"THE VISUAL OUTCOME AFTER CATARACT SURGERY WITH MULTIFOCAL INTRAOCULAR LENSES AND MONOFOCAL INTRAOCULAR LENSES AT TERTIARY CARE HOSPITAL - A PROSPECTIVE OBSERVATIONAL STUDY"

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This is to certify that the dissertation entitled **"THE VISUAL OUTCOME AFTER CATARACT SURGERY WITH MULTIFOCAL INTRAOCULAR LENSES AND MONOFOCAL INTRAOCULAR LENSES AT TERTIARY CARE HOSPITAL - A PROSPECTIVE OBSERVATIONAL STUDY"** is a bonafide research work done by **REGISTRATION NO.BK0114002**

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LIST OF ABBREVIATIONS USED

SL No.	ABBREVIATIONS	LONG FORM
1	ICCE	Intra capsular cataract extraction
2	ECCE	Extra capsular cataract extraction
3	SICS	Small incision cataract surgery
4	IOL	Intraocular lens
5	PCIOL	Posterior chamber intraocular lens
6	ACIOL	Anterior chamber intraocular lens
7	Phaco	Phacoemulsification
8	Cpd	Cycles per degree
9	D	Diopter
10	Log MAR	Logarithm of the minimum angle of resolution
11	CI	confidence interval
12	BSS	Balanced salt solution
13	BCVA	Best corrected visual acuity
14	AS	Anterior segment
15	PS	Posterior segment
16	VFQ	Visual Function Questionnaire

ABSTRACT

BACKGROUND:

The crystalline lens is part of the optical system of the eye that focuses rays of light on the retina. Apart from contributing to the optical power of the eye as a whole, the crystalline lens is able to dynamically change the optical power of the system by the process of accommodation for younger eyes. During life the ability of the crystalline lens to change in shape decreases, leading to presbyopia. For optimal visual performance crystalline lens should be transparent. Cataract describes the pathological opacification of the crystalline lens. Removal of the crystalline lens followed by implantation of an artificial intraocular lens (IOL) in the capsular bag of the eye, as practiced in cataract surgery, offers an opportunity to address refractive anomalies in patients who are ametropic due to removal of cataract. Implantation of an IOL with a fixed focal point (Monofocal IOL) will render a patient at best emmetropic for a single fixed working distance only, leading to a postoperative result comparable to presbyopia in an emmetropic subject; pseudo-accommodation can play a role in increasing the depth of field but spectacle independence for a range of working distances is not to be expected after implantation of a Monofocal IOL. To restore the missing accommodation we can implant Multifocal IOLs. Multifocal IOLs on the other hand, are designed to have two or more fixed focal points, thus facilitating a sharp retinal image of objects at multiple working distances resulting in increased spectacle independence, but these lenses can cause reduction in contrast sensitivity and higher incidence of photic phenomena such as halos, flare and glare.

AIM OF THE STUDY

The study was carried out with the aim of comparing the visual outcome after cataract surgery with Multifocal Intraocular Lenses and Monofocal Intraocular Lenses in respect to distant visual acuity, near visual acuity, contrast sensitivity, subjective symptoms and to assess functional status and quality of life.

MATERIALS AND METHODS:

A Prospective observational study was conducted in the Department of Ophthalmology, KLES Dr. Prabhakar Kore Hospital and Medical Research Centre, Belagavi on patients undergoing cataract surgery during the period of 1st January 2015 – 31st December 2015. The study was approved by the Ethical and Research Committee of Jawaharlal Nehru Medical College, Belagavi. 40 eyes of 40 patients underwent phacoemulsification surgery with IOL implantation under LA. Choice of IOL inserted given according to their desire for spectacle independence. Monofocal group was taken as control. Both the groups were evaluated post operatively after 3 weeks and 6 weeks for distant vision, near vision, contrast sensitivity for distance, subjective satisfaction by standard questionnaire method and subjective symptoms like glare and halos and difficulty with night driving. Data was analyzed by chi-square test ($p < 0.05\%$).

RESULTS:

Distant visual acuity 6/6 – 6/9 in 80% and 75% of the patients of Multifocal and Monofocal groups respectively, remaining patients had 6/12 – 6/18 vision. 85% of Multifocal group had N6 – N8 vision ($p < 0.0001$). High contrast sensitivity for distance was almost similar in both the groups, but low contrast was significantly

reduced in Multifocal group as compared to Monofocal group (p = 0.0023). 15% of multifocal group had complained of glare and halos compared to Monofocal group who never had these visual sensations. 5% of patients in Multifocal group had difficulty with nighttime driving. 80% of patients in Multifocal group and 40% of patients in Monofocal group had become spectacles independent.

INTERPRETATION AND CONCLUSION:

The Multifocal IOL group experienced reduced spectacle dependency for near vision and a high level of patient satisfaction despite some reports of halos, glare and difficulty with night driving. The Monofocal IOL group experienced spectacle dependency for near vision. Overall, Multifocal IOLs offer best near vision acuity, good distant vision acuity, less limitation in visual function in selected and motivated individuals.

Key words: Phacoemulsification; Monofocal intraocular lens; Multifocal intraocular lens; Near vision; Contrast sensitivity; Glare & Halo.

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INTRODUCTION

The crystalline lens is part of the optical system of the eye that focusses rays of light on the retina. In subjects with an emmetropic refractive state, parallel rays emerging from a distant object focus on the fovea with the different parts of the optical system in their natural state. In ametropic subjects, the power of the optical system needs to be adjusted (with spectacles, contact lenses, or refractive surgery) in order to reach this desired situation. Apart from contributing to the optical power of the eye as a whole, the crystalline lens is able to dynamically change the optical power of the system by the process of accommodation for younger eyes. Light rays emerging from objects at near distance rather than at infinity are entering the eye at an angle rather than parallel. The optical power of the lens must therefore be increased in order to let the light rays converge at the retina. According to the theory pioneered by Helmholtz, contraction of the ciliary muscle decreases tension on the zonular fibers, resulting in a change in shape and therefore the optical power of the crystalline lens. The dynamic optical power of the system contributes to the ability of the subject to visualize objects at a range of distances. During life the ability of the crystalline lens to change in shape decreases, leading to presbyopia.[1]

For optimal visual performance crystalline lens should be transparent. Cataract describes the pathological opacification of the crystalline lens.[2]

Cataract surgery has evolved through many phases from the olden days of intra-capsular cataract extraction to extra-capsular cataract extraction, followed by manual small incision cataract surgery to finally standard phacoemulsification and recent advance is femtosecond laser-assisted phacoemulsification.

Removal of the crystalline lens followed by implantation of an artificial intraocular lens (IOL) in the capsular bag of the eye, as practiced in cataract surgery, offers an opportunity to address refractive anomalies in patients who are ametropic due to removal of cataract. Advances in preoperative calculations of the optical power of the IOL necessary for a desired refractive result, smaller incision sizes at the time of cataract surgery and the introduction of IOLs with a wide range of spherical and cylindrical optical powers in small increments have contributed to the current state where cataract surgery is not just a treatment for a vision-threatening disease, but should additionally be considered as a refractive surgery procedure.

Despite these advances, implantation of an IOL with a fixed focal point (Monofocal IOL) will theoretically render a patient at best emmetropic for a single fixed working distance only, leading to a postoperative result comparable to presbyopia in an emmetropic subject. Although more complex optical phenomena such as certain higher order aberrations, corneal shape and pseudoaccommodation can play a role in increasing the depth of field, spectacle independence in a range of working distances is not be expected after implantation of a Monofocal IOL.

Compensating this lack of accommodation is one of the most important challenges in ophthalmology research. Despite extensive investigations, the problem has not been fully solved. To restore the missing accommodation we can implant Multifocal IOLs. Multifocal IOLs on the other hand, are designed to have two or more fixed focal points, thus facilitating a sharp retinal image of objects at multiple working distances resulting in increased spectacle independence, but these lenses can cause reduction in contrast sensitivity and higher incidence of photic phenomena such as halos, flare and glare. [1]

So this study was done to compare and assess the effect of multifocal and monofocal IOL with reference to visual acuity both distant and near, contrast sensitivity, spectacle independence, complaints of glare and halos and patient's visual satisfaction.

AIMS AND OBJECTIVES

- Primary objective - To compare the visual outcome after cataract surgery with Multifocal Intraocular Lenses and Monofocal Intraocular Lenses.

- Secondary objective – Assessment of functional status and quality of life with Multifocal Intraocular Lenses and Monofocal Intraocular Lenses.

REVIEW OF LITERATURE

Multifocal IOLs are growing in popularity among patients and surgeons and opened the way to refractive lens exchange. Still, they are not used routinely in cataract surgery. Multifocal IOLs are available, which claim to allow good vision at a range of distances and are capable of correcting refractive errors as well as eliminating patients need for near-vision addition. So we conducted a study to compare the visual performance of Multifocal Intraocular Lenses and Monofocal Intraocular Lenses after cataract surgery.

