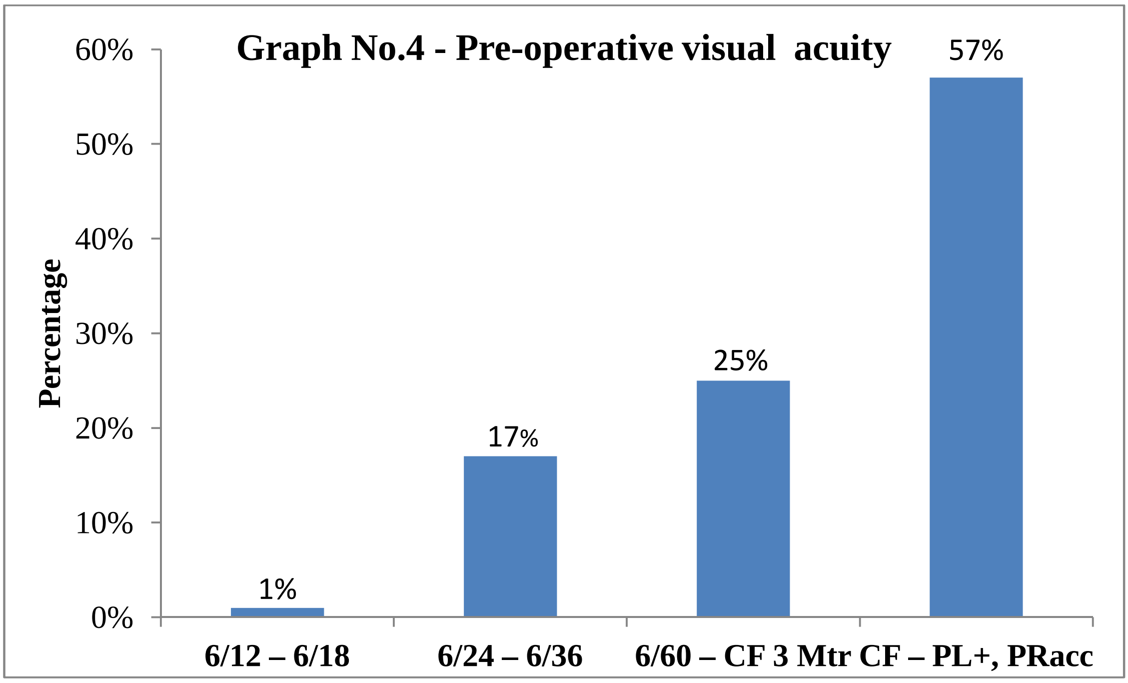


TABLE No.5 –Range of Pre-existing Astigmatism

Range of Pre-existing Astigmatism	Number	Percentage
0 – 0.5D	16	27%
0.6 – 1D	21	35%
1.1D – 1.5D	13	22%
1.6D – 2D	7	11%
2D – 2.5D	3	5%

Maximum number of patients had pre-operative astigmatism between 0.6D – 1.0D being 21 in number (35%). It was followed by patients having astigmatism in the range from, 0 - 0.5D (n=16, 27%) and then 1.1D - 1.5D (n = 13, 22%), and 1.6D – 2D (n = 7, 11%) and finally 2D – 2.5D. (n = 3, 5%)

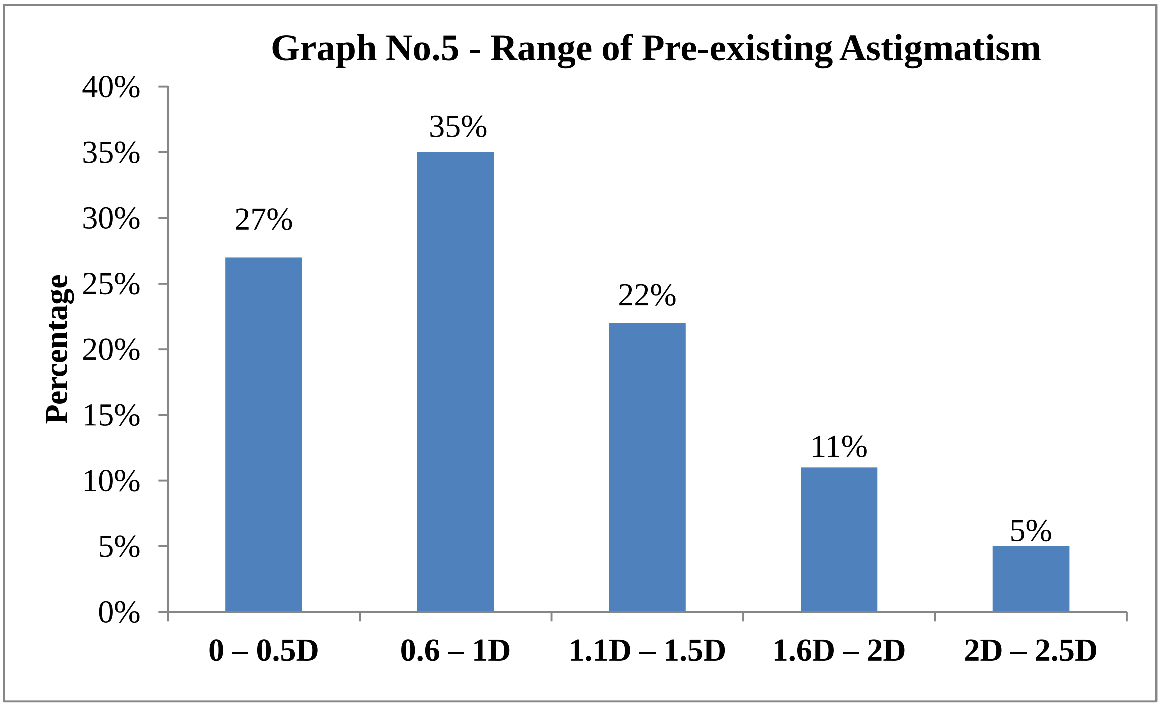


TABLE No. 6 – Site of Incision taken during Cataract Surgery

Type of Pre-operative Astigmatism	Number	Percentage (%)
Superior	34	57
Temporal	26	43
Total	60	100%

In this study, about 34 patients (57%) had pre-operative astigmatism of the WTR type, while 43% had pre-operative astigmatism of ATR type. It was seen that both the types of astigmatisms were almost equally distributed in the study population with WTR astigmatism showing a slight majority.

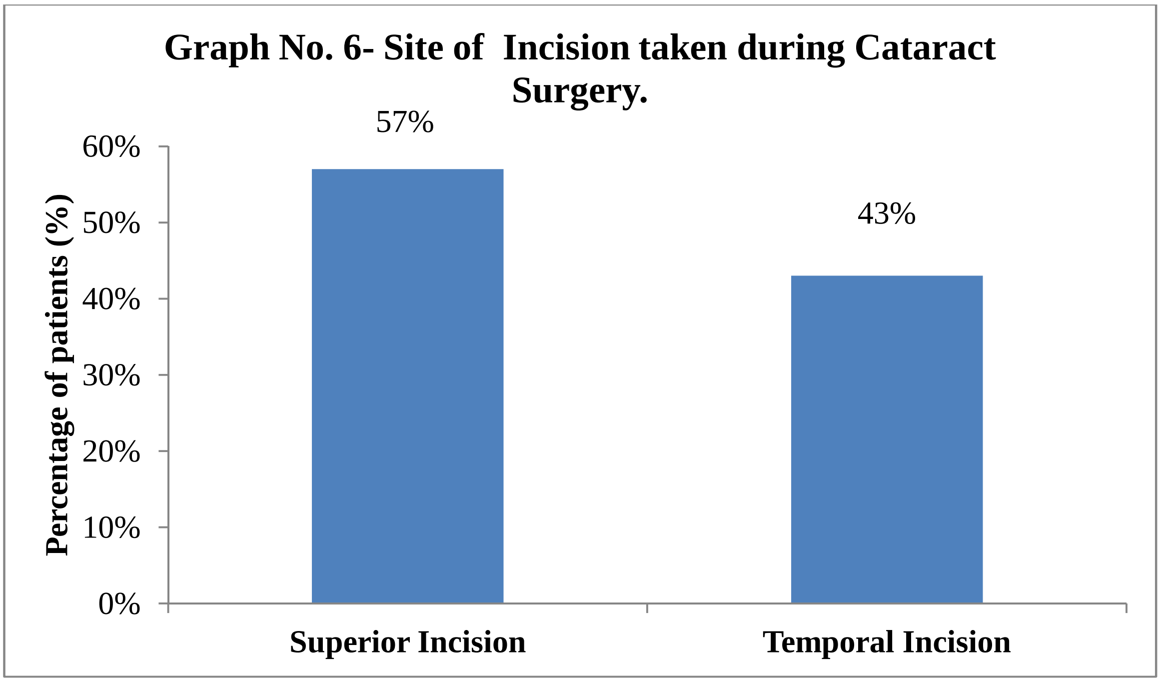


Table No. 7 – Course of Change of Astigmatism on follow-up Visits of Day 1, Day 7, Day 21 and 6 Weeks.

	Day 1		Day 7		Day 21		6 weeks	
	No. of Patients	Percentage (%)	No. of Patients	Percentage (%)	No. of Patients	Percentage (%)	No. of Patients	Percentage (%)
0D – 0.5D	24	40%	13	22%	13	22%	28	47%
0.6D – 1.0D	12	20%	17	28%	37	61%	27	45%
1.1D – 1.5D	11	18%	19	32%	6	10%	4	6%
1.6D – 2.0D	10	17%	6	10%	1	2%	1	2%
2.1D – 2.5D	2	3%	2	3%	2	3%	0	0
2.6D – 3.0D	0	0	2	3%	1	2%	0	0
3.1D – 3.50D	1	2%	1	2%	-		-	

It was seen on Post – operative Follow-up Day 1,

24 patients (40%) had magnitude of astigmatism in the range from 0D to 0.5D.

12 patients (20%) had magnitude of astigmatism in the range from 0.6D to 1.0D.

11 patients (18%) had magnitude of astigmatism in the range from 1.1D to 1.5D.

10 patients (17%) had magnitude of astigmatism in the range from 1.6D to 2.0D.

2 patients (3%) had magnitude of astigmatism in the range from 2.1D to 2.5D.

1 Patient (2%) had magnitude of astigmatism in the range from 3.1D to 3.5D.

It was seen on Post – operative Follow-up Day 7,

13 patients (22%) had magnitude of astigmatism in the range from 0D to 0.5D.

17 patients (28%) had magnitude of astigmatism in the range from 0.6D to 1.0D.

19 patients (32%) had magnitude of astigmatism in the range from 1.1D to 1.5D.

6 patients (10%) had magnitude of astigmatism in the range from 1.6D to 2.0D.

2 patients (3%) had magnitude of astigmatism in the range from 2.1D to 2.5D.

2 patients (3%) had magnitude of astigmatism in the range from 2.6D to 3.0D.

1 patient (2%) had magnitude of astigmatism in the range from 3.1D to 3.5D.

It was seen on Post – operative Follow-up Day 21,

13 patients (22%) had magnitude of astigmatism in the range from 0D to 0.5D.

37 patients (61%) had magnitude of astigmatism in the range from 0.6D to 1.0D.

6 patients (10%) had magnitude of astigmatism in the range from 1.1D to 1.5D.

1 patient (2%) had magnitude of astigmatism in the range from 1.6D to 2.0D.

2 patients (3%) had magnitude of astigmatism in the range from 2.1D to 2.5D.

1 patient (2%) had magnitude of astigmatism in the range from 2.6D to 3.0D.

It was seen on Post – operative Follow-up 6 weeks,

28 patients (47%) had magnitude of astigmatism in the range from 0D to 0.5D.

27 patients (45%) had magnitude of astigmatism in the range from 0.6D to 1.0D.

4 patients (6%) had magnitude of astigmatism in the range from 1.1D to 1.5D.

1 patient (2%) had magnitude of astigmatism in the range from 1.6D to 2.0D.

Graph No. 7 – Course of Change of Astigmatism on follow-up Visits of Day 1, Day 7, Day 21 and 6 Weeks.