Optics of the Human Eye

- The eye is divided into three compartments:
    1. **1.** The anterior chamber between the cornea and iris, which contains aqueous humor.
    2. **2.** The posterior chamber between the iris, the ciliary body and the lens, which contains aqueous humor.
    3. **3.** The vitreous chamber between the lens and the retina, which contains a transparent gel called the vitreous humor.[3]

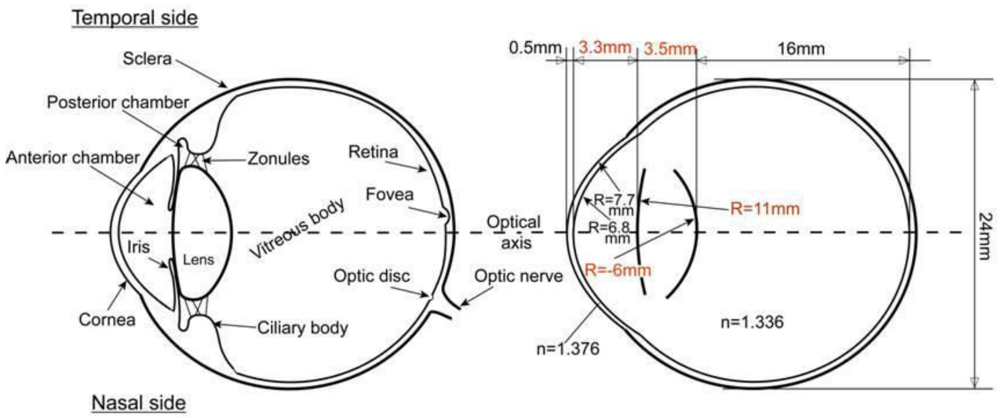


Fig 1: Optics of the Human Eye

Principles of image formation by the eye

- Light enters the eye through the cornea and is refracted by the cornea and lens.
- The cornea has the greater power.
- The lens shape can be altered to change its power when the eye needs to focus at different distances (accommodation).

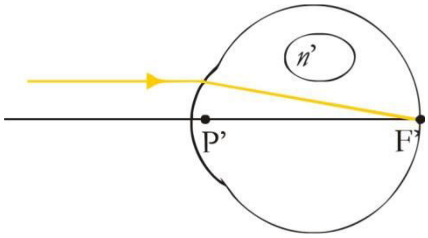


Fig 2: Principles of image formation by the eye

- The beam diameter is controlled by the iris, the aperture stop of the system. The iris opening is called the pupil. The aperture stop is a very important component of an optical system, affecting a wide range of optical processes.
- The image on the retina is inverted - like a camera.

Power of the eye

- One of the most important properties of any optical system is its equivalent power.
- Measure of the ability of the system to bend or deviate rays of light.
- The higher the power, the greater is the ability to deviate rays.

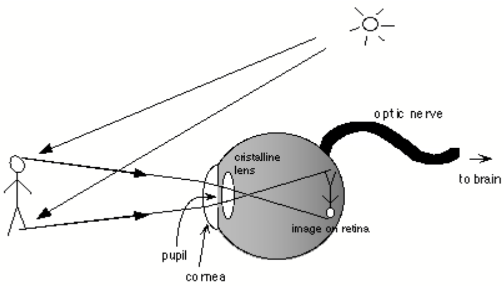


Fig 3: Power of the eye

- Equivalent power F of the eye is given by

  F = n'/P'F'

  P' is the second principal point, just inside the eye.

  F' is the second focal point.
- Light entering the eye from the distance is imaged at F' n' is the refractive index of the vitreous.
- The average power of the eye is 60 m^{-1} or 60 diopters (D).

Binocular vision

- The use of two eyes provides better perception of the external world than one eye alone.
- Two eyes laterally displaced by ~60 mm give the potential for a 3- D view of the world, including the perception of depth known as stereopsis.
- The total field of vision in the horizontal plane is about 210º.
- Binocular overlap is 120º.

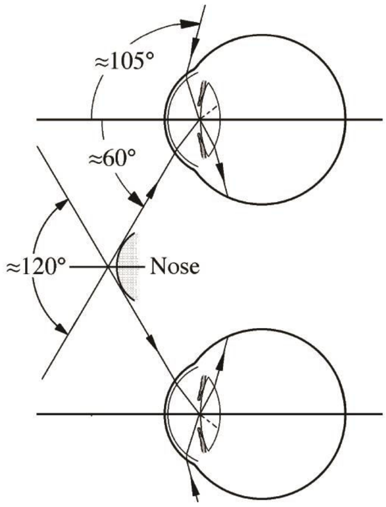


Fig 4: Binocular vision

Refractive Components

- Refracting components are *cornea* and *lens*.
- Elements must be transparent and have appropriate curvatures and refractive indices.
- Refraction takes place at four surfaces - the anterior and posterior surfaces of the cornea and lens. [47]
- There is also continuous refraction within the lens.

1) **Cornea**

- 40 D (2/3rds power) provided by the cornea.
- Supports the tear film and has a number of layers.
- ~ 0.5 mm thick in center.
- Posterior surface is more curved than the anterior surface.
- The anterior surface has greater power (48 D) than the posterior surface (-8 D) because of low refractive index difference between the cornea and aqueous.
- Frequently curvature is different in different meridians (Toric).
- In general, the radius of curvature increases with distance from the surface apex – Aspheric.
- Corneal surface asphericity influences higher order aberrations (subtle optical defects).

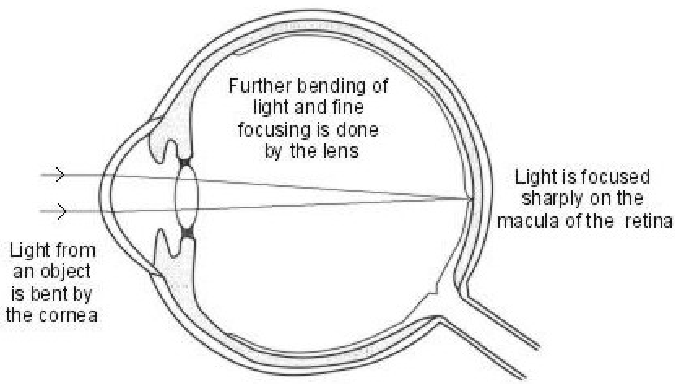


Fig 5: Refractive components: Cornea & Lens

2) **Lens**

- Lens bulk is a mass of cellular tissue of non-uniform refractive index, contained within an elastic capsule.
- Do not yet have an accurate measure of the refractive index distribution.
- Most cells are long fibres which have lost their nuclei, lens grows continuously with age, with new fibers laid over the older fibers.
- Anterior radius of curvature is about 12 mm.
- The posterior radius of curvature is about -6mm (note negative sign).
- Changes in shape with *accommodation* and aging, particularly at the front surface.

Accommodation

- In accommodation, when the eye changes focus from distant to closer objects:
  - Ciliary muscle contracts and causes the zonules supporting the lens to relax.
  - This allows the lens to become more rounded under the influence of its elastic capsule, thickening at the center and increasing the surface curvatures, particularly the anterior surface.
  - The anterior chamber depth decreases.

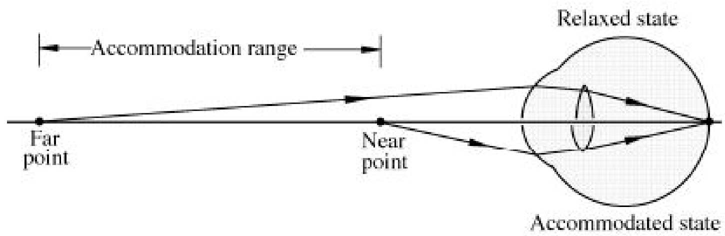


Fig 6: Optics of Accommodation

- In accommodation, when the eye changes focus from close to distant objects:
  - Reverse process occurs.
- In a young eye (20 years), accommodation can increase the power of the lens from about 20 to 33 D.[48]
- The furthest and closest points that we can see clearly are the far and near points.
- The difference between the inverses of their distances from the eye is the amplitude of accommodation (not quite the same as the increase in lens power, but closely related). [3]
- The average power of the eye is 60 m^{-1} or 60 diopters (D).

Refractive Error

- Refractive error more important than the equivalent power.
- Can be regarded as an error in the length due to a mismatch with the equivalent power.
- If the length is too great for its power, the image is formed in front of the retina and this results in *Myopia*.
- If the length is too small, the image is formed behind the retina and this results in *Hypermetropia*.