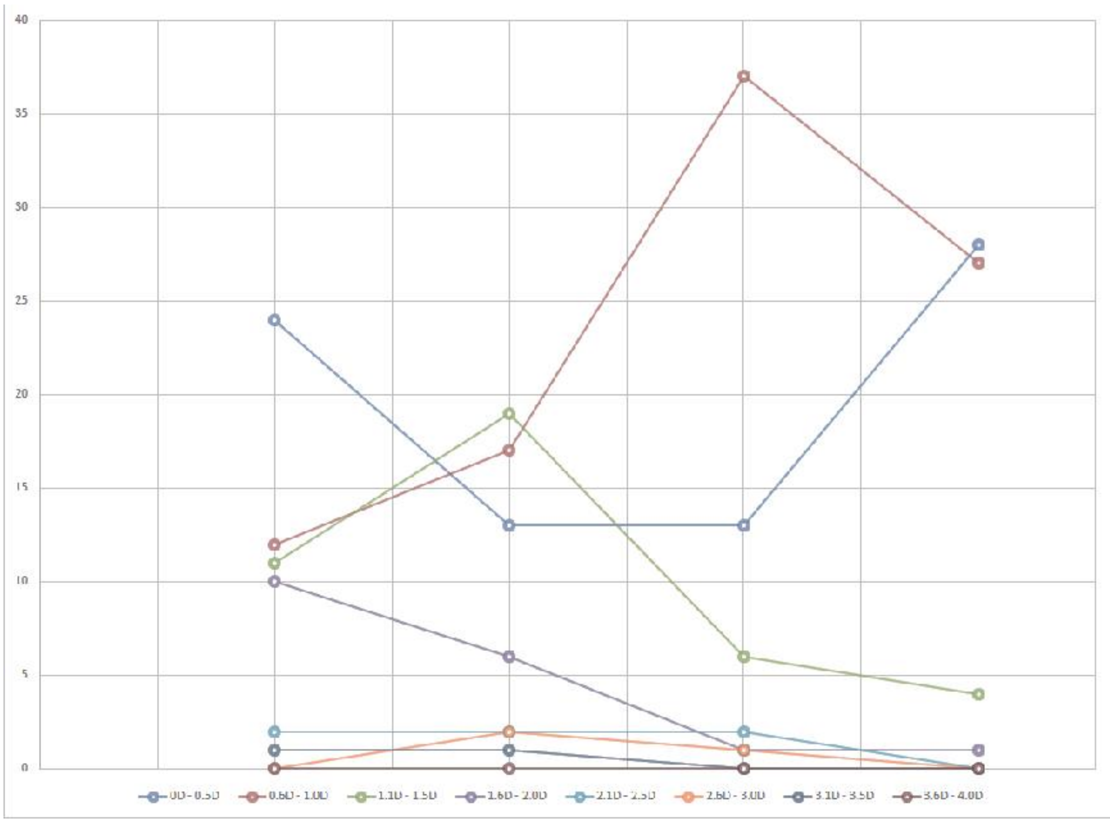


TABLE No. 8 - Range of Post-operative Astigmatism

Post-operative astigmatism	Number	Percentage (%)
0-0.5D	23	38
0.5D – 1.0D	31	52
1.0D – 1.5D	5	8
1.5D – 2.0D	1	2

This Study showed the maximum number (52%) of patients having post-operative astigmatism 0.5D – 1.0D. It was then followed by the presence of surgically induced astigmatism of about 0-0.5D which was about 38%. About 5 patients (8%) of the total study population had post-operative astigmatism about of 1.0 – 1.5D and only 1 person had astigmatism of about 1.50 – 2.0D.

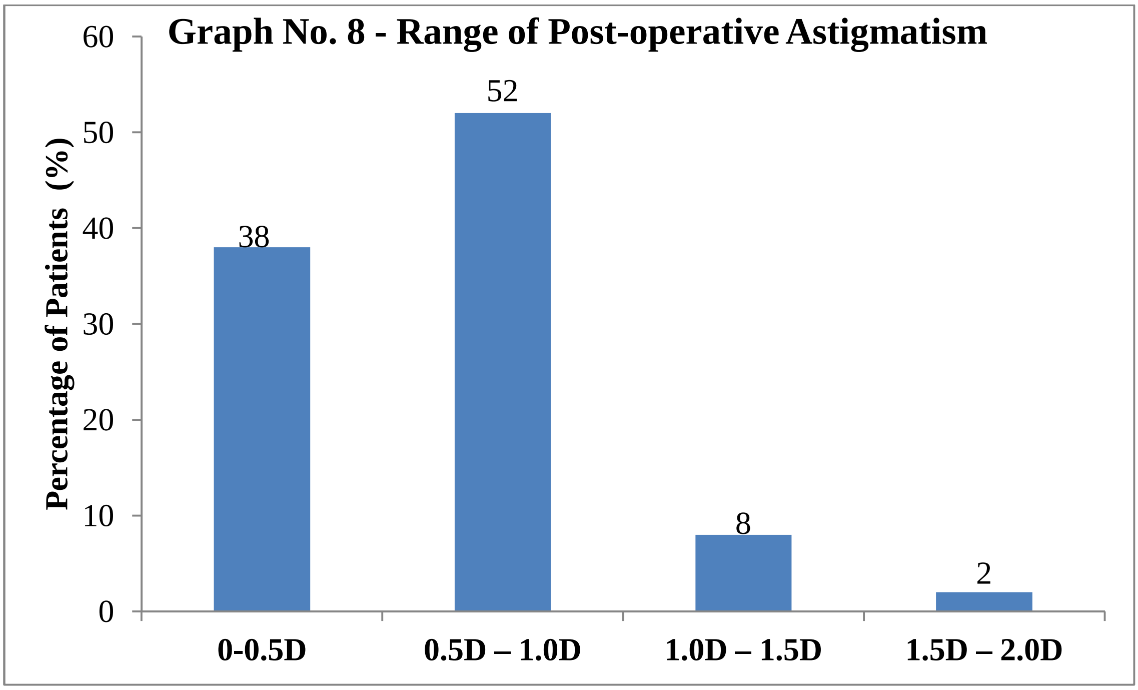


TABLE No. 9 - Type of Post-operative Astigmatism

Type of Astigmatism	Number	Percentage (%)
WTR	14	24%
ATR	46	76%
TOTAL	60	100%

In the study about 24% of the patients had WTR type of astigmatism post-operatively while 76% of the patients post-operatively had astigmatism of ATR type.

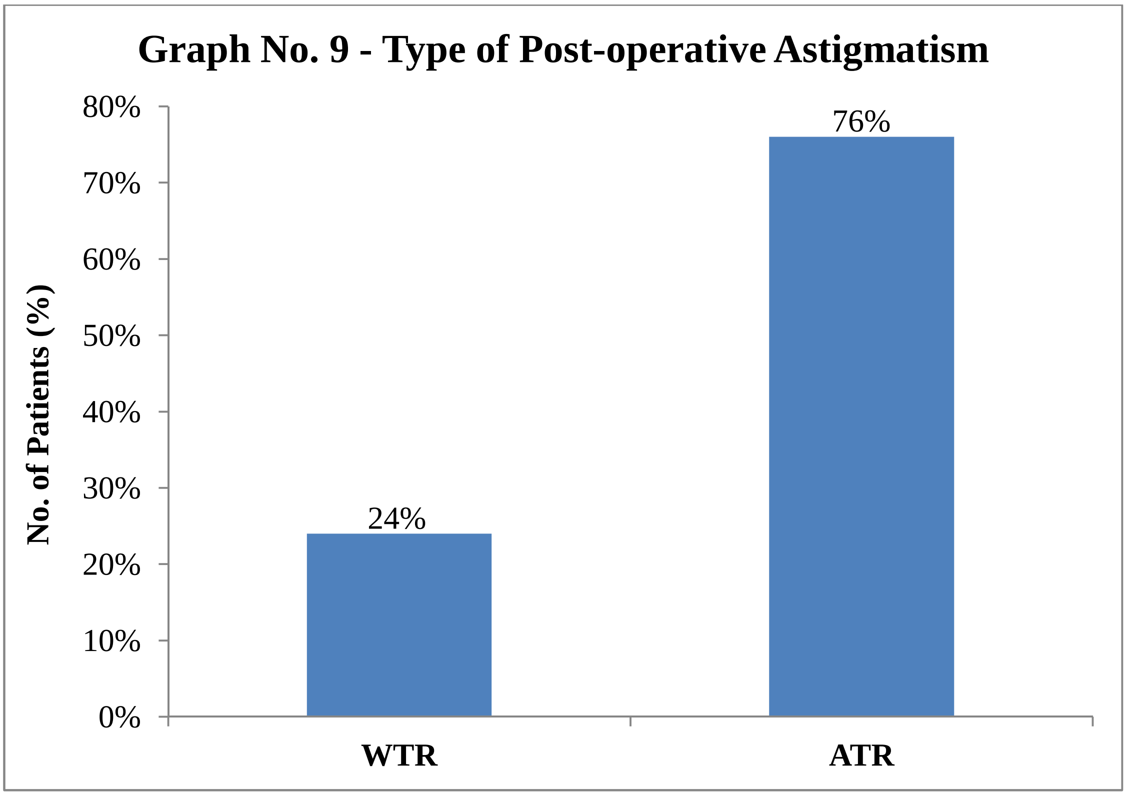


TABLE No. 10 - Change of Astigmatism

Change in Astigmatism	Number	Percentage (%)
ATR-ATR	17	28
WTR – WTR	5	9
WTR – ATR	29	48
ATR – WTR	9	15

The study showed that about 48% of the patients studied showed a transition from WTR astigmatism pre-operatively to ATR astigmatism post-operatively; while about 9% of the study group having pre-operatively WTR astigmatism remained to have WTR astigmatism post – operatively too. While 28% of the patients of the study group having ATR astigmatism pre-operatively remained to have ATR astigmatism post-operatively too, the rest 15% of the group having pre-operative ATR astigmatism showed a turn over to the WTR type post-operatively.

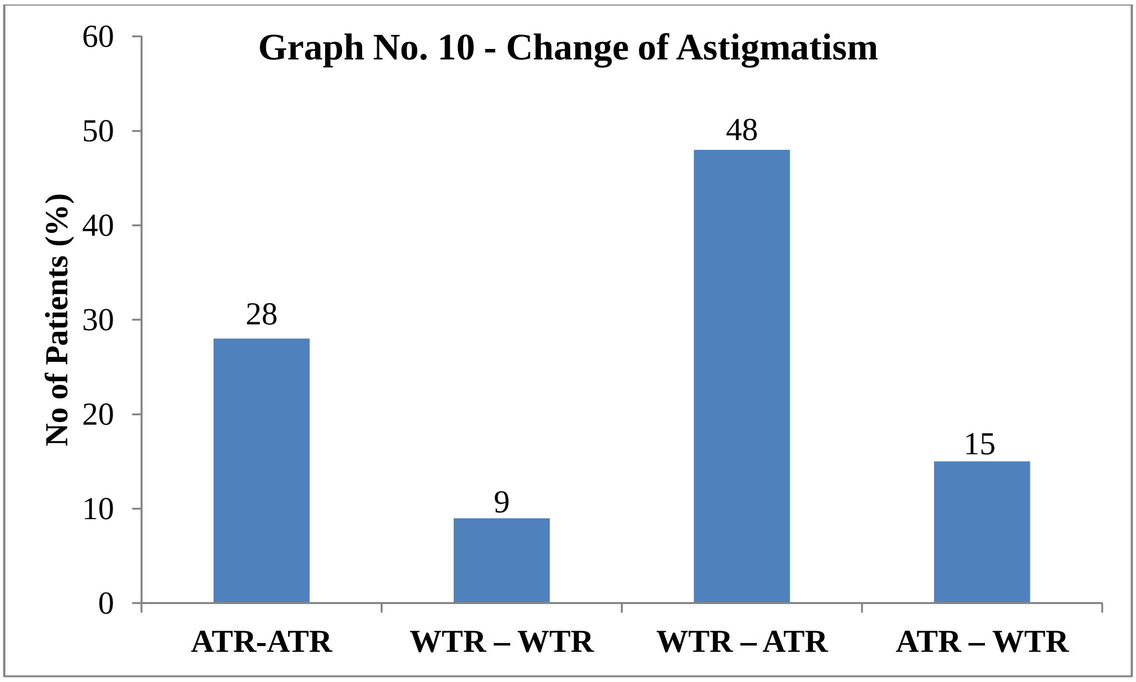


TABLE No. 11 - Range of Surgically induced Astigmatism

Surgically induced astigmatism	Number	Percentage (%)
0 – 0.5D	15	25%
0.5D – 1.0D	4	8%
1.0D – 1.50D	22	37%
1.50D – 2D	8	14%
2.0D – 2.50D	5	9%
2.50D – 3.00D	2	3%
3.0D – 3.50D	2	4%

About 25% of the patients had surgically induced astigmatism of about 0 – 0.5D, 8% in the range of 0.5D – 1.0D. The maximum number of 37% had surgically induced astigmatism of about 1.0D – 1.5D. 14% had surgically induced astigmatism in the range of 1.50D – 2.0D, 9% of about 2.0D – 2.50D, 4% in the range of 2.50D – 3.00D and 3% had surgically induced astigmatism of 3.0D – 3.50D.

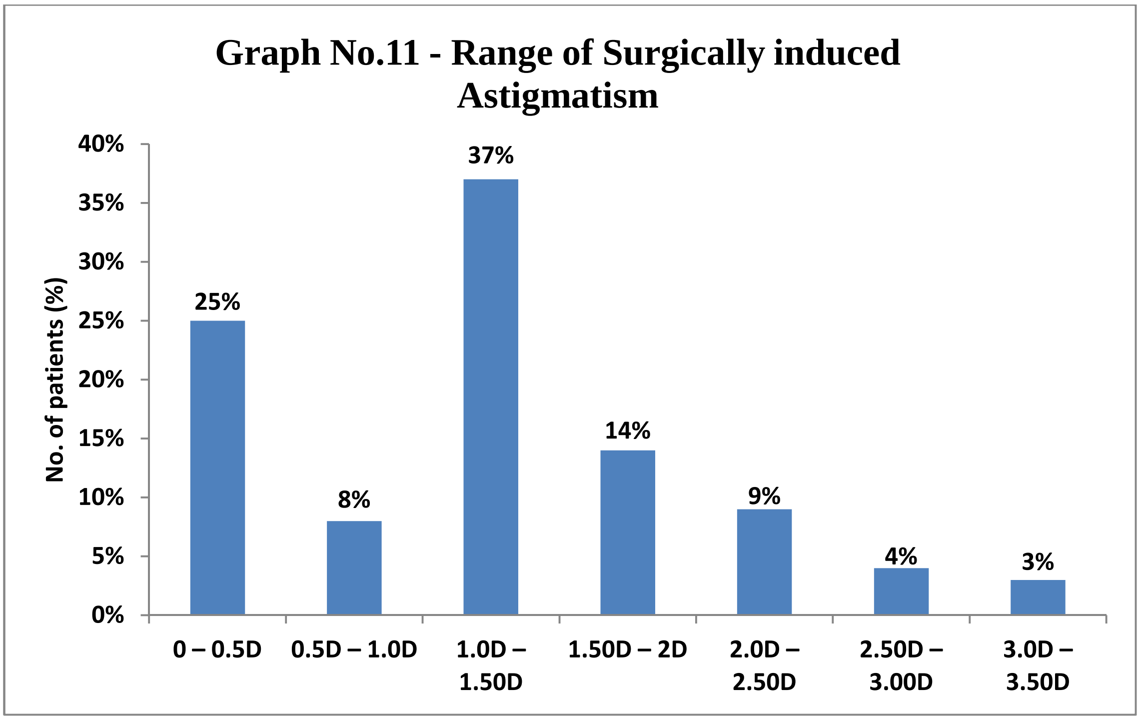

Graph No.11 - Range of Surgically induced Astigmatism
No. of patients (%)
40%
35%
30%
25%
20%
15%
10%
5%
0%
25%
8%
37%
14%
9%
4%
3%
0 – 0.5D
0.5D – 1.0D
1.0D – 1.50D
1.50D – 2D
2.0D – 2.50D
2.50D – 3.00D
3.0D – 3.50D

TABLE No.12 - Amount of Surgically Induced Astigmatism in Superior and Temporal Incision

Type of incision	Average SIA induced	SD
Superior	1.33	0.45
Temporal	0.84	0.67
Total Average	1.12	0.6

In this study the average SIA induced was 1.12 + 0.6 with p<0.001. (Statistically significant).

The average SIA induced by Superior incision was 1.33D + 0.45.

The average SIA induced by the temporal incision was 0.84D + 0.67.

The difference between the SIA caused by both the Superior and Temporal incision was very significant with a p value of 0.0011. (Very Significant).

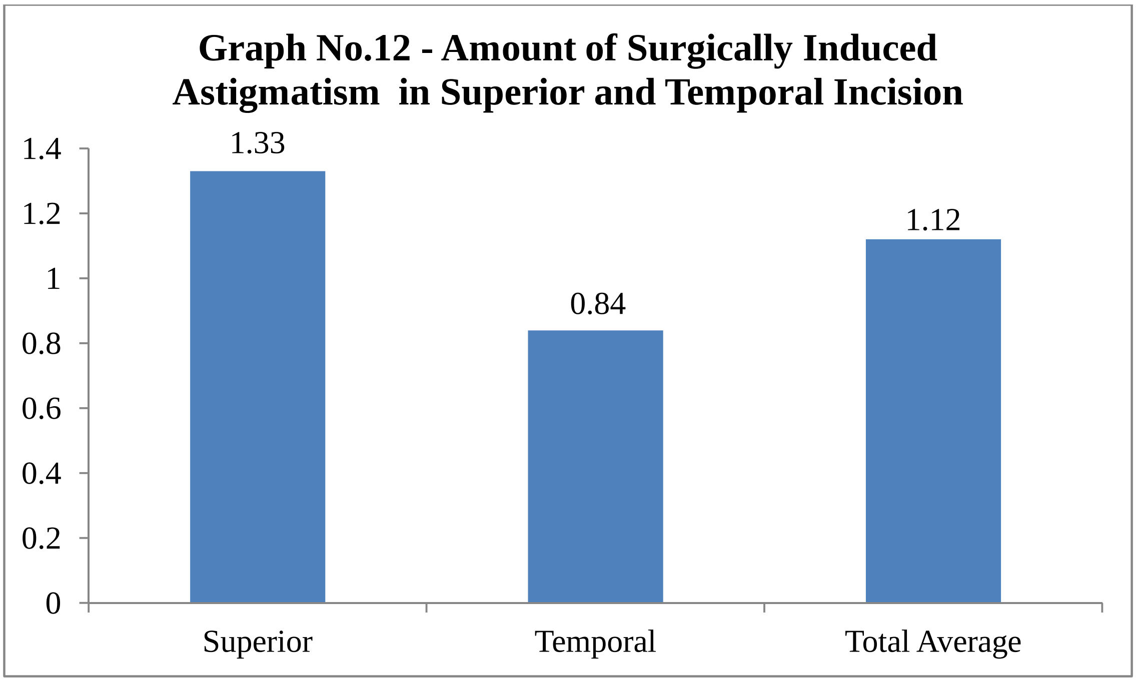

Graph No.12 - Amount of Surgically Induced Astigmatism in Superior and Temporal Incision
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1.33
0.84
1.12
Superior
Temporal
Total Average

TABLE No.13 - Temporal Incision - Range of pre-operative astigmatism and postoperative Astigmatism

Range of pre-operative astigmatism	Number	Percentage (%)	Range of Post-operative astigmatism	Number	Percentage (%)
0 – 0.5D	6	23%	0 – 0.5D	12	46
0.5D – 1.0D	10	39%	0.5D – 1.0D	12	46
1.0D – 1.5D	5	19%	1.0D – 1.5D	2	8
1.5D – 2.0 D	4	16%	1.5D – 2.0 D	0	0
2.0D – 2.50D	1	3%	2.0D – 2.50D	0	0

Pre-operatively,

23% of the patients had astigmatism in the range of 0 -0.5D

39% of the patients had astigmatism from 0.50D – 1.0D.

19% had astigmatism from 1.0D – 1.50D.

16% had astigmatism from 1.5D – 2.0D.

3% had astigmatism from 2.0 – 2.50D

Post – operatively,

46% of the patients had astigmatism in the range of 0 -0.5D

46% of the patients had astigmatism from 0.50D – 1.0D.

8% had astigmatism from 1.0D – 1.50D.

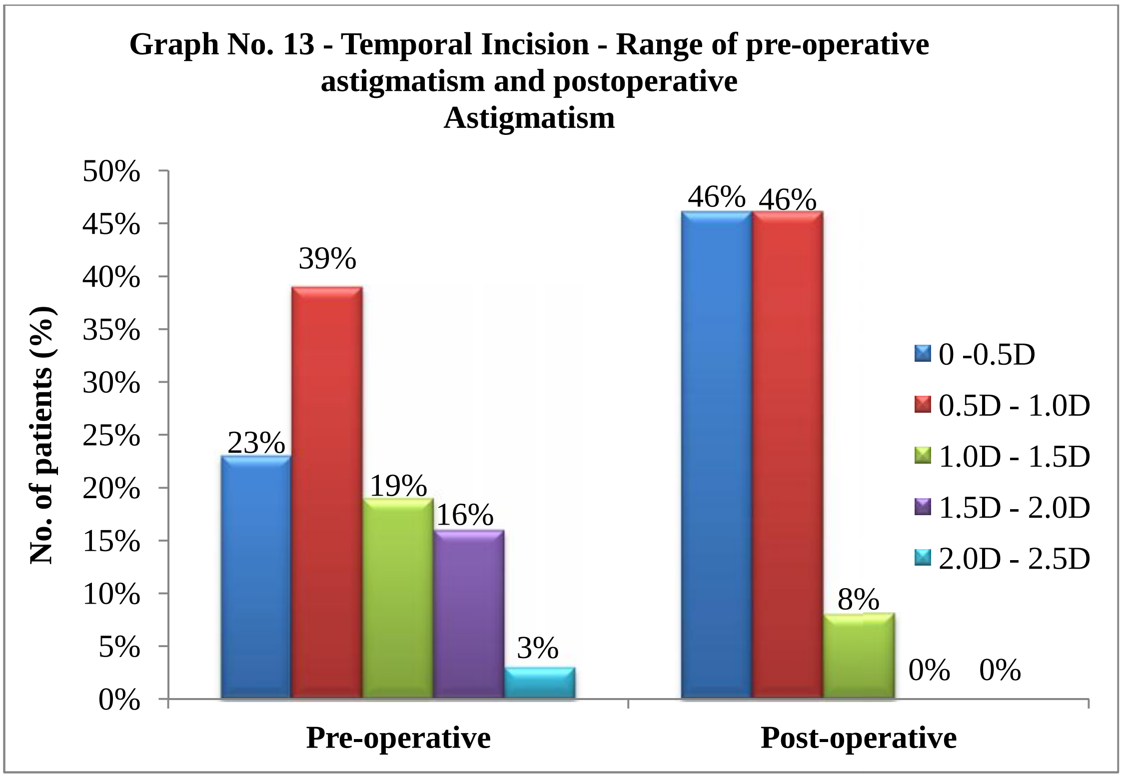

Graph No. 13 - Temporal Incision - Range of pre-operative astigmatism and postoperative Astigmatism
No. of patients (%)
50%
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
23%
39%
19%
16%
3%
46%
46%
8%
0%
0%
Pre-operative
Post-operative
0 -0.5D
0.5D - 1.0D
1.0D - 1.5D
1.5D - 2.0D
2.0D - 2.5D

TABLE No.14 - Superior Incision - Range of pre-operative astigmatism and postoperative Astigmatism

Range of preoperative astigmatism	Number	Percentage (%)	Range of Post-operative astigmatism	Number	Percentage (%)
0 – 0.5D	10	29%	0 – 0.5D	11	17%
0.5D – 1.0D	11	33%	0.5D – 1.0D	19	56%
1.0D – 1.5D	8	24%	1.0D – 1.5D	3	9%
1.5D – 2.0 D	3	8%	1.5D – 2.0 D	1	3%
2.0D – 2.50D	2	6%	2.0D – 2.50D	0	0%

Pre-operatively,

29% of the patients had astigmatism in the range of 0 -0.5D

33% of the patients had astigmatism from 0.50D – 1.0D.

24% had astigmatism from 1.0D – 1.50D.

8% had astigmatism from 1.5D – 2.0D.

6% had astigmatism from 2.0 – 2.50D.

Post-operatively,

17% of the patients had astigmatism in the range of 0 -0.5D

56% of the patients had astigmatism from 0.50D – 1.0D.

9% had astigmatism from 1.0D – 1.50D.

3% had astigmatism from 1.5D – 2.0D.