Refractive Anomalies

- Ideally, when the eyes fixates an object of interest, the image is sharply focused on the fovea.
- An eye with a far point of distinct vision at infinity is called *an emmetropic eye*. This is regarded as the "normal eye", provided that it has an appropriate range of accommodation.
- A refractive anomaly occurs if the far point is not at infinity. An eyes whose far point is not an infinity is referred to as *an ametropic eye*.
- Types of refractive anomalies: 1. Myopia
  2. Hypermetropia
  3. Astigmatism
  4. Presbyopia

1. **Myopia**

   - Far point is at a finite distance in front of the eye.

   - This eye can focus clearly on distant objects by viewing through a negative powered lens of appropriate power.

2. **Hypermetropia** - The far point of the eye lies behind the eye.

   - The eye can focus clearly on distant objects.

     - If sufficient amplitude of accommodation.
     - By viewing through a positive powered lens of appropriate power.

3. **Astigmatism**

   - The power of the eye changes with meridian.

   - Usually due to one or more refracting surfaces having a toroidal shape. May be due to surface displacement or tilting. We usually relate this to the error in the principal meridians of maximum and minimum power.

   - Astigmatism may be related to myopia and hypermetropia.

   - Hence we may have myopic astigmatism, hypermetropic astigmatism, and mixed astigmatism.

4. **Presbyopia** - The range of accommodation is reduced so that near objects of interest cannot be seen clearly.

5. Aphakia

- Aphakia literally means absence of crystalline lens.
- From an ophthalmological point of view, aphakia is the absence of the lens in the pupillary area.
- Before intraocular lenses (IOLs) were developed, cataract was removed and eye was left aphakic after ICCE and ECCE.
- The lens is important in refraction and hence its removal results in considerable decreased in the refractory power of the eye and it becomes highly hypermetropic.
- The power of eye decreases from +60D to +44D.
- The power of accommodation lost and the posterior focal point lies behind the eyeball.
- Due to aphakia vision will be defective – due to high hypermetropia and loss of accommodation and there will be erythropsia and cyanopsia – due to entry of infrared and ultraviolet rays in the absence of the crystalline lens.
- Because of defective vision and lost accommodation correction of aphakia requires. In Initial days spectacles were prescribed to correct this defective vision.
- This includes +10D lens for correction of aphakic part; this also includes correction for surgical astigmatism and +3-4D for near vision.

- But using spectacles in aphakia has many disadvantages like
    - The images are magnified – about 30% – hence not useful in unilateral aphakia as it causes diplopia.
    - The field of vision in decreased considerably.
    - Spherical and chromatic aberration of high power lenses.
    - Roving ring scotoma (Jack in the box phenomenon).
    - Prismatic effect of the thick lenses.
    - High power are cosmetically not acceptable.

- Gradually contact lenses come in to place but they also have some disadvantages like high cost, more care required – may not be suitable for use in young children and elderly and contact lens induced infections.

- Because of many disadvantages and complications of spectacles and contact lenses, intraocular lenses (IOLs) have taken a shape.(49)

Aging Eye

- Refractive errors are relatively stable between the ages of 20 and 40 years, after which there is a shift in the hypermetropic direction.
- Many of the optical changes taking place in the adult eye produce a progressive reduction in visual performance. Some of these can be considered as pathological.
- The most dramatic age-related changes take place in the lens. Its shape, size and mass alter markedly, its ability to vary its shape diminishes and its light transmission reduces considerably.
- In unaccommodated state:
    - Centre thickness ↑ at 0.024 mm/year.
    - Anterior surface radius of curvature ↓ at 0.044 mm/year
- The amplitude of accommodation reaches a peak early in life, then gradually declines.
- Becomes a problem for most people in their forties when they can no longer see clearly to perform near tasks – *presbyopia.*
- Accommodation is completely lost in the fifties.
- The cause of presbyopia has been controversial in recent years, but the majority of investigators believe that it is due to changes within the lens and capsule in which the lens loses its ability to change shape.

Cataracts

- Cataracts are defined as any opacification of the crystalline lens.
- This reduced optical quality of the crystalline lens has a negative impact on the resultant retinal image, but is dependent on the extent and position of the cataract within the pupil margins.
- Cataracts can be classified by their location and aetiology.
- Cataracts can develop as a result of developmental abnormalities (Lloyd *et al.,* 1992), systemic and ocular diseases such as diabetes and uveitis, drug induced changes, and trauma, but the main cause remains to be ageing (Mitchell *et al.,* 1997; Livingston *et al.,* 1994).[(4)(5)(6)]
- Several classification systems, which use photographic illustrations to assist grading, exist for the assessment of cataract extent and location.
- The lens opacities classification scale 111 (LOCS 111) (Chylack *et al.,* 1993a), oxford clinical cataract classification and grading system (OCCCGS) (Sparrow *et al.,* 1986), world health organisation (WHO) simplified cataract grading system (Thylefors *et al.,* 2002) and the Wilmer nuclear grading system (West *et al.,* 1988) are all commonly used classification systems for the assessment of cataracts. [(7)(8)(9)(10)]
- An alternative to these subjective methods is the use of Scheimpflug photography with lens densitometry, which has shown good levels of repeatability and validity for the measurement of nuclear cataracts (Datiles *et al.,* 1995; Grewal *et al.,* 2009).[(11)(12)]
- Age related cataracts are generally categorised into cortical (the most common), nuclear or posterior subcapsular cataracts although these do not have to occur in isolation (Beebe, 2003).[(13)]

1. ***Sub-capsular cataracts*** – these form at the central posterior cortex at the position_of the fourth purkinje image. Glare and reduced visual acuity are common visual symptoms associated with sub-capsular cataracts.

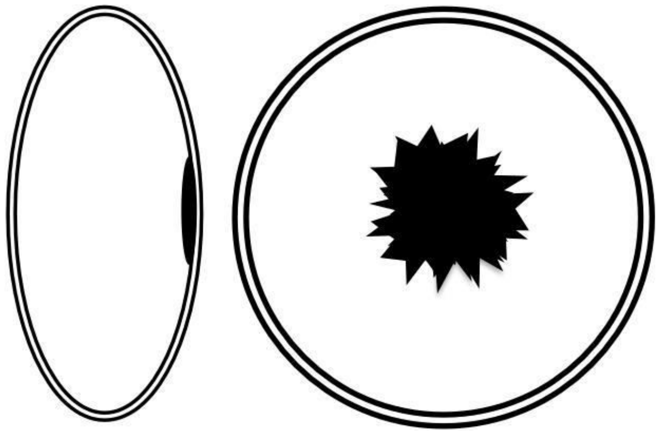


Fig 7: Sub-capsular cataracts

2. ***Cortical Cataracts*** – these opacities develop within the lens cortex and often appear as spokes within the crystalline lens. Visual symptoms are unlikely unless the cataract encroaches on the visual axis.

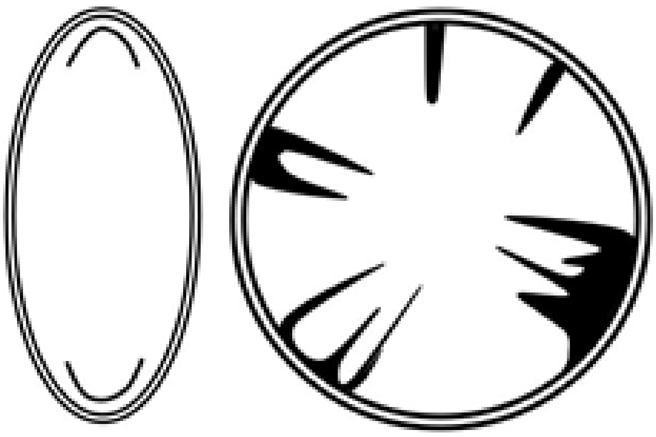


Fig 8: Cortical cataracts

3. ***Nuclear cataracts*** – characteristically affect the lens nucleus often creating a myopic shift and cause a brown colouration known as brunescence (Millodot, 2002).