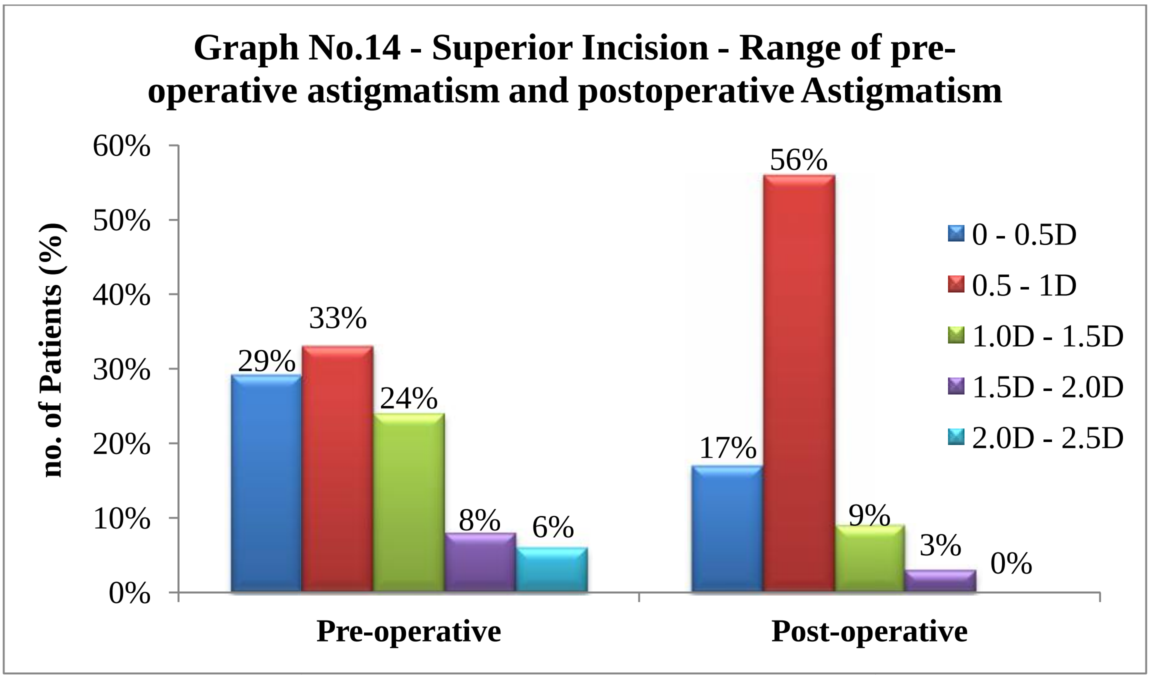

Graph No.14 - Superior Incision - Range of pre-operative astigmatism and postoperative Astigmatism
60%
50%
40%
30%
20%
10%
0%
no. of Patients (%)
29%
33%
24%
8%
6%
17%
56%
9%
3%
0%
Pre-operative
Post-operative
0 - 0.5D
0.5 - 1D
1.0D - 1.5D
1.5D - 2.0D
2.0D - 2.5D

TABLE No.15 - Temporal incision – Average pre-operative and post-operative keratometric reading and effect on opposite meridian

	Pre-operative average reading	Post-op operative reading
Steeper meridian	44.63	44.05
Flatter meridian	43.67	43.77

In the study, by taking the incision on the steeper meridian; i.e. temporally on the operating eye, the keratometric reading in the steeper meridian was reduced from 44.63D $\pm$ 1.52 pre-operatively to 44.05D $\pm$ 1.40 post-operatively with p value = 0.003 (Highly Significant).

At the same time the keratometry readings in the opposite meridian showed a increase from 43.67D + 1.70 pre-operatively to 43.77D + 1.59 post-operatively with p = 0.2515. (Not Significant)

Graph No.15 - Temporal incision – Average pre-operative and post-operative keratometric reading and effect on opposite meridian

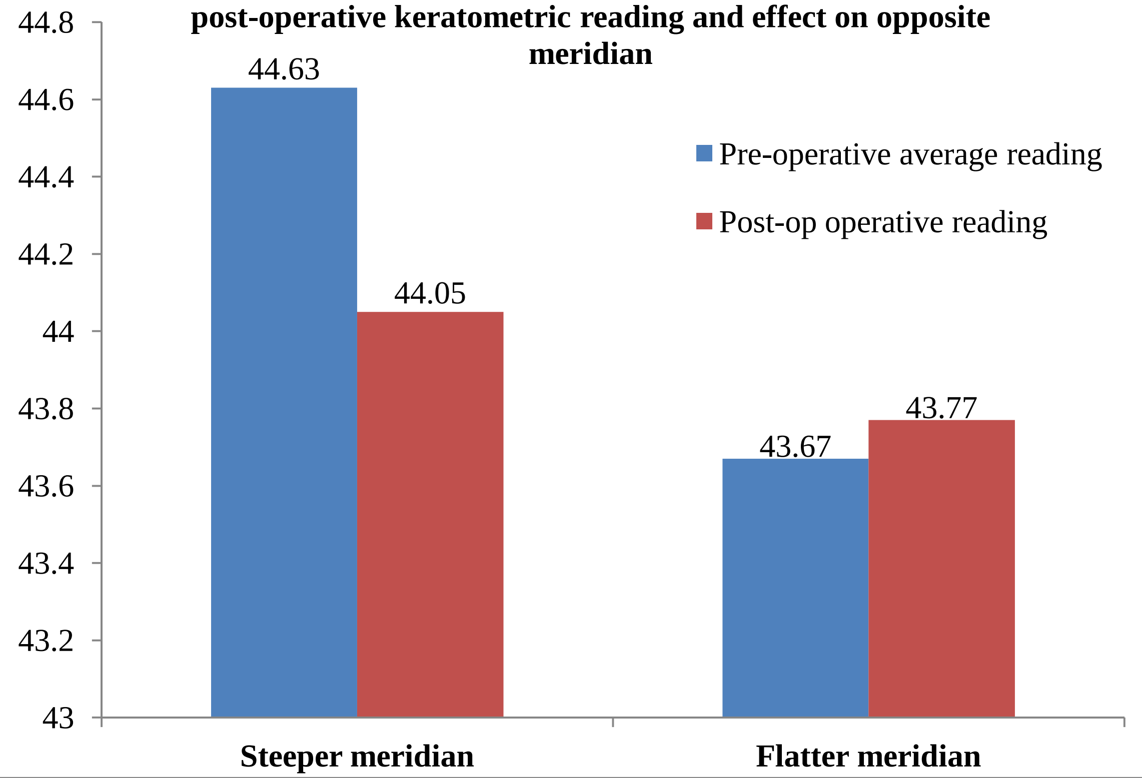


TABLE No.16 - Superior incision – Average pre-operative and post-operative keratometric reading and effect on opposite meridian

	Pre-operative average reading	Post-op operative reading
Steeper meridian	44.12	43.62
Flatter meridian	44.57	43.87

In the study, by taking the incision on the steeper meridian; i.e. superiorly on the operating eye, the keratometric reading in the steeper meridian was reduced from 44.57D $\pm$ 1.57 pre-operatively to 43.87D $\pm$ 1.44 post-operatively with p value = 0.0016 (Very Significant.)

While at the same time an incision on the steeper superior meridian also affected the keratometric reading on the flatter horizontal meridian from 43.62D $\pm$ 1.59 pre-operatively to 44.12D $\pm$ 1.65 post – operatively with p value < 0.0001 (Highly Significant.)

Graph No.16 - Superior incision – Average pre-operative and post-operative keratometric reading and effect on opposite meridian

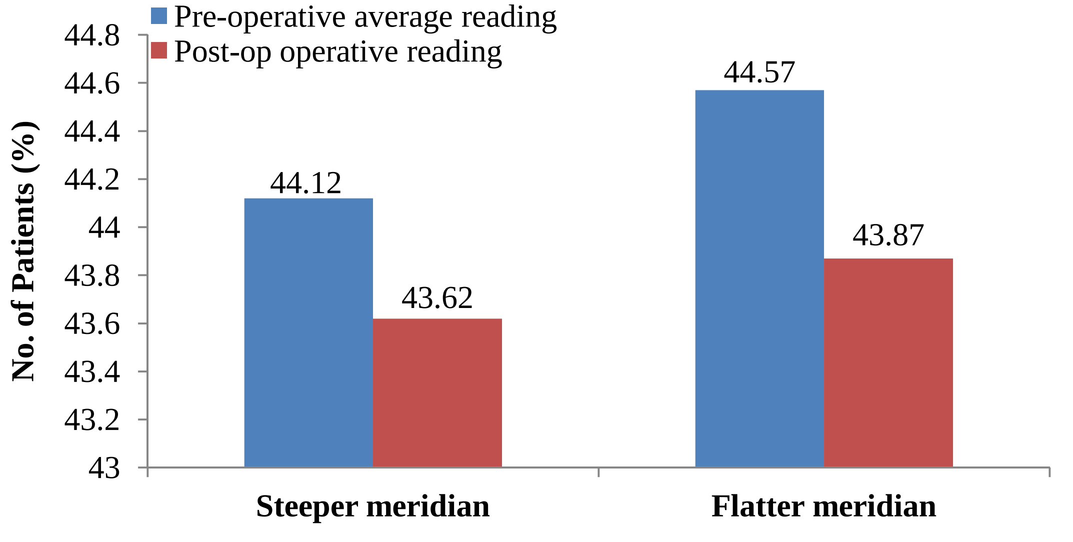


TABLE No.17 - Post-operative uncorrected visual acuity at follow ups

Range of visual acuity	Follow-up days	No. of Patients	Percentage (%)
6/12 – 6/6	21 days	37	62%
	45 days	40	67%
6/24 – 6/18	21 days	22	36%
	45 days	19	31%
6/60 – 6/36	21 days	1	2%
	45 days	1	2%

Post – operatively on day 21 of follow-up,

2% of the study group had visual acuity from 6/60 – 6/36.

36% had visual acuity from 6/24 – 6/18.

62% of the patients had visual acuity from 6/12 – 6/6.

sOn the post – operative day 45 of follow-up,

2% of the study group had visual acuity from 6/60 – 6/36.

31% had visual acuity from 6/24 – 6/18.

67% of the patients had visual acuity from 6/12 – 6/6.

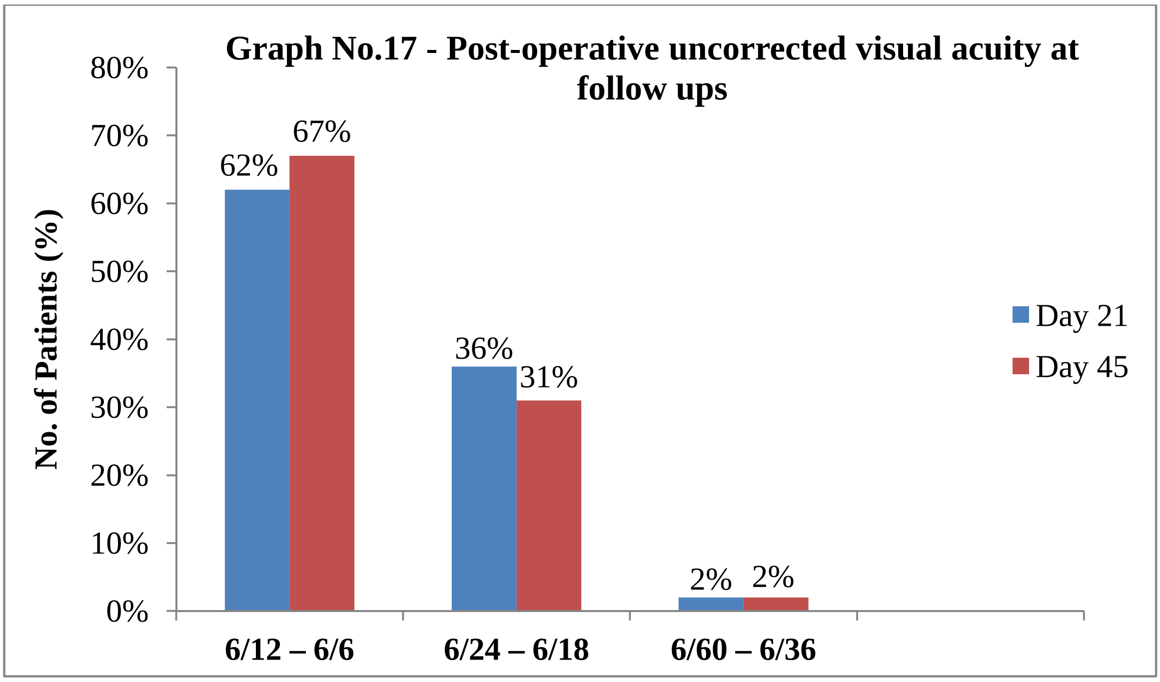
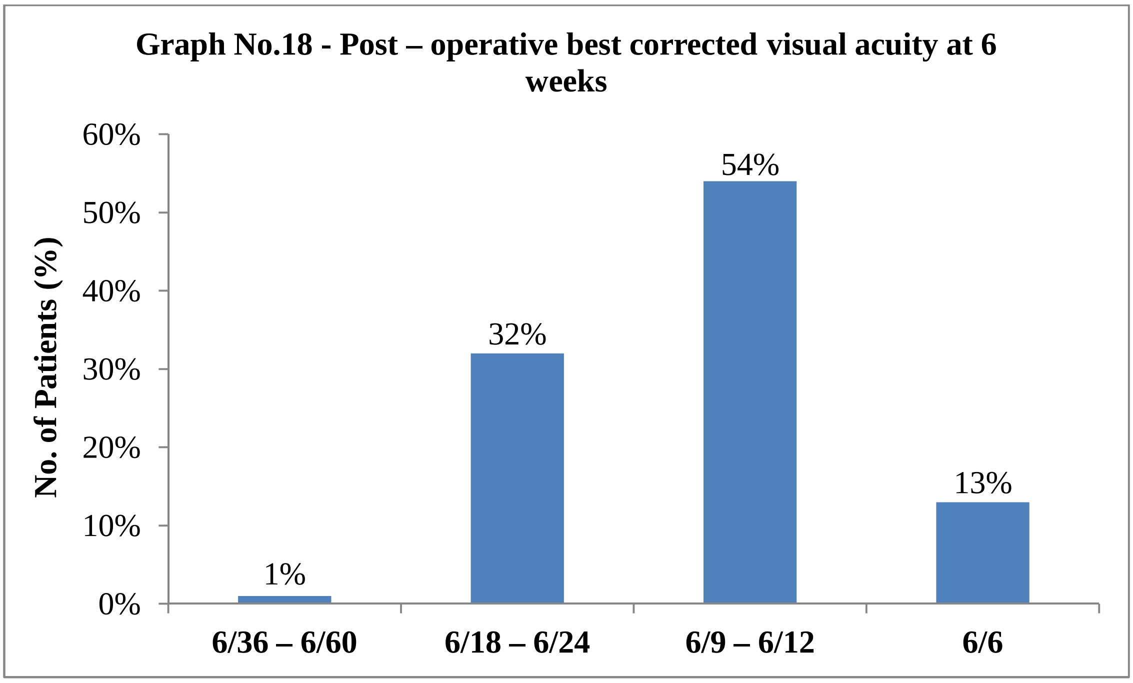

Graph No.17 - Post-operative uncorrected visual acuity at follow ups
No. of Patients (%)
80%
70%
60%
50%
40%
30%
20%
10%
0%
62%
67%
36%
31%
2%
2%
6/12 – 6/6
6/24 – 6/18
6/60 – 6/36
Day 21
Day 45

TABLE No.18 - Post – operative best corrected visual acuity at 6 weeks

Range of Visual Acuity	Number of Patients	Percentage (%)
6/36 – 6/60	1	1%
6/18 – 6/24	19	32%
6/9 – 6/12	32	54%
6/6	8	13%

On post – operative follow – up day 45, about 54% of the patients in this study had a best corrected visual acuity of 6/9 – 6/12. While about 13% of the patients had post – operative best corrected visual acuity of 6/6. 32% of the patients had visual acuity of 6/18 – 6/24. 1% had the visual acuity from 6/36 – 6/60.



DISCUSSION

Our study was conducted on 60 eyes of 60 patients who underwent Manual SICS in the Department of Ophthalmology, KLES Dr. Prabhakar Kore Hospital and Medical Research Centre, Belagavi. It was conducted in the time period of one year; from 1st January 2016 to 31st December 2016.

The patients underwent Manual SICS with the incision placed on the steeper meridian as determined pre-operatively.

It has been seen that an incision placed along the meridian of the steeper corneal curvature leads to flattening of that meridian and steepening of the corneal curvature along the meridian which lies perpendicular to it. This is known as the coupling effect. Coupling effect may be put to use to reduce the pre-existing astigmatism in during cataract surgery. This has been referred to as ‘Astigmatically Beneficial Cataract Surgery’ by David D Dillman.[65] The purpose of this study was to put to use this principle by placing the incision on the steeper corneal curvature in eyes with pre-existing corneal astigmatism to reduce the pre-existing astigmatism post-operatively; thus making cataract surgery a type of refractive surgery.

In this study the average age of the study group was about 63.7 $\pm$ 9.73 years. The maximum incidence of cataract was seen in the age group of 50 – 70 years which made up about 75% of the study group. The range of age distribution of the patient group was 35 years to 81 years. The age distribution and the pre-operative visual acuity were similar to those in a study done by Yadav H et al. [62] where majority of the study population was also distributed in the age groups from 51years – 70 years. (65%). A similar distribution of the patients among different age groups was seen in the study done by Malik et al. [61] There was an increase seen in the distribution of patients’ population from 50 years with a peak at around 70 years. Also more patients were in the age group from 71 – 90 years than from the extreme of 31-40 years. This is probably due to the increase in astigmatism after the age of 60 years as shown in the study done by Lyle and William M.[67]

In our study, about 53% of the patients were females and the rest 47% were male, giving a Female: Male ratio of 1.13:1. The ratio of Females: Males was similar to the ratio seen in studies done by Edmund Arthur et al. [36] where the Female: Male ratio was much greater at 2.05:1. Also a study done by K. Sathish et al, where the amount of female patients in the study group was greater and Female: Male ratio was similar to our study. [68] The most probable cause for this female preponderance may be the difference in the nutritional status between both the sexes and the role of the female gender in house work causing more demand of greater visual acuity.[44]

In the study, it was seen that the maximum number of patients pre-operatively had visual acuity in the range of Counting Fingers (CFCF) to PL+, PR accurate which was about 57% of the study population. This was followed by lesser number of patients in the group of better visual acuity i.e. 25% in the range of 6/60 to CF 3mtr, 17% in the group had visual acuity 6/24 to 6/36 and 1% only had visual acuity from 6/12 to 6/18.

In the study 60 eyes of 60 patients having pre-existing astigmatism were operated either using a superior or temporal incision depending upon the patient's pre-operative keratometry readings. About 27 % of the patients had pre-operative astigmatism of 0 – 0.5D. 35% patients had astigmatism pre-operatively in the range of 0.6 – 1.0D. 22% patients had pre-operative astigmatism in range of 1.1D – 1.5D and 11% had pre-operative astigmatism 1.6D – 2D and finally 5% had astigmatism of 2D – 2.5D pre-operatively.

The distribution of pre-operative astigmatism was also similar to a study done by K. Sathish et al where out of the study group of 1000 patients the maximum number of patients (29.2%) were seen to have a pre-operative astigmatism in the range of 1.0D – 1.5D which was almost equal to the number of patients having pre-operative astigmatism of around 0.5D – 1.0D which was around 28.1% [68] These results of our study also corroborate with the those stated in the study by Lee .B S. et al which stated that at least 60% of the total population has astigmatism up to 1D.[69] Similar distribution of the type of pre-operative astigmatism was seen in a study done by Alam J et al. which had about 65 patients had WTR astigmatism and had to undergo Manual SICS via superior incision and about 55 patients had ATR astigmatism and had to undergo Manual SICS via Temporal incision.[70]

Out of the total study group of 60 eyes about 34 patients had WTR astigmatism pre-operatively and hence underwent Manual SICS surgery with Superior incision and 27 patients had ATR astigmatism and thus Manual SICS was done for them via temporal incision. The distribution of pre-operative astigmatism was seen in a study done by Malik et al where the patients undergoing cataract surgery with pre-operative WTR astigmatism was 54 and those with ATR astigmatism was 35.[61]

The post-operative astigmatism of the patients ranged from 0D- 2.0D with the majority of the patients having post-operative astigmatism in the range of 0.5D – 1.0D about 52%. It was closely followed by the group of patients having post-operative astigmatism in the range of 0 – 0.5D which was about 38%. The percentage of patients having astigmatism from 0-1.0D was seen to have increased post-operatively to 90% from 62% pre-operatively. Also the patients having astigmatism in the range of 1.5D – 2.0D were pre-operatively 33% which reduced to 10% post-operatively. This indicated that placing an incision on the steeper meridian based on pre-operative keratometry helped to reduce the pre-operative astigmatism of the patients. In the study about 24% of the patients had WTR type of astigmatism post-operatively while 76% of the patients post-operatively had astigmatism of ATR type. In this about 48% of the total sample of patients studied showed a transition from WTR astigmatism pre-operatively to ATR astigmatism post-operatively; while about 9% of the study group having pre-operatively WTR astigmatism remained to have WTR astigmatism post – operatively too. While 28% of the patients of the study group having ATR astigmatism pre-operatively remained to have ATR astigmatism post-operatively too, the rest 15% of the group having pre-operative ATR astigmatism showed a turn over to the WTR type post-operatively.

Also in the pre-operative stage, the percentage of patients having WTR astigmatism was more being around 57% and those having ATR astigmatism being lesser at around 43%. This result helps us to come to a probable conclusion that a steeper axis incision in the superior position helps to decrease the astigmatism to a greater extent than the temporal incision. This may be due to the fact that the action of the superior incision of flattening the steeper vertical meridian is aided by the age related changes of the action of the horizontal recti on the globe and in turn on the corneal curvature and also the decreased pressure of the eyelids on the corneal thus causing lesser outward bending of the vertical corneal curvature and hence more ATR astigmatism. [71], [62]

The placement of the cataract incision on the steeper axis can help reduce the astigmatism in that meridian. The incision is seen to have an AK effect with incisions placed on the superior meridian showing more drift than the temporal incisions. This statement is consolidated by the findings of increase in the amount of ATR astigmatism seen in this study post-operatively. The superior incisions have been said to have two times the astigmatic effect than that of temporal incisions which also is consistent with the increase in ATR astigmatism seen post-operatively. [67] This was found to be beneficial as having a little amount of residual ATR astigmatism helps to achieve better near visual acuity, as states in a study by Nichamin.L.D.[71]

In our study, the progression of the magnitude of astigmatism was studied over the follow visits of post-operative day 1, post-operative day 7, post-operative day 21 and post –operative 6 weeks. It was seen that the number of people having 0D – 0.5D was 24 on the post-operative day 1 follow-up visit and this number decreased to 13 at post –operative follow-up of 7 days and 21 days and then ultimately increased at 6 weeks follow-up visit. It was seen that at 6 weeks maximum number of patients had astigmatism in the range of 0D – 0.5D. The number of people having post-operative astigmatism in the range of 0.6D – 1.0D increased gradually from 11 on the 1st post-operative day follow-up visit and then showed a sharp increase in number up to 37 at 21 days post-operative follow – up visit. It eventually decreased to 27 in number at 6 weeks post-operative follow – up visit. A similar pattern was seen in the number of patients having magnitude of astigmatism in the range of 1.0D – 1.5D. It was seen that the number of patients having post-operative astigmatism in the range of 1.0D – 1.5D was 11 on the 1st post-operative day follow-up visit and then increased to 19 on the post-operative follow – up visit of 7 days and then showed a steady decrease from 6 in number at post-operative follow – up visit of 21 days. At about 6 weeks post-operative follow – up visit, the number of patients having astigmatism of 1.0D – 1.5D was 4. Hence it was observed from our study that at post-operative 7 days in most patients there was slight increase seen in the amount of astigmatism from post-operative day 1 astigmatism values which then seemed to decrease to a lesser magnitude at post – operative 21 days follow – up visit. These values further decreased and seemed to have stabilised at 6 weeks follow – up visit to lesser values of 0D – 0.5D. This is in accordance to the findings observed in a study by Beltrame G, Salvetat M et al where the keratometric readings post cataract surgery done via scleral tunnel incisions was seen to show a slight increase from 0.72 $\pm$ 0.59D at post – operative 1 day follow – up to about 1.01 $\pm$ 0.27D at 1 week post-operative follow – up visit. At subsequent follow – up of 1 month and 3 month, the magnitude of astigmatism was seen to decrease to 0.93 $\pm$ 0.33D.[5] According to the findings of a study done by Reading V, it was observed that flattening of the steeper meridian and subsequent steepening of the flatter meridian was seen to occur in about only 6.5% of the sample size post-operativey while the above mentioned change was seen in 42.3% patients by the 1st post-operative month. The probable cause for the stabilisation of the astigmatism after 2 weeks was attributed to the 1st signs of development of ingrowth of subepithelial connective tissue between stromal edges at around this time.[53] In a study done by Haldipurkar S S et al,[21] it was said that this wound healing begins at around 1 week post-operatively and continues up to 3 weeks post-operative time period. Likewise in a study done by Dodiya K and Parmar N, it was seen that there was seen to occur a slight increase in the magnitude of astigmatism from 1.0D on 1st post-operative day to 1.25D on the post-operative 7 days. This was seen to be followed by a decrease in the magnitude of post-operative astigmatism at 6 weeks post-operative follow – up with maximal patients having magnitude of astigmatism of 1.0D. [55]

In this study, the average SIA induced was 1.12D $\pm$ 0.6 with $p<0.001$. The average SIA induced by Superior incision was 1.33D $\pm$ 0.45. The average SIA induced by the temporal incision was 0.84D $\pm$ 0.67. The difference between the SIA caused by both the Superior and Temporal incision was very significant with a p value of 0.0011. (Very Significant). The results of the study were similar to a study conducted by Malik et al,[61] where a total of 88 eyes were operated for cataract surgery with the incision site being on the steeper meridian (Superior or Temporal) based on the pre-operative keratometry readings. The mean SIA induced by the superior incision was 1.45D+0.7387 and that by Temporal incision was 0.75+0.4067; which is very similar to the results obtained by the present study. The difference of SIA between the two incisions viz. superior and temporal was found to be statistically significant with p value < 0.001 which was similar to the findings in our study. Also the mean SIA induced in the study was 1.2 + SD which is quite similar to the results obtained in this study. Similarly a study done by Alam J et al[70], the SIA induced by Superior and Temporal incisions in 130 eyes of 130 patients were compared The site of incision was chosen according to the steeper corneal meridian according to the pre-operative keratometry readings. The mean SIA induced by the superior incision was 1.45± 0.4D. Whereas the SIA induced by the temporal incision was much lower at 0.7± 0.3D. The difference between the two groups was found to be statistically significant with a p value of 0.000 and t = 11.444. These findings were seen to be consistent with the results of our study. Also a study done by Yadav H, Rai V[62], the surgically induced astigmatism by the superior and temporal incision was found to be similar to those obtained by our study with the SIA by superior incision being around 1.37 ± 0.65D and the temporal incision SIA being at around 0.67 ± 0.40D. These findings were also seen to be similar to the findings obtained by our study with the difference between the two SIA being statistically significant with p value<0.001. Also the SIA obtained by the superior incision was found to be 45.28% more than that induced by the temporal incision. The findings in our study were also similar to the results of a study carried out by Gokhale N and Sawhney S, where they found the SIA with the Temporal incision being 0.37D and SIA with Superior incision being 1.28D in Superior Incision Group.[63]

One of the simplest methods to correct pre-existing astigmatism during cataract surgery is to place the incision along the steeper axis of the cornea. The incision on the temporal side induces a WTR astigmatism.[71] According to a study done by Grabow et al, the induced astigmatism by a superior 3mm incision was almost double i.e. about 1.25D; while that induced by a temporal incision was only 0.56D at one month follow-up. [72] A study done by Kwon H J et al, described the effect of the distance of the incision from the optical centre on the SIA it induced. It was seen that the scleral incision produced the least amount of SIA at 0.7 ± 0.48D, followed by the limbal incision having an SIA of 1.04 ± 0.37D and the corneal incisions produced the greatest amount of SIA which was about 1.21 ± 0.57D. The authors also inferred that the length of the incision and its distance from the optical centre were primary factors affecting the SIA induced by any type of incision with the length being directly proportional and the distance from the optical centre being inversely proportional to the amount of SIA produced.[73]

The reduced SIA by temporal incision may be attributed to the fact that the distance of the incision from the corneal centre is more in case of a temporal incision than in superior incision[3].