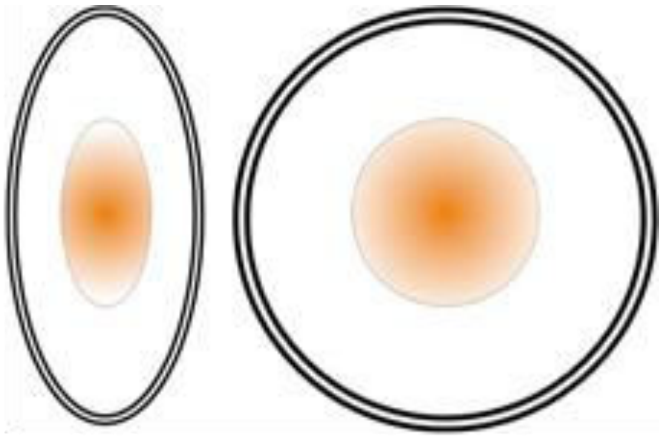


Fig 9: Nuclear cataracts

- As well as reducing the overall light transmission through the lens cataracts can affect vision through *refractive changes* or by increasing *ocular light scatter* (Stray light).
- Light scatter does not always affect high contrast measurements of visual acuity and thus measurement of contrast sensitivity (Chylack *et al.,* 1993b) and Stray light (Michael *et al.,* 2009) can provide greater insight into the visual effects of the cataracts.[(7)(11)]

Cataract Surgery

- Cataract is the most prevalent ophthalmic disease. Although a pharmacological preventive or therapeutic treatment for this blinding is being sought actively, the solution still appears to be many years away. Therefore, the extraction of opaque lens and replacement of optical power with suitable lenses, which increasingly includes IOL implantation, remains the only viable alternative.
- The implantation of IOLs is now a highly successful operation. The safety and efficacy of the procedure are now well established. Studies are still needed to determine which surgical technique and which IOL designs, most practical and most economic for high volume use in the least advantaged areas of the world.
- Posterior chamber IOLs following a long period of disfavour after the Ridley lens was discontinued, were reintroduced in the mid-1970s and early 1980s. Jaffe and other authors compared posterior chamber lenses with iris supported lenses and were impressed by the superior results achieved with the former type of lens using an extra capsular cataract extraction technique. The use of posterior chamber IOLs is now clearly the treatment of choice.[15]

- **History:** Sir Harold Ridley inserted the first posterior chamber IOL in the left eye of a 45 years old lady after an ECCE at St. Thomas Hospital, London on 29th November 1949. Ridley was not aware of the earlier attempts of Tadini and Casaamata. Ridley first got the idea when a medical student observing him operating a cataract case asked why he did not replace the cataractous lens which he had removed, with a new one. As an Air Force ophthalmologist, Ridley had observed that retained foreign bodies of airplane canopies made of polymethyl-methacrylate were tolerated well by the eyes. Thus, he chose this material for making the intraocular lens.

SURGICAL TECNIQUES FOR CATARACT EXTRACTION

1. Intracapsular Cataract Extraction (ICCE)

2. Extracapsular Cataract Extraction (ECCE)

Conventional Or with suture

Sutureless (SICS)

Manual

Instrumental (Phaco)

1. Intracapsular Cataract Extraction (ICCE):

- In this technique, the entire cataractous lens along with the intact capsule is removed. Therefore, weak and degenerated zonules are a pre-requisite for this method. Because of this reason, this technique cannot be employed in younger patients where zonules are strong. ICCE can be performed between 40-50 years of age by use of the enzyme alpha chymotrypsin (which will dissolve the zonules). Beyond 50 years of age usually there is no need of this enzyme. Absolute indications are markedly subluxated and dislocated lens. This technique has now become obsolete because of post-operative complications.

2. Conventional Extracapsular Cataract Extraction (ECCE):

- It involves the removal of almost the entire natural lens while the elastic lens capsule (posterior capsule) is left intact to allow implantation of an intraocular lens. It involves manual expression of the lens through a large (usually 10–12 mm) incision made in the cornea or sclera. Although it requires a larger incision and the use of stitches, the conventional method may be indicated for patients with very hard cataracts or other situations in which phacoemulsification is problematic.

Advantages of ECCE over ICCE:

1. ECCE is a universal operation and can be performed at all ages, except when zonules are not intact; where as ICCE cannot be performed below 40 years of age.
2. The Posterior chamber IOL can be implanted after ECCE, while it cannot be implanted after ICCE.
3. Post-operative vitreous related problems associated with ICCE are not seen after ECCE.
4. Incidence of post-operative complications such as endophthalmitis, cystoid macular edema and retinal detachment are much less after ECCE as compared to that after ICCE.
5. ICCE needs larger wound with a higher postoperative astigmatism.

However, ECCE inherently has few **disadvantages**

1. Posterior capsular opacification (after cataract) which necessitates subsequent surgery or YAG laser capsulotomy.
2. Any residual cortical matter after incomplete wash can excite phacogenic uveitis and secondary glaucoma.
3. Any PC rent with vitreous disturbance makes cortical wash problematic.
4. Moderate post-operative astigmatism.

- In the era of early Extracapsular cataract extraction (ECCE), due to increased incidence of the lens matter induced inflammation, pupillary membrane (after cataract) formation and rise of IOP (Secondary glaucoma) effort started to remove the lens in entirety.

- In modern ECCE techniques which have improved with the availability of intraocular lenses, newer instruments, use of microscopes, better techniques of anterior capsulotomy and improved infusion/aspiration modalities has gained popularity.

- Although this technique of conventional ECCE became popular, surgically induced astigmatism was very high due to the sutures and longer incision length. So, SICS came into picture which proved better than conventional ECCE as it had many advantages

Advantages of SICS over conventional ECCE:

1) Better wound stability and early ambulation of patient.
2) Reduction of induced astigmatism.
3) Greater patient comfort with early visual rehabilitation.
4) Less chances of anterior chamber collapse during surgery
5) Dreaded complications like expulsive haemorrhage can be avoided.
6) Suture and suture-related complications can be avoided as the wound is self-sealing and sutureless (e.g. Iris prolapse, endophthalmitis, bleeding, epithelial defects).
7) Minimal post-operative visits.

- But still SICS has many disadvantages like conjunctival congestion may persist at the site of the conjunctival flap for 5-7 days and sometimes there may be mild tenderness resulting from scleral incision, postoperative hyphaema may occur and there is a possibility that surgically induced astigmatism can be more in SICS as a result of a larger incision than phacoemulsification.

Phacoemulsification:

- In the late 1960's Dr. Charles Kelman introduced a new technique of phaco-emulsification by which an adult cataractous nucleus could be removed by a small incision i.e. by 3 mm. The nucleus was subjected to ultrasonic energy through a needle probe, by which it could be broken or emulsified into smaller, softer fragments, which it could be broken or emulsified into smaller, softer fragments, which could then be aspirated. This was possible by agitating the needle at 55,000 cycles per records, producing linear movement of 3/1000 an inch with an acceleration of 80,000 G. Following lens extraction the IOL of smaller diameter corresponding to the incision or tunnel was placed in the capsular bag with the advent of foldable intraocular lenses, made of silicone, acrylic and hydrogel, IOLs of bigger diameter could be folded into half and inserted into the bag.

- Charles D.Kelman introduced the concept of phacoemulsification, as early as 1948, but it was accepted in 1967. The original equipment was known as Cavitron-Kelman Phacoemulsifier Mark I. A significant breakthrough in the surgical removal of cataracts occurred with the introduction of clear corneal incisions by I. Howard Fine, M.D., in 1992.(21)

Advantages of Phacoemulsification over manual SICS

1) Phacoemulsification can be performed through a smaller 2.8 to 3.2mm incision and with advent of microphaco it could be still further reduced to 1.8 to 2.2 mm.
2) It can be performed in the posterior chamber minimizing the risk of corneal endothelial damage.
3) The surgically induced astigmatism is least in phacoemulsification, moderate in SICS, more in ECCE and maximum in ICCE.

- Minassian et al. conducted a randomized trial on extracapsular cataract extraction (232 patients with age related cataracts) and Phaco (244 patients). They found that surgical complications and capsule opacity within 1 year after surgery were significantly less in Phaco; and a higher proportion of the Phaco group achieved unaided VA 6/9 or better. Phaco was noted as the cheaper option.(22)

- George et al. compared surgically induced astigmatism and endothelial loss following conventional ECCE, SICS and phacoemulsification with non-foldable intraocular lens implant in 186 eyes with nuclear sclerosis of grade 3 or less. The mean endothelial cell loss was similar in all the three groups (P = 0.855); ECCE induced a loss of 4.72% (SD: 13.07); SICS 4.21% (SD: 10.29) and Phaco 5.41% (SD: 10.99). Mean surgically induced astigmatism was 1.77D (1.61D) in the ECCE group, 1.17D (0.95D) in the SICS group and 0.77D (0.65D) in the Phaco group (P = 0.001). SICS caused an intermediate amount of astigmatism as compared to ECCE and Phacoemulsification. Less astigmatism was induced by Phacoemulsification than SICS and ECCE.(23)

- Dr. Fine IH developed the clear corneal incision which had obvious advantages over scleral tunnel incisions like less bleeding, prevention of cautery and induced astigmatism, view during surgery is unhampered by conjunctival flap and a good visualization of intraocular structures during surgery.(24)

MONOFOCAL INTRAOCULAR LENSES

- Monofocal IOLs have a fixed or single focal point and are the current standard of treatment for lens replacement. A standard monofocal IOL provides good distance and sometimes-intermediate vision, but does not correct near vision. It has a fixed focusing power set for distant vision. The accommodating capability of the eye, which allows variable, focusing, is lost after cataract surgery. Visual accommodation is the ability of the eye to change focus and provide clear image over a range of distance. During accommodation, the ciliary body applies pressure to the vitreous as it contracts. This pressure in combination with the increasing laxity of the zonules, causes the lens to more forward increasing its relative optical power allowing the eye to focus for close work. After extraction of the cataractous lens contents, the lens capsule still retains a certain level of accommodating capability. However the use of monofocal IOLs usually requires corrective lenses or eyeglasses after surgery for reading and near vision tasks.(16)

Types of Intraocular Lenses(17):

a. Anterior chamber IOL
b. Iris supported lenses
c. Posterior chamber lenses
    1. Endocapsular fixation
    2. Sulcus fixation
    3. Scleral fixation

1. **<u>Anterior chamber IOL:</u>** These lenses lie entirely in front of the iris and are supported in the angle of the anterior chamber. These are not very popular, when indicated Kelman Multiflex type of AC IOL is used commonly.

Types of surgical techniques – ICCE or ECCE

<u>Common complications:</u>

a) Corneal edema

b) Bullous Keratopathy

c) UGH syndrome

2. **<u>Iris supported lenses:</u>** These lenses are fixed on the iris with the help of sutures, loops or claws. These lenses are also not very popular due to high incidence of postoperative complications.

Example of iris-supported lens are Singh & Worsts iris claw lens, Moltese cross lens and Fydorov’s sputnik lens.

Type of Surgical Techniques - ICCE or ECCE

<u>Common Complications:</u>

a) Bullous Keratopathy

b) Secondary glaucoma

c) Iris atrophy

3. Posterior chamber Intraocular Lens:

a) Types:

Type 1: Depending upon the material used in the construction of the optic and haptics, posterior chamber intraocular lens can be broadly classified into:

a) Single Piece – Where the haptic and optic is made of the same material.

b) Three Piece – Where haptics are of a different material and are attached to the optic made out of a different material loops are commonly made of polypropylene.

Advantage of the single piece intraocular lens is that they have better 'loop memory' which simply means that on insertion the loops are pulled towards the optic, when released they return to their original position. Complete return to original position leads to better contact with sulcus bag and less chances of posterior capsular opacification.

Type 2: Depending upon the support to the IOL

i) Capsular bag

ii) Ciliary sulcus

i) **Capsular bag:**

Surgical Technique - Planned ECCE → Conventional

Surgical Technique - Planned ECCE → Small incision → Manual

Small incision → Instrumental-Phaco

- Phacoemulsification

- After above following surgery, lens is implanted, provided there has not been a significant zonular dialysis or loss of most of the posterior capsule.

- Surgeons prefer to inject a viscoelastic material into the anterior chamber. This is used for both a continuous curvilinear capsulorhexis and a can-opener anterior capsulotomy. Some prefer to use air to avoid the expense of a viscoelastic. It is far less satisfactory as a space maintainer, especially when one encounters an elevated intraocular pressure. Viscoelastic material into the capsular bag for IOL implantation.

- The lens is from its sterile container. It is irrigated with a balance saline solution. It is grasped at the edge of the optic with Blaydes or Clayman forceps. The leading loop is passed through the cataract incision without lifting the cornea. It is placed into the inferior capsular fornix. The forceps are released, leaving the trailing loop protruding from the wound. Many lenses have a hole or notch in this loop. A hook device engages the hole or the notch. The loop is flexed into the eye until the convexity can be passed under the superior edge of the anterior capsule. To be certain of in the bag placement, the lens is rotated to the horizontal position by dialing.

ii) **Ciliary Sulcus Fixation:**

- Currently this is used only in cases in which there is large PC rent or in some cases of zonular dialysis. Small amount of zonular dialysis can be managed by endocapsular rings. The advantage of a continuous curvilinear capsulorhexis allows easy passage of the lens over the remaining anterior capsule into the ciliary sulcus. Placement of the loops of the lens in the ciliary sulcus is a blind procedure surgically because the surgeon cannot visualize the sulcus. The sulcus area is also an inexact region with many anatomic variations. The ciliary processes may prevent access to the ciliary sulcus. One should be certain that the loops pass over the remaining anterior capsule and not behind it to present dislocation through an open posterior capsule. In addition, in some cases it might be wise to implant a lens with a larger optic and longer length.

- Recognition of the potential dangers of contact of poorly polished lenses with delicate ocular tissues stimulated a change to capsular bag fixation as the preferred method.

Complications:

1) Decentration
2) Pupil capture
3) Posterior synechiae and synechiae at the margin of the optic
4) Posterior iris chafing syndrome
5) Erosion and perforation of the ciliary body
6) Loop perforation through a peripheral iridectomy

GEOMETRY OF INTRAOCULAR LENES

- There are two basic aspects of an IOL. On the one hand, there is the optic zone, of which we need to consider the diameter, thickness, shape and radii of curvature. On the other hand, there are the haptics whose size, geometry and shape must be taken into account since they determine the zone where the lens will be implanted as well as the possible side effects of the lens being "off center" or inclined together with the possible effects of aberrations.

- The design has become ever simpler, the lens lighter and the haptics configuration is such that they prove a minimum hindrance in the zone of union and to their insertion in the eye. This geometry presents the lens from rotating, inclining or moving off center.

MATERIALS

- The ideal implant material should have the following properties:
  - i) High optical quality
  - ii) Light weight
  - iii) Resistant to biodegradation
  - iv) Lack of inflammatory reaction
  - v) Lack of antigenicity
  - vi) Lack of carcinogenicity
- To protect the cells various safer materials are sought which are less toxic and dangerous to the endothelium. Methacrylate has been considered in order to increase the flexibility of the lens so that it can be inserted inside the eye through a small incision. Barrett et al suggested that a soft, flexible hydrogel intraocular lens produces minimal endothelial damage. Nobel et al reported that although hydrogel lenses gives good visual results, its stability and tendency to cause pigment-shedding needs to be closely monitored. Foldable and autoclavable HEMA and silicon lenses are undergoing clinical trials at present.
- Optic – Polymethylmethacrylate, acrylic, Lucite, Plexiglas, Perspex, Silicone hydrogels
- Haptic – Polyethylene Terephthalate (DACRON)
  Polyethylene glycolterephthelate (Mersilene)
  Polypropylene (Prolene)
  Metals – Alloys of platinum (iridium Titanium stainless steel)
  Polyamides – Perlon, supramid, Nylon 66.

OPTIC (PMMA)

- It has withstood the test of time and reliability, making it the most widely used material in IOL manufacturing. Some of its properties that give it an edge over the glass are that it is lighter, unbreakable, but pitting of the lens by YAG laser is only disadvantage and can be easily sterilized by gas.
- PMMA is desired through “addition” polymerization of meth acrylic acid methyl ester which itself derives from acrylic acid.

HAPTICS

- Polyamides their strength, flexibility and manufacturing properties make them suitable for intraocular has haptics. But they undergo biological degradation when placed in sulcus. They also had poor loop memory, which led to their abandonment.
- Polyethylene terephthalate / glycolterephthelate: They are resistant to hydrolysis and U.V radiation; at the same time they are well tolerated by ocular tissue. PMMA most commonly used material for loops could be a single piece or three piece.

STERILISATION

- Initially, the sterilization of the plastic created difficulties due to the danger of depolymerisation of polymer during sterilization. Heat sterilization cannot be done and it releases toxic monomers. Ridley first used detergents, but these often caused post-operative iritis. Binkhorst and Flu tried ultraviolet light for sterilization, however, it did not work because of its unsatisfactory sterilizing effect, (Binkhorst C.D. Flu F.P. 1956) later on Gamma radiations were tried but they altered the polymer structure of polymethyl methacrylate and make the implant yellow. Over sterilization produces toxic breakdown produces of polymethyl methacrylate leading to serious inflammatory sequelae.
- In 1957, Frederick Ridley introduced sodium hydroxide sterilization.
- (Ridley F.L.1957) The greatest flaw in this method being that lens has to be transferred before implantations into a neutralizing solution of sodium hydrogen carbonate which in it has no sterilizing effect. The contamination of the neutralizing solution leads to endophthalmitis epidemics in the USA in 1975 and 1976 (Link D.M. 1977). Recently the efficacy of sodium hydroxide against the fungal spores has been challenged.
- Recently Ethylene oxide gas is generally used for sterilization. Theoretically, this technique is risky because ethylene oxide can react with any monomer present in polymethyl methacrylate to form a highly toxic compound, however in practice; no problems of this nature have been encountered. Occasionally it causes irritation, inflammation and sterile endophthalmitis. One disadvantage of dry sterilization is that polymethyl methacrylate plastic is electrostatic when dry and tends to attract and hold any lint or other debris floating near it in the air. If the lens is kept moist, it is less apt to attract extraneous material.

Chemical Sterilization

a) By immersion in 1% solution of tetradecyl-trimethylammonium bromide (cetrimide). Main disadvantage was post-operative iridocyclitis, hypopyon. A technique now abandoned.

b) By soaking in 10% sodium hydroxide at 35^0 C for at least three hours. Shortly before use, the lens in washed with distilled water and residual sodium hydroxide is neutralized by 1% sodium bicarbonates.

Gas Sterilization

- IOL is placed in a low pressure chamber (22-25 mm Hg) with a relative humidity level of 45 to 65 percent, and then it is exposed to ethylene oxide in a mixture of 12% ethylene oxide and 88% dichloroflouromethane for 4 hours at 50°C. Ethylene oxide kills all microorganisms, but penetrated into the plastic. These lead to postoperative inflammation.

Thermal Sterilization

- It leads to depolymerisation of P.M.M.P, but can be used to sterilize silicone and glass IOL. Dry sterilization at 160^0 C for l hr or 190^0 C for 15 minutes. It moist heat is used than 135^0 C is enough.

Gamma Radiation Sterilisation

- It is the most effective method of sterilization for mass production of IOL's P.M.M.A. can be exposed up to 2.5 M Rad without affecting its properties. All the leading manufacturers of IOL's are now using this method to sterilize their products. It is more cost effective and does not alter the physical and chemical properties of P.M.M.A.

POWER CALCULATION

- For perfect lens implantation it is important that optimum power of pseudophakos should be calculated for given patient. For this, three factors are important:

    i) The refractive power of corneal surface

    ii) The axial length of globe

    iii) The refractive power of the crystalline lens

- Weinstein showed that this can be accomplished better with ultrasound than with the formerly employed x-rays (Weinstein et al 1966). In Germany, Gernet was the first to work with "echometry" (Gernet H.1967) several investigators developed useful formulas for calculation of intraocular lens power.[18]

- Some of these are:

  a. SRK Formula: This has developed by sanders et al (1981) & Retzlaff (1980).

  P = A – 2.5 L – 0.9 K

  P - Implant Power

  A - Specific constant for Lens

  L - Axial Length (mm)

  K - Average Keratometric Reading (Diopters)

  - Retzlaff after collecting data from 230 eyes with posterior chamber lenses compared the prediction of accurate results than did other formulas (Refzlaft 1980).

b. Gills Formula: This method called 'computer generated intraocular lens power equation formula.

P lens = 129.404739 + (-1.08023xk) + (-2.793507 X L eye) +

(0.262593 X LCl) + (-0.384961 X Ref)

P lens – lens power needed for desired post-operative refraction

K – Refraction power of cornea in dio|

L eye – Axial length of eye in mm

LCI – Distance of apex of anterior corneal surface to apex of the intraocular lens in mm

Ref – Desired post-operative refraction

c. Colenbrander's Formula:

$$P\ lens = \frac{NAV}{Leye - (Lcl + d)} - \frac{NAV}{NAV - \frac{(Lcl + d)}{K}}$$

P lens = Power of intraocular lens (Diopters)

NAV = Refractive index of aqueous

L eye = Axial length of eye (in meters)

Lcl = Distance of apex of the anterior corneal surface of intraocular lens in meters

K = Refractive power of cornea

D = Distance of 2nd principal point of the intraocular lens from the apex of its anterior surface equals 0.00005meters ($5 X 10^{-5}$) m

d. Clinical evaluation:

P = 19 + (R x 1.25)

P = Implant Power

R = Refractive error before onset of cataract

MULTIFOCAL INTRAOCULAR LENSES

INTRODUCTION

- Throughout history, the ability to see clearly at near has had a deep impact on a person's occupational performance and recreational pursuits. Prior to spectacle correction for presbyopia over 200 years ago, many people in their later years in life suffered a severe visual handicap due to the loss of adequate near vision. The initial use of single power spectacles followed by the popularity of bifocals has greatly enhanced the lives of presbyopic patients. However the nuisance and expense of spectacles frequently make this method unpopular.[(19)]

- Over the past decade, refractive surgical procedures have been rapidly evolving, especially for myopic and astigmatic eyes. The correction of presbyopia has remained somewhat elusive. However, cataract surgeons have been making steady progress in improving near vision IOL's and newer operative techniques with improvements in IOL power calculations and the reduction of post-operative astigmatism, patients are now enjoying and even expecting, better unaided distance and near vision after cataract removal.

- Today's cataract surgeons have a number of modalities to restore unaided near vision.

EVOLUTION OF MULTIFOCAL IOL

- Accommodation in the healthy eye: The normal eye is constructed so that the various refracting surfaces and ocular media focus parallel rays of light from a distant object upon the retina. The eye can also adjust its dioptric power through the accommodating process to bring near objects into the focus. In an analysis of Purkinje images during accommodation. Helmholtz has shown that the posterior lens surface remains fixed in position and undergoes a slight increase in curvature, but the major dioptric shift during accommodation results from the forward movement and marked increase in the convexity of the anterior pole of the lens.

- The cortex of the young lens is a soft, easily molded material contained in an elastic capsule. The traction of the zonular fibers opposes the natural tendency of the lens to assume a spherical shape. During accommodation, however contraction of the ciliary muscles pulls the zonular attachment sites inward towards the lens equator, reducing the tension on the zonules and lens capsule and they're by allowing the lens to passively increase its convexity. The resultant steepening of the anterior and posterior poles of the lens affects the accommodating process.

- The amplitude of accommodation is greatest in childhood and slowly decreases until it is lost in middle age. The loss of accommodation, although fairly uniform in the population, fluctuates with the demands of the visual task, the level of illumination, drug effects, pupillary size and a person's general health. When the inability to carry out prolonged near-vision tasks due to fatigue, headache and other symptoms of asthenopia occurs, the condition is called presbyopia. Duane's standard curve of accommodative amplitude verses age reveals that by the age of 60 all accommodation has generally been lost.

- Without exaggeration, the difficulties in adapting to bifocal glasses are often considerable. As the reading addition is increased in strength or the patient requires Trifocal or Multifocal reading segments there is often frustration and discouragement.

- Since standard IOL's are monofocal the loss of accommodation becomes absolute with surgery and the need to correct the resultant presbyopia is apparent. In what may be considered an evolutionary step, bifocal and Multifocal IOL's of several different designs have been introduced. They differ from conventional Monofocal IOL's in that they offer the potential for providing both distance and near vision without additional spectacle correction.

CHARACTERS OF MULTIFOCAL IOLS:

- Multifocal IOL’s have two or more optical foci. This means the presence of at least two co-axial dioptric powers usually separated by a 4D interval to provide a 3D interval at the spectacle plane. On the retina, the two dioptric powers will produce two super improved images of any observed object. Under the best condition, one image will be in sharp focus and the other image will be blurred by a 3D defocus aberration. For example, a black line on white paper will appear surrounded by a narrow gray ribbon. This is the optical reason for the reduction in modulation transfer function observed with Multifocal IOL’s unfortunately a reduction strictly connected to the presence of co-axial different process. This lower optical quality as compared with Monofocal IOL’s emerges and as lower contrast sensitivity in implanted patients.(19)

TYPES OF MULTIFOCAL IOLS

- Multifocal IOL designs to date incorporate either refractive or diffractive optical principles to achieve simultaneous distance and near visual acuity. Although most of bifocal design of the lenses is termed Multifocal because of their ability to function at more than two foci, often with a satisfactory activity for distant, near and intermediate vision.
- Refractive optics can be broken down further into spheric and aspheric designs. The anterior and\or posterior IOL surface can be utilized for single or combination designs.
- There are, at present **four** different designs are available:

i) Two or three zone bifocal refraction:

The lens is biconvex with a 2 mm Central button for near vision.

Fig 10a: Two Zone bifocal design.

FIG 10b: Three Zone bifocal design.

- This involves the combination of two or more different anterior spheric refractive surfaces for distance and near correction (the Iolab Nuvue ™ bifocal IOL and Pharmacia Ophthalmics bifocal). The Iolab IOL has a 2mm diameter central optical for near vision. The remainder of the lens, which is lower in power by 4D, is a ring-shaped zone for distance correction. When the pupil size is 2.8mm the light distribution between near and distance focus on the retina is even, when 4mm the distribution is ¼ for near and ¾ for distance assuming that the lens is perfectly centered.

- The Pharmacia design has a central circular distance zone (2.1mm diameter) surrounded by a ring-shaped near zone of 0.7mm width, which is then surrounded by another peripheral ring shaped zone for distance correction. Both of these designs effect their dioptric changes for distance and nearby refractive spheric curvature changes on the anterior surface of the IOL. Both of these lenses are rigid non-foldable implant and require a large wound size at least 7mm.

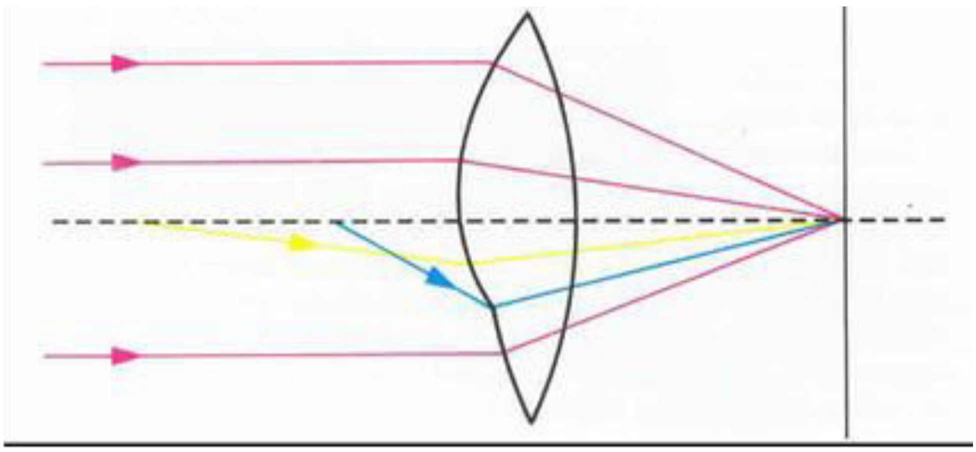


Fig 11: Ray diagram of light entering the aspheric lens

ii) <u>Combination of spheric and aspheric surfaces for multifocal refraction:</u>

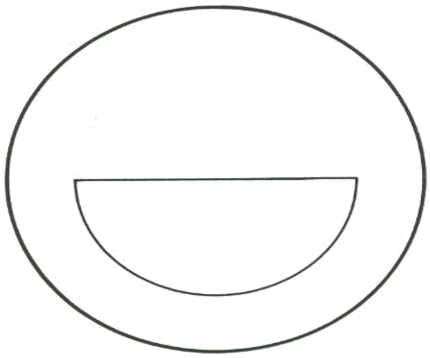


Fig 12: The semicircle for intermediate and near is aspheric in both horizontal and vertical directions. The peripheral 1 mm is for distance.

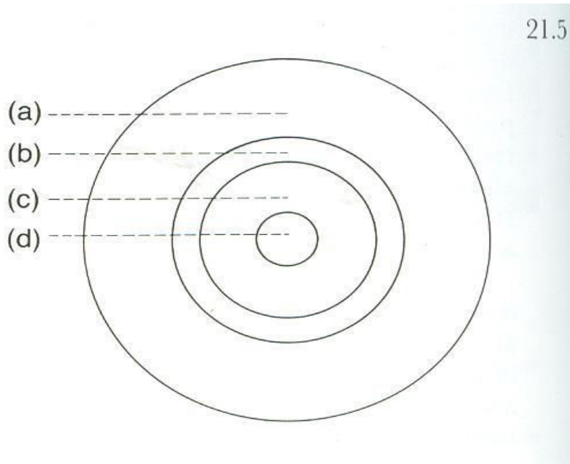


Fig 13: Ray diagram of light entering the concentric aspheric system of lens

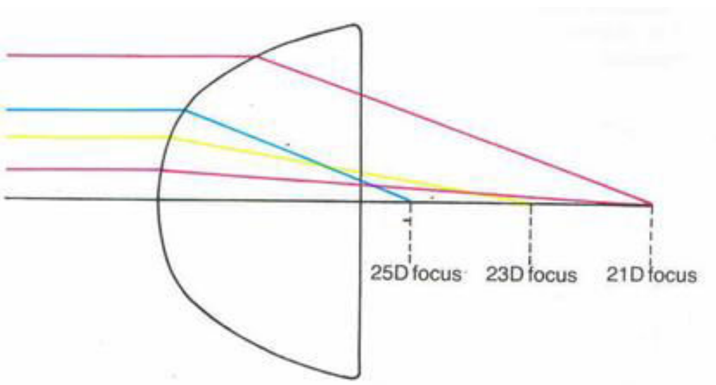


Fig 14: Lens optic combining aspheric & spheric zones on the anterior surface: a)n spherical zone b) aspherical flatting zone c) aspheric steepening zone d) spherical distance zone.

- This involves the combination of an anterior spheric and an anterior aspheric refractive surface as designed by Lee Nordan for true multifocal refraction (wright medical, Inc. and Ioptex Aspheric Multifocal lenses). As it is not necessary to involve the entire visual axis for a multifocal design the Nordan IOL made by weight medical incorporates a spheric and aspheric combination on a one half segment of the anterior surface of a biconvex lens. The radius of curvature of this aspheric segment constantly changes, thus incorporating a smooth increase in power towards the midperiphery of the lens of up to 3D. Ioptex, which combines spheric, uses a second design and aspheric curves concentrically for a progressive power increase of 4D. The smooth transition minimizes observation and ensures a truly multifocal function. The dioptric power changes that occur as the more peripheral optical zones are reached. The mid zones represent the anterior aspheric refractive surfaces for near correction.

iii) <u>Multiple zone refraction multifocals:</u>

- There are a combination of a posterior spheric refractive surface and multiple anterior spheric refractive surfaces for distance, intermediate and near correction (Allergan Medical Optics: Array design). The front surface of the array design has five zones, each of which progressively adds from 0 to 3.5D to the overall lens power. All distances from infinity to the near point would be expected to be focused by each zone of this IOL. Theoretically, the multifocal function should not be compromised by decentration or pupillary abnormalities.

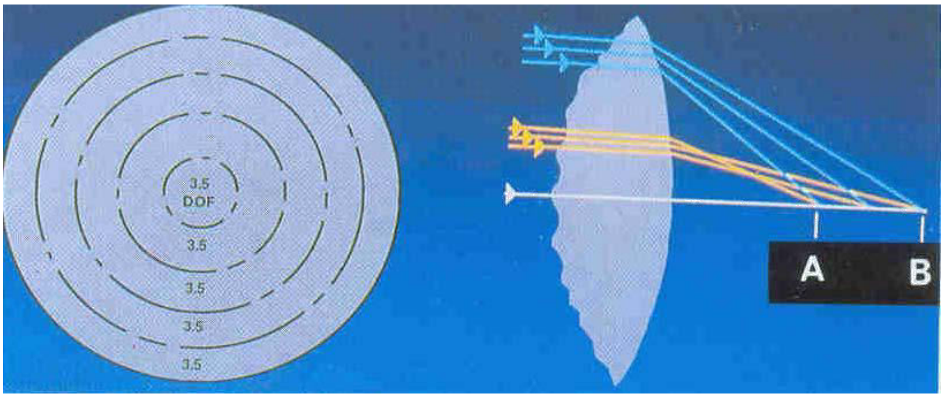


Fig 15: Refractive design showing 5 zones of progressive power addition and a ray diagram of light entering 2 such zones: A-Near 23.5D; B Far 20.

iv) **<u>Multiple zone diffraction bifocals:</u>**

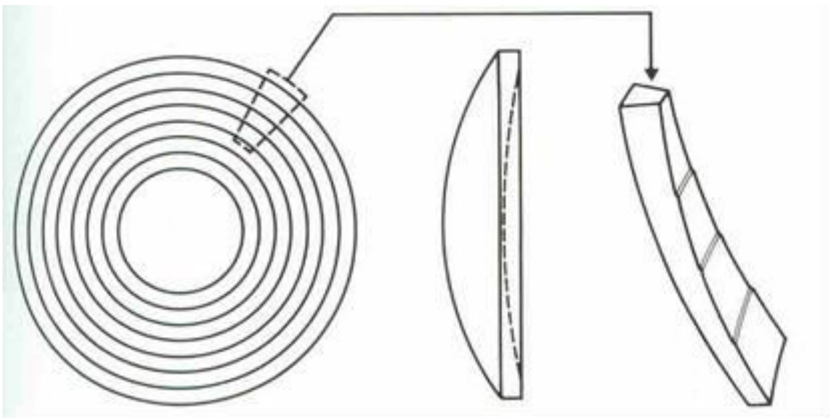


Fig 16: Diagram of light entering zones of the optics: A-Near image; B-Distance image.

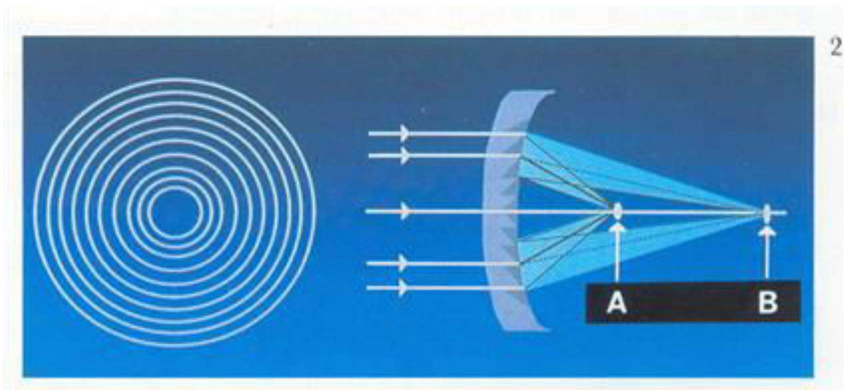


Fig 17: Diagram of Diffractive optic showing micro slope rings, edge on representation of the optic and exaggerated detail of stepped discontinuities.

- These are the combination of an anterior spheric refractive surface and multiple posterior diffractive plate surfaces for distance and near correction (3M: microscope design). The 3M IOL combines both conventional refractive (on the anterior IOL surface) and diffractive (on the posterior IOL surface) optical principles. The combination can be reversed with the diffractive plates worked onto the anterior surface if a smooth refractive surface is required posteriorly. By choosing suitable dimensions for 20 to 30 concentric zones, each bounded by step discontinuities on the posterior surface, light is diffracted towards two foci. Diffraction can be interpreted as a spreading of wave fronts. After encountering discontinuities if the waves are in phase, they summate and if they are out of phase, there is a destructive interface. The design allows approximately 41% of light to be in phase and focused for distance, 41% to be in phase and focused for near and 18% to be permanently out of focus. Both foci receive light from every zone, so the bifocal function is independent of pupil size and lens centration.

- Theoretically, each of these lenses will focus both distance and near objects on the fovea simultaneously, but often by sacrificing contrast and therefore resolution. At either object location two or more images are formed on the retina; one is in focus and the other is out of focus. The degree to which the contrast in the focused image is reduced by the out of focus images will characterize in part the performances of each lens design.

Advantages of Multifocal over Monofocal IOL:

1. Post-operative spectacle independence in patients with Multifocal IOL for both distance and near vision.
2. Spectacle independence in traumatic cataract patients in young adults in order to facilitate binocularity at near, especially if the fellow eye has no refractive error or is corrected by contact lenses.

Disadvantages of Multifocal over Monofocal IOL:

1. Subjective symptoms like Glare, halos, reduced in depth perception.
2. Difficulty in driving, especially in night
3. Reduced contrast sensitivity

Advantages of Monofocal over Multifocal IOL:

1. Best corrected distance visual activity
2. Normal contrast sensitivity
3. No difficulties with night driving
4. No subjective symptoms like, Glare, Halos, etc.

Disadvantages of Monofocal over Multifocal IOL:

1. Post-operative spectacle dependency for near vision.
2. In young patients with unilateral traumatic cataract, post operatively difficult to adapt to since they will lose their physiologic accommodation completely and suddenly, when cataract surgery is undertaken.

i) Diffractive Multifocal Lens

Advantage:

(i) Diffractive lens optics are somewhat more successful than refractive lens optics in achieving a high standard of unaided reading vision.

(ii) This lens is less pupil dependency and the ability to provide an even distribution of near and distance vision.

Disadvantages:

i) Diffractive lens optics has only been placed on rigid, non-foldable implants. Their implants typically have an optic diameter of 6mm. So that they will require a wound size of at least 7mm to allow insertion.

ii) As is well documented any wound size of greater than 2.5mm will cause induced surgical astigmatism and when wound sizes are greater than 4mm, the induced astigmatism will comprise unaided distance and near vision, so the patients will not be able to achieve any multifocal effect or bifocal visual effect and will be spectacle dependent the exact situation they were hoping to avoid. In addition, patients with induced surgical astigmatism will generally be spectacle dependent for distance, intermediate and near vision, whereas those who receive a monofocal implant using a wound size of 3mm or lens, will at least be free of spectacles for distance vision even if they cannot be certain of achieving complete spectacle independence for near vision.

(iii) Both diffractive and refractive lens designs appear to have an incidence of patient awareness of halos or blur circles of approximately 10%. These blur circles are particularly prominent in dim light, when point sources of light will manifest as having defocused circles of lights around them (street lights, car headlights or brake lights, footlights in the theatre). This occurs because both refractive and diffractive lens optics create two planes of focus, so that if, for example light from a distant object is clearly focused, there will also be a defocused imaged from the same object (from the nearest component of the implant) being perceived by the retina. In the majority of patients this defocused image is ignored, but in some patients this cannot be ignored and causes significant symptoms.

(iv) When these complaints occur their symptoms will be present for all pupil size in patients with a diffractive implant, since the diffractive surface functions regardless of pupil size. This means that there is no effective way of controlling or eliminating the complaint.

(v) If this complaint occurs in the presence of a refractive multifocal intraocular lens implant, it can largely be controlled by shifting the near point further out with a – 0.50 to –1.0 diopter lens (since there are refractive lenses) or if this fails, by reducing the pupil size (for instance with dilute pilocarpine drops instilled at night). Since refractive lens optics are very sensitive to pupil size**.**

(ii) <u>Refractive Multifocal Lens</u>

<u>Advantage</u>

- With a pupil size of 2mm or less, refractive multifocal or bifocal implants will effectively function as a monofocal lens and no light will pass through the near or intermediate focusing elements. This can be a real advantage since it allows the ophthalmologist to eliminate or reduce the halo effect (when it occurs) in symptomatic patients by prescribing medications to reduce pupil size.

(iii) Three – Zone multifocal IOL[50]

Advantage

- Normal pupil patients do enjoy both near and distance vision, but smaller pupils can obstruct the near component with some three zone Multifocal IOLs. One advantage of this lens design is that even though there is pupil dependency, distance vision is always preserved despite the loss of near acuity with miosis.

- Cillino et al in 2014 compared visual outcomes, reading performance, and quality of life (QoL) of working-age cataractous patients bilaterally implanted with three different diffractive multifocal intraocular lenses (MIOLs) in a randomized, prospective, and double-masked study. Sixty-three consecutive patients (126 eyes) were randomized to receive the ReSTOR SN6AD3 (Alcon Laboratories, Inc., Irvine, CA, USA) (20 patients, group A), ReSTOR SN6AD1 (Alcon Laboratories, Inc.) (21 patients, group B), or TECNIS ZMA00 (Abbott Medical Optics, Santa Ana, CA, USA) (22 patients, group C) MIOL. They concluded that newer-generation aspheric diffractive MIOLs, especially low-add hybrid apodized or full diffractive, are highly suited for working-age cataractous patients in terms of visual outcomes, reading performance, and QoL. Intrinsic optical differences, such as optimizing for computer or dim-light working, or night driving, could be useful tools to customize the IOL in each single case.[24]

CLINICAL RESULTS

- Clinical trials comparing Multifocal lens implantation in the same patient also revealed improved intermediate and near vision in the Multifocal eye compared to the Monofocal eye.
- Many studies have evaluated both the objective and subjective qualities of contract sensitivity, steroacuity, glare disability and photic phenomena following implantation of Multifocal IOLs.
- Refractive Multifocal IOLs were found to be superior to Diffractive Multifocal IOLs by demonstrating better contrast sensitivity and less glare disability.
- One of the potential drawbacks of the Multifocal IOLs has been the potential for an appreciation of halos around point sources of light at night in the early weeks and months following surgery. Most patients will learn to disregard their halos with time and bilateral implantation appears to improve these subjective symptoms. Concerns about the visual function of patients at night have been allayed by a driving simulation study in which bilateral Multifocal patients performed only slightly worse than patients with bilateral Monofocal IOL's. The results indicated no consistent difference in driving performance and safety between the two groups.
- Overall, subjects with bilateral Multifocal IOLs reported better overall vision, less limitation in visual function and less use of spectacles than monofocal controls.

PATIENT SELECTION

- As a result of a surgeon's experience, they have developed specific guidelines with respect to the selection of candidates & surgical strategies that enhance outcomes with this Multifocal IOL.

Indications

1. Bilateral cataract & moderate to severe visual loss without ocular pathology.
2. Normal sized pupil, but mobile pupils. This implies that the pupil can constrict to approximately 2mm or less in bright light, but dilate to approximately 4mm in dimmer light. The patient should be counselled to use less light when reading, after Multifocal lens implantation to allow adequate pupil dilatation for the near component of the lens to be useful.
3. There are special circumstances in which implantation of a Multifocal IOL should be strongly considered. Alzheimer's patients frequently lose or misplace their spectacles and thus they might benefit from the full range of view that a Multifocal IOL provides without spectacles.
4. Patients with arthritis of the neck or other conditions with limited range of motion of the neck may benefit from a Multifocal IOL rather than Multifocal spectacles, which require changes in head position.
5. Photographers who want to alternate focusing through the camera without spectacles and adjust imaging parameters on the camera without placing spectacles on in these patients the focusing eye could have a monofocal IOL and the non-dominant eye a multifocal.
6. A traumatic cataract in young adults in orders to facilitate binocularity at near, especially