In this study the superior incision group showed a reduction in the steeper meridian readings and an increase in the keratometric readings of the flatter meridian. The difference between the pre-operative and post-operative keratometric readings in both the steep and flat meridians were statistically significant with a p value of 0.016 and <0.0001 respectively.

Also in the patients with pre-operative ATR astigmatism who underwent Manual SICS via Temporal incision, the difference between the pre-operative and post-operative values of the keratometric readings of the steep meridian were statistically significant with p value being 0.0003. However the amount of steepening of the meridian perpendicular to the steep axis was not statistically sig nificant; but was seen to be lesser post –operatively than pre-operatively consistently on clinical examination.

The magnitude of absolute mean astigmatism post-operatively in WTR group was seen to be lesser than that seen pre-operatively with the pre-operative magnitude of absolute mean astigmatism being around 0.95D and then post-operatively was seen to reduce to 0.25D post-operatively. Similarly the magnitude of absolute astigmatism pre-operatively in ATR group was seen to be 0.96D which was seen to reduce to 0.28D post –operatively. These findings were similar to a study done by Akura J et al [60], where pre-operative absolute astigmatism of 1.15D was seen to reduce to 0.75 post –operatively via a superior incision while a temporal incision caused a pre-operative magnitude of absolute astigmatism of 1.00D to reduce to 0.66D post-operatively.

The mean flattening seen in this study in the WTR group was 1.33D while that in the ATR undergoing Manual SICS via Temporal incision was 0.64D. This was seen to be a little more than with the values for flattening seen in the study done Akura J et al[60], which was seen to 0.64D and 0.59D for superior and temporal incision. These findings in this study were seen to be consistent with the findings of a study done by Akura J et al[60], where there was reduction of magnitude of absolute astigmatism seen in about 30 of 33 patients with the maximum decrease being of 0.75D with the on steep axis temporal incision in patients having pre-existing ATR astigmatism. While all the patients in the WTR group who underwent cataract surgery via superior incision showed some amount of reduction in the magnitude of absolute astigmatism with the range of reduction being from 0.25 to 1D. Also here the reduction in astigmatism caused by superior incision was seen to be little more than that induced by temporal incision with mean values being 0.64D and 0.52D respectively.

The pre-operative distribution of visual acuity was such that majority of the patients had visual acuity PL+, PR accurate. Post –operatively, the visual acuity for the majority of the patients improved and was seen to be in the range of 6/12 -6/6 for 62% of the patients at follow-up day 21 and 67% at 6 weeks post-operative follow-up. This improvement may be attributed to the removal of cataract and the decreased amount of astigmatism due to the incision on the steeper axis. This post-operative distribution of visual acuity was similar to the results of a study done by K. Sathish et al where about 82.3% patients had 6/9 to 6/6 visual acuity by Snellen's chart at post-operative 6 weeks follow – up. [68]

Hence this study helped us to conclude that a cataract incision placed on the steeper meridian in eyes having pre-operative astigmatism helps to reduce the pre-existing astigmatism. Also this study helps to conclude that the surgically induced astigmatism caused due to the superior incision is more than that due to temporal incision.

CONCLUSION

This study was conducted on 60 eyes of 60 patients undergoing Manual Small Incision Cataract Surgery (Manual SICS) in KLES Dr.Prabhakar Kore Charitable Hospital, Belagavi for the period of one year. The site of the incision was chosen to be either superior or temporal on the basis of the steeper axis which was determined by pre-operative keratometry.

The post-operative astigmatism was significantly lesser than the pre-operative values by placing the incision along the steeper axis. This was due to flattening of the steeper axis and steepening of the perpendicularly opposite meridian. (Superior Incision p value = 0.0016) (Temporal incision p value = 0.003)

The surgically induced astigmatism was lesser with the temporal incision than with superior incision with the difference between the 2 being statistically significant. (p value of 0.0011)

SUMMARY

Cataract surgery has been known to mankind since the last 200 years. It has evolved from the crude methods of couching to the highly advanced and precise method of Phacoemulsification. The surgically induced astigmatism occurring due to cataract surgery is a major deterrent to the goal of achieving emetropia after cataract surgery. This study aimed to use the process of placing the incision on the steeper axis to reduce the amount of surgically induced astigmatism by causing a flattening of the steeper meridian.

The study was conducted on 60 patients who underwent Manual SICS in KLES Hospital, Belagavi during January 2016 to December 2016. The steeper meridian of the cornea was determined by doing keratometry to find out the corneal curvature using the Bausch-Lomb Manual Keratometer. Pre-operatively the steeper axis was marked using a marker pen and Manual Small incision Cataract surgery was carried out along an incision placed along the pre-operatively determined steeper axis - either superior or temporal.

In the study the average age of the subjects was 63.7 $\pm$ 9.73 years (range 35years – 81 years). 47% of the subjects were male and the rest 53% were female.

About 27% of the total study population had pre-operative astigmatism of 0-0.5D, 35% of the study population had astigmatism of 0.5-1.0D, 22% of the patients of 1.1D – 1.5D and the rest had astigmatism of about 1.6D - 2.5D.

About 38% of the total study population had post-operative astigmatism of 0-0.5D, 52% of the study population had post-operative astigmatism of 0.5-1.0D and the rest had astigmatism of about 1.0D - 2.0D.

The surgically induced astigmatism with the temporal incision was 0.84D $\pm$ 0.67 while that with superior incision was 1.33D $\pm$ 0.45. It was seen to be statistically significant with p value of 0.0011.

Superior incision induced ATR while Temporal incision was seen to WTR astigmatism.

The comparative increase in the post-operative astigmatism with the superior incision is because the temporal limbus is farther away and has a lesser effect on the astigmatism than the superior group. Also the eyelids exert pressure and cause an increase in the WTR astigmatism as an additive effect to the astigmatism by the superior incision.

It was hence seen that placement of the incision on the steeper axis will cause flattening of the steeper axis and will reduce the amount of astigmatism.

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CONSENT FORM

CONSENT FOR PARTICIPATION IN RESEARCH STUDY

ID NO. ☐☐☐

Mr/Mrs/Ms____

You are invited to participate in our research study titled **"A longitudinal Study to evaluate the effect of Manual SICS sclerocorneal tunnel incision placed in the steepest meridian on pre-existing astigmatism and surgically induced astigmatism by this incision on eyes undergoing cataract surgery at KLES Hospital, Belagavi"** Conducted by Dr. ______________ , Post Graduate in M.S. Ophthalmology under the guidance of **Dr. __________,** DOMS, MS, Ph.D, Professor and Head in the department of Ophthalmology, J.N. Medical College, Belgaum.

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

Purpose of the study: - The purpose of the research is to evaluate the beneficiary effect of Surgically Induced Astigmatism with length of incision in manual small incision cataract surgery with pre-existing Astigmatism.

Procedure Involved: - If you agree to enroll yourself in this study, you will be asked to give detailed history. Then you will be clinically examined in detail by slit-lamp examination, fundoscopy, tonometry for measurement of intraocular pressure. Syringing for patency of the lacrimal sac, keratometry and A scan ultrasonography and investigations like Blood Pressure measurement, Random Blood sugar will be done. Then you will be undergoing small incision cataract surgery where the incision. You will be asked to follow up on specified dates when your progress would be monitored and documented.

Risks and Benefits: - Rare complications of cataract surgery include endophthalmitis, vitreous loss, globe perforation, retro bulbar hemorrhage, expulsive choroidal hemorrhage for which all necessary precautions will be taken.

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

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

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

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

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

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

Questions: - If you have any questions about the research you may please contact:

1) Chief Investigator, Dr. ________________ , P.G, Department of Ophthalmology, JNMC, Belgaum. Contact No.________________

2) Dr.__________, Professor, Guide, Department of Ophthalmology, JNMC, Belgaum.

Consent for participation in research trial

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

Subject Name: ____

Signature or the Left Thumb Print of Subject: _____________________________

Witness Name: ________________________________

Signature of Witness: ___________________________

Investigators Name: _____________________________

Signature of Investigator: __________________________

Name of the Guide: - DR. ___________

Signature of the guide: - _________________________________

Date: ___________

Place: ____________

PROFORMA

PATIENTS ID NO

NAME:

AGE: Years

SEX: (1-Male; 2-Female)

ADDRESS

CONTACT NUMBER

OP NUMBER:

IP NUMBER:

DATE OF ADMISSION

DATE OF DISCHARGE

IS THE PATIENT ELIGIBLE FOR STUDY? (1-YES; 2-NO)

HAS INFORMED CONSENT BEEN GIVEN? (1-YES; 2-NO)

FINAL RESULT INFORMATION

1- INELIGIBLE
2- ELIGIBLE- REFUSAL
3- ELIGIBLE- PARTICIPATING

SURGEON'S NAME: | | | | | | | | | | | | | | | | | |

SURGEON'S SIGNATURE: ________________________

DATE: | | | | | | | | |

CHIEF COMPLAINTS:

DIMINUTION OF VISION ☐

Duration: ________ days/ months/years

L ☐

Duration: ________ days/ months/years

HISTORY OF PRESENT ILLNESS:

1 .DIMINUTION OF VISION 1- Gradual; 2- Sudde ☐

1- Progressive; 2- Static ☐

1- Painless; 2- Painful ☐

1- For distance; 2- For nea ☐

2. DIPLOPIA/POLYOPIA 1- Present; 2- Abser ☐

3. COLOURED HALOS 1- Present; 2- Abser ☐

4. BLACK SPOTS BEFORE THE EYES 1- Present; 2 - Absent ☐

5. WATERING 1- Present; 2 - Absen ☐

6. REDNESS 1- Present; 2 - Abser ☐

7. DISCHARGE 1- Present; 2 - Abser ☐

8. H/O WEARING GLASSES (1-Distance; 2-Near; 3-Both) ☐

Duratio ☐☐ months/years

PAST HISTORY:

TRAUMA TO THE EYE: 1- Present; 2- Absent ☐

OCULAR SURGERY: 1- Present; 2- Absent ☐

Type of surgery: ____________________

Duration: ☐☐ months/years

DIABETES: 1- Present 2- Absent ☐

Duration: ☐☐ months/years

HYPERTENSION: 1- Present 2- Absent ☐

Duration: ☐☐ months/years

ANY OTHER MEDICAL DISORDERS: ______________________________

PERSONAL HISTORY:

SMOKING: 1- Present; 2- Absent ☐

Duration: ☐☐ months/years

ALCOHOLISM: 1- Present; 2- Absent ☐

Duration: ☐☐ months/years

ANY OTHER ADDICTIONS: ______________ ☐

Duration: ☐☐ months/years

GENERAL PHYSICAL EXAMINATION:

General Appearance:

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

Pallor: 1- Present 2- Absent ☐

If present 1- Mild 2- Moderate 3- Severe ☐

Pulse: ☐☐☐ /minute

BP:- ☐☐☐ ☐☐☐ mm of hg

Temperature: ☐☐☐ degree Fahrenheit

Respiratory rate: ☐☐ /minute

SYSTEMIC EXAMINATION:

CVS: 1- Normal 2- Abnormal ☐
if 2, specify :_______________

RS: 1- Normal 2- Abnormal ☐
if 2, specify: _______________

CNS: 1- Normal 2- Abnormal ☐
if 2, specify :_______________

Per Abdomen: 1- Normal 2- Abnormal ☐
if 2, specify :_______________

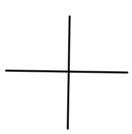
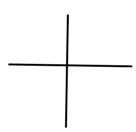
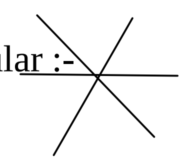
OCULAR EXAMINATION:

Head posture: 1- Erect ,2- Tilted ☐

Visual Axis: 1- Parallel, 2- Deviated ☐

Facial Symmetry: 1- Symmetrical, 2- Asymmetrical ☐

Extraocular movements:

RE-  LE-  Binocular :- 

☐

(N- Normal, R- Restricted)

1) Visual Acuity:

	RE	LE
DISTANT		
PINHOLE		
NEAR		
AIDED		

REFRACTION/RETINOSCOPY:

Prescription	Spherical	Cylindrical	Axis	BCVA
RE				
LE				

2. Adnexa (1- Normal; 2-Abnormal)	☐	☐

3. Sclera (1- Normal; 2- Congested)	☐	☐
4. Conjunctiva (1-normal; 2-conjunctival congestion; 3-ciliary congestion; 4-chemosis)	☐	☐
5. Cornea (1- normal; 2-opacity; 3-vascularisation)	☐	☐
6. Anterior chamber (1- normal depth; 2-shallow; 3-deep)	☐	☐
7. Iris (1-normal colour & pattern; 2-Abnormal)	☐	☐
8. Pupil: Size- _____ in mm Shape- 1- Round & Regular; 2-Abnormal Reaction: Direct (1. Present, 2. Absent) Indirect (1. Present, 2. Absent) Near reflex (1. Present, 2. Absent)	☐ ☐ ☐ ☐	☐ ☐ ☐ ☐
9. Lens Clarity- 1. Clear, 2. Opaque Cataract - (1) , PCIOL - (2) Cataract if present- 1.immature 2.mature	☐ ☐ ☐	☐ ☐ ☐

3. hyper mature A) CORTICAL- (1.Present, 2. Absent)		☐	☐
B) NUCLEAR SCLEROSIS- 1. PRESENT, 2-ABSENT If present- 1. Grade-1 2. Grade-2 3.Grade-3 4. Grade-4		☐ ☐	☐ ☐
(C) POSTERIOR SUBCAPSULAR CATARACT 1. PRESENT, 2. ABSENT		☐	☐

FUNDUS	RE	LE
GLOW		
MEDIA		
DISC		
C:D RATIO		
BLOODVESSELS		

BACKGROUND		
MACULA		

DIAGNOSIS:-

IMPRESSION:-

INVESTIGATIONS:

1. Ocular

A) Lacrimal patency

(1-PATENT;2- regurgitation: 2A- Clear fluid, 2B- Mucopurulent ; 3-BLOCKED)

RE ☐

LE ☐

B) IOP:

RE: ☐ mm of hg

LE : ☐ mm of hg

C) Blood sugar: __________mg%

D) Blood Pressure:___________mm of hg

PREOPERATIVE KERATOMETRY:

EYE: ☐ (1-Right eye; 2- Left eye)

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

A SCAN BIOMETRY : SRK II FORMULA

	RE	LE
Kh		
Kv		
Axl		
ACD		
PCIOL		

OPERATIVE PROCEDURE: SMALL INCISION CATARACT SURGERY WITH SUPERIOR INCISION WITH PCIOL IMPLANTATION.

DATE:_____/______/________

OPERATING EYE : _________________________

ANAESTHESIA: PERIBULBAR BLOCK/ TOPICAL

INCISION: 1. Superior ☐

2.Temporal ☐

INTRAOCULAR LENS TYPE: ________________________________

Operative Complications: 1. Present, 2. Absent ☐

If present- specify

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

If present- specify

FOLLOW UP PLAN: 1 DAY post-operatively

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

VISUAL ACUITY	RE	LE
DISTANT		
PINHOLE		

POSTOPERATIVE KERATOMETRY:

1 DAY

EYE: ☐ (1-Right eye; 2- Left eye)

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

FOLLOW UP PLAN: 1 week post-operatively

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

VISUAL ACUITY	RE	LE
DISTANT		
PINHOLE		

POSTOPERATIVE KERATOMETRY:

1 week

EYE ☐ (1-Right eye; 2- Left eye)

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

FOLLOW UP PLAN: 21 DAYS post-operatively

1. Conjunctiva (1-normal; 2-conjunctival congestion; 3-ciliary congestion; 4-chemosis)	☐
2.Section/suture site (1-edges opposed; 2- edges gaping)	☐
3.Cornea (1-clear; 2-hazy/descemets fold)	☐

4. Anterior chamber (1- normal depth; 2-shallow; 3-deep)	☐
5. Pupil: Size- _____ in mm Shape- 1- Round & Regular; 2-Abnormal IF 2(Specify) :	☐
6.Intraocular Lens (1-in situ, 2-decentred)	☐

VISUAL ACUITY	RE	LE
DISTANT		
PINHOLE		

POSTOPERATIVE KERATOMETRY:

21 DAYS

EYE ☐ (1-Right eye; 2- Left eye)

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

FOLLOW UP PLAN: 6 week post-operatively

1. Conjunctiva (1-normal; 2-conjunctival congestion; 3-ciliary congestion; 4-chemosis)	☐
2.Section/suture site (1-edges opposed; 2- edges gaping)	☐
3.Cornea (1-clear; 2-hazy/descemets fold)	☐

4. Anterior chamber (1- normal depth; 2-shallow; 3-deep)	☐
5. Pupil: Size- _____ in mm Shape- 1- Round & Regular; 2-Abnormal IF 2(Specify) :	☐
6.Intraocular Lens (1-in situ, 2-decentred)	☐

VISUAL ACUITY	RE	LE
DISTANT		
PINHOLE		

POSTOPERATIVE KERATOMETRY:

6 weeks

EYE☐ (1-Right eye; 2- Left eye)

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

Prescription	Spherical	Cylindrical	Axis	BVCA
RE				
LE				

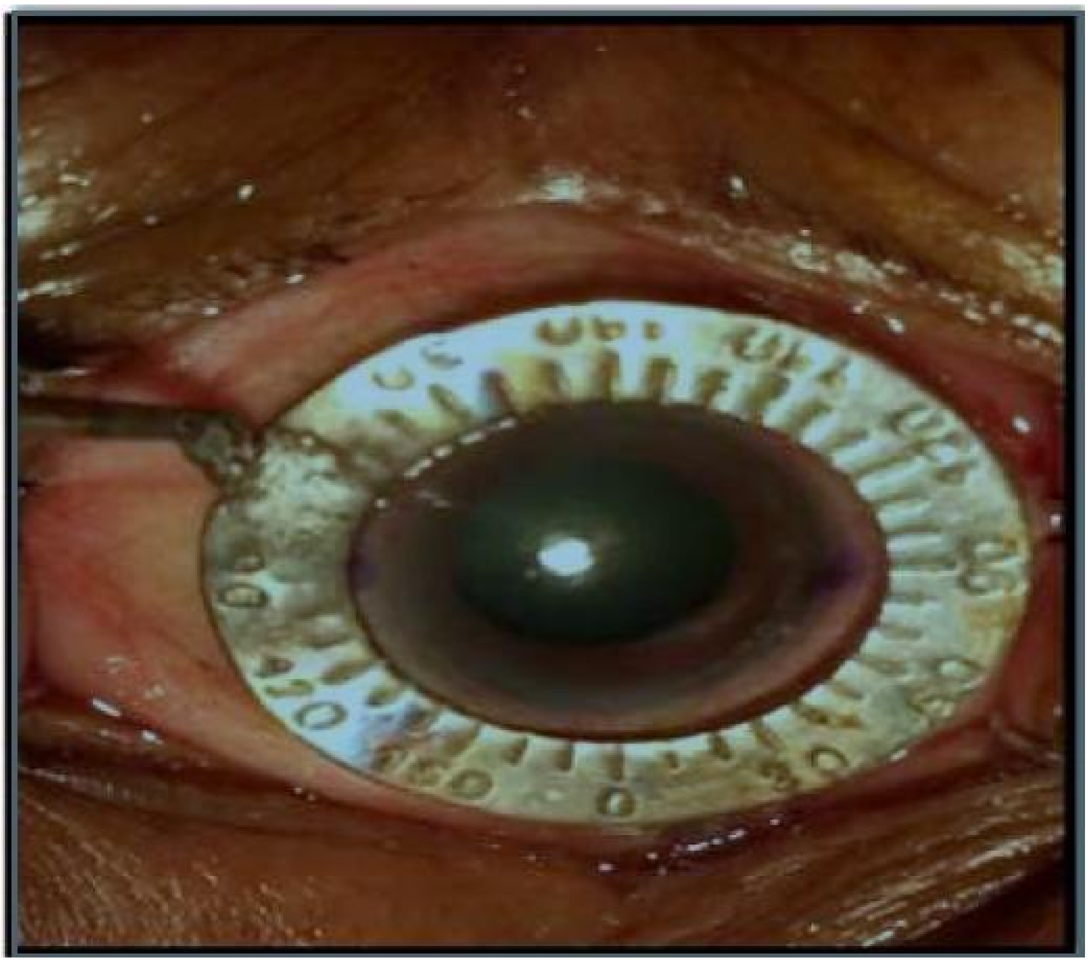
SURGICALLY INDUCED ASTIGMATISM:

SURGICALLY INDUCED ASTIGMATISM	Astigmatism in dioptres (KH – KV)	AXIS in degrees
1 DAY		
1 WEEK		
21 DAYS		
6 WEEKS		

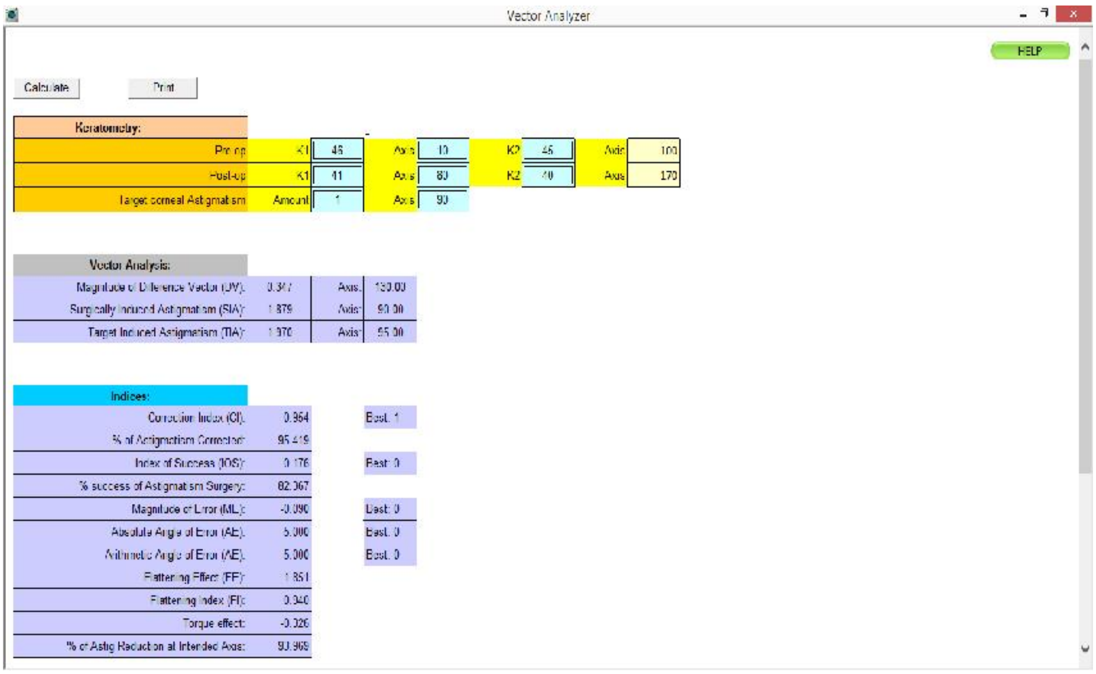
ANNEXURE III – PHOTOGRAPHS

Photograph 1 – Pre-operative Keratometry by Bausch Lomb Keratometer.

Photograph no. 2 – Axes marked for Cataract Surgery



Photograph no. 3 – Determination of site of Incision by using Mendez Marker.



Photograph no. 3 – Dr. Peymans SIA Calculator

KEY TO MASTERCHART

Kh – Keratometry along Horizontal meridian.

Kv – Keratometric Reading along Vertical Meridian

PCIOL – Power of Posterior Chamber Intraocular Lens

UCVA – Uncorrected Visual Acuity.

K2 – Dioptric Magnitude of Surgically induced astigmatism.

A2 – Axis of surgically induced astigmatism.

Sph – Shperical

Sph - Spherical Correction post-operative

Cyl - Cylindrical Spectacle correction post - operative

D – Dioptres.

LE – Left eye.

RE – Right Eye.

HMCF - Hand Movements close to Face.

CFCF – Counting Fingers Close to Face.

Mtr – Metres.

PL+ - Perception of light present

PL+, PR acc – Perception of Light present, Projection of Rays accurate.

WTR – With The Rule Astigmatism.

ATR – Against The Rule Astigmatism.

ATR - Against the rule Astigmatism

WTR - With the Rule Astigmatism

A1 - Pre-operative axis of astigmatism

K1 - Magnitude of Pre-operative astigmatism

M - Male

F - Female

SIA - Surgically Induced astigmatism.

S.No	OPD No.	Age	Eye	PRE-OPERATIVE							POST-OPERATIVE																								
											UCVA				Astigmatism																				
				Visual Acuity	Kh	Kv	PCIOL	K1	A1	Type	Day 1	Day 7	Day 21	Day 45	Day 1		Day 7		Day 21		Day 45				SIA								Refraction		
															Dioptres	Axis	Dioptres	Axis	Dioptres	Axis	Kh (180)	Kv (90)	Dioptres	Axis	K2	A2	% astigmatism corrected	% succes of astigmatism surgery	Flattening effect	Intended axis	Angle of error	Correction index	Sph	Cyl	Axis
1	3925761	46	LE	6/24(p)	46.00	46.25	+22.00D	0.25	90	WTR	CF2MTR	6/12	6/9(p)	6/9	0.00D	-	0.00D	-	0.25D	180	46.00	45.00	1.00	180	1.25	180	500.00	-300.00	1.25	180	0	5.00	-0.5	-0.5	110
12	3951484	60	LE	6/36	45.00	46.75	+22.00D	1.75	90	WTR	6/12	6/6	6/18	6/9(p)	3.50D	180	3.00D	180	3.00D	180	46.00	44.00	2.00	180	1.25	180	71.42	71.42	1.25	180	0	0.71	-	-1.5	80

S.No	OPD No.	Age	Eye	PRE-OPERATIVE Visual Acuity	Kh	Kv	PCIOL	K1	A1	Type	POST-OPERATIVE UCVA Day 1	UCVA Day 7	UCVA Day 21	UCVA Day 45	Astigmatism Day 1 Dioptres	Axis	Day 7 Dioptres	Axis	Day 21 Dioptres	Axis	Day 45 Kh (180)	Kv (90)	Dioptres	Axis	SIA K2	A2	% astigmatism corrected	% succes of astigmatism surgery	Flattening effect	Intended axis	Angle of error	Correction index	Refraction Sph	Cyl	Axis
30	4089709	81	RE	6/24	45.75	43.25	+21.00D	2.5	180	ATR	HMCF	6/60	6/60	6/36	1.50D	180	1.25D	180	0.75D	180	44.75	43.75	1.00	180	1.50	90	60.00	60.00	1.50	90	0	0.60	-1	-0.75	70
31	765457	60	RE	CF 2mtr	45.00	46.25	+21.50D	1.25	180	ATR	6/9(p)	6/12	6/6(p)	6/6(p)	1.25D	90	0.25D	90	1.00D	90	45.50	45.25	0.25	180	1.00	90	80.00	80.00	1.00	90	0	0.80	-0.25	-0.75	90
32	4092057	45	RE	CF 4mtr	41.75	43.25	+22.50D	1.5	90	WTR	6/18	6/12	6/24(p)	6/24(p)	0.75D	180	1.50D	180	1.00D	180	41.75	41.75	0.00	0	1.75	180	116.67	83.33	1.75	180	0	1.17	-1.25	-0.5	160
33	4098906	65	RE	HMCF	44.25	44.75	+22.00D	0.5	90	WTR	6/24	6/24	6/12	6/24	1.00D	180	1.00D	180	0.75D	180	46.00	45.25	0.75	180	1.25	180	250.00	-50.00	1.25	180	0	2.50	-0.5	-1	90
34	4098908	80	LE	CF 2mtr	43.00	44.00	+20.00D	1	90	WTR	HMCF	6/24	6/18(p)	6/18	1.75D	180	1.50D	180	1.00D	180	44.00	43.50	0.50	180	1.50	180	150.00	50.00	1.50	180	0	1.50	-1	-0.5	90
35	4098910	35	LE	CF1/2mtr	44.50	45.25	+22.00D	0.75	90	WTR	6/6(p)	6/9(p)	6/9(p)	6/9(p)	0.50D	90	0.25D	90	1.00D	180	45.50	44.75	0.75	180	1.50	180	200.00	0.00	1.50	180	0	2.00	-	-0.5	80
36	4085430	75	RE	CF1mtr	44.00	44.25	+13.00D	0.25	90	WTR	CF 5mtr	6/18(p)	6/18	6/12	2.25D	180	1.75D	180	1.50D	180	44.50	43.00	1.50	180	1.75	180	700.00	-500.00	1.75	180	0	7.00	-1.5	-1.5	100
37	4108645	70	RE	CF 4mtr	46.50	47.25	+19.50D	0.75	90	WTR	CF 5mtr	6/24	6/12	6/12	0.75D	90	1.00D	90	0.75D	180	46.00	45.00	1.00	180	1.75	180	233.33	-33.33	1.75	180	0	2.33	-0.25	-0.5	90
38	4108548	70	LE	6/24	43.75	45.75	+20.00D	2	90	WTR	6/24	6/18	6/12	6/18	1.75D	90	1.75D	90	0.75D	90	45.50	46.25	0.50	90	1.50	180	75.00	75.00	1.50	180	0	0.75	-0.5	-1	180
39	4111339	80	RE	CF1mtr	42.00	41.25	+20.00D	0.75	180	ATR	6/12(p)	6/18(p)	6/12(p)	6/12	2.00D	90	1.00D	90	1.50D	90	41.50	41.00	0.50	90	0.00	0	0.00	0.00	0.00	90	-90	0.00		-1	180
40	4111428	60	RE	CF1/2mtr	47.00	46.50	+20.50D	0.5	180	ATR	6/12	6/9(p)	6/9	6/12	0.00D	-	1.00D	180	0.75D	90	46.00	46.25	0.25	90	0.25	90	50.00	50.00	0.25	90	0	0.50	-	-0.5	160
41	4127603	63	LE	CF 2mtr	45.50	43.75	+19.50D	1.75	180	ATR	6/24	6/12(p)	6/9(p)	6/12(p)	0.50D	180	0.25D	180	0.75D	180	44.50	44.25	0.25	180	1.50	90	85.70	85.70	1.50	90	0	0.86	-0.5	-1	90
42	4111524	73	LE	CF1mtr	43.25	44.25	+17.00D	1	90	WTR	CF 2mtr	6/36	6/12	6/9	0.50D	90	1.00D	90	0.00D	-	43.25	44.00	0.75	90	1.25	180	125.00	75.00	1.25	180	0	1.25	-0.5	-0.25	180
43	4153532	60	RE	CF1mtr	45.00	45.00	+20.00D	0.5	180	ATR	6/9	6/12	6/9(p)	6/6(p)	1.50D	180	1.50D	180	0.75D	180	45.50	45.00	0.50	180	0.00	0	0.00	0.00	0.00	90	-90	0.00	-1	-1	90
44	4206332	55	LE	6/60	46.75	47.75	+22.00D	1	90	WTR	6/12(p)	6/12(p)	6/12(p)	6/12(p)	0.75D	90	0.25D	180	0.50D	180	46.50	46.25	0.25	180	1.25	180	125.00	75.00	1.25	180	0	1.25	-	-0.75	90
45	4563271	60	LE	HMCF	42.00	41.25	+21.00D	0.75	180	ATR	6/12	6/18(p)	6/12	6/12(p)	1.50D	180	1.00D	180	1.00D	180	42.00	41.00	1.00	180	0.25	90	33.33	-33.33	-0.25	90	90	0.33	-0.5	-1.5	90
46	4187402	69	LE	6/36	45.25	44.50	+21.50D	0.75	180	ATR	6/9	6/9(p)	6/6(p)	6/9	0.50D	180	1.25D	90	0.25D	180	44.00	44.50	0.50	90	1.25	90	166.67	33.33	1.25	90	0	1.67	-0.5	-1	180
47	3938697	60	LE	CF1/2mtr	42.75	44.00	+22.50D	1.25	90	WTR	6/36(p)	6/24	6/12(p)	6/6(p)	0.75D	180	1.25D	180	0.25D	180	42.75	42.50	0.50	180	1.75	180	140.00	60.00	1.75	180	0	1.40	-0.75	-1.5	90
48	4204326	66	RE	CF 2mtr	43.25	45.50	+18.00D	2.25	90	WTR	6/24	6/36	6/24	6/24	0.00D	-	2.00D	180	2.50D	180	44.00	44.50	0.50	90	1.75	180	77.78	77.78	1.75	180	0	0.78	-0.75	-1	180
49	4218148	55	LE	PL+	42.00	41.25	+20.50D	0.75	180	ATR	6/18	6/9(p)	6/12	6/9(p)	2.00D	90	1.00D	90	1.50D	90	41.50	41.00	0.50	180	0.25	90	33.33	33.33	0.25	90	0	0.33	-0.75	-1	90
50	4105374	68	RE	6/36	42.50	44.00	+20.00D	1.5	90	WTR	6/18	6/18	6/18	6/12	1.00D	90	0.75D	90	0.50D	90	43.50	44.00	1.00	90	1.50	180	100.00	100.00	1.50	180	0	1.00	-1	-0.75	180
51	3383979	70	RE	6/36	44.25	43.00	+19.50D	1.25	180	ATR	6/36	6/18	6/18	6/24	1.25D	180	2.75D	180	1.00D	180	43.00	43.25	0.25	180	1.50	90	120.00	80.00	1.50	90	0	1.20	-1	-0.5	120
52	4235635	78	LE	HMCF	44.75	43.75	+21.00D	1	180	ATR	6/24	6/18(p)	6/18	6/24	0.50D	90	0.75D	90	0.25D	180	43.50	44.25	0.75	90	1.75	90	175.00	25.00	1.75	90	0	1.75	-0.5	-0.5	120
53	3414049	68	RE	6/60	45.25	45.75	+22.00D	0.5	90	WTR	6/9	6/9(p)	6/6(p)	6/9	0.25D	180	1.75D	180	0.25D	180	45.00	44.75	0.25	180	0.75	180	150.00	50.00	0.75	180	0	1.50	-	-0.75	90
54	4207344	60	RE	6/60	44.75	45.50	+19,50D	0.75	90	WTR	6/12	6/9	6/9	6/6(p)	1.75D	90	1.00D	180	0.75D	180	45.25	44.50	0.75	180	1.50	180	200.00	0.00	1.50	180	0	2.00	-1	-1	90
55	4282353	59	RE	CF 3mtr	45.00	43.75	+19.50D	1.25	180	ATR	6/36	6/18	6/18(p)	6/9(p)	1.75D	180	0.25D	180	1.50D	180	44.00	43.50	0.50	180	0.75	90	60.00	60.00	0.75	90	0	0.60	-1	-1	90
56	4287561	65	RE	6/36	43.25	42.75	+23.50D	0.5	180	ATR	6/36	6/24	6/12(p)	6/12	0.25D	90	1.00D	180	1.00D	180	44.00	43.75	0.50	90	0.25	90	50.00	50.00	0.25	90	0	0.50	-1	-0.75	180
57	4287549	68	LE	CFCF	42.25	43.00	+24.50D	0.75	90	WTR	6/24	6/9	6/6(p)	6/12(p)	1.25D	90	0.00D	0	1.25D	180	43.50	42.50	1.00	180	1.75	180	233.30	-33.30	1.75	180	0	2.33	-1	-2	90
58	4292736	65	RE	CF1/2mtr	45.25	43.50	+22.00D	1.75	180	ATR	6/9(p)	6/9	6/6(p)	6/6(p)	0.00D	0	2.50D	90	1.00D	90	44.75	43.50	1.25	180	0.50	90	28.57	28.57	0.50	90	0	0.29	-0.5	-2	90
59	4330217	70	RE	CF 3mtr	46.50	45.00	+22.00D	1.5	180	ATR	6/9(p)	6/9(p)	6/9	6/6	0.50D	180	0.50D	180	0.75D	180	45.50	45.00	0.50	180	0.00	0	0.00	0.00	0.00	90	-90	0.00	-0.5	-0.5	90
60	4331175	55	LE	CF1mtr	44.00	43.00	+18.00D	1	180	ATR	6/12	6/9	6/12	6/9(p)	0.50D	90	0.75D	90	0.50D	90	43.50	42.75	0.75	180	0.25	90	25.00	25.00	0.25	90	0	0.25	-0.5	-1	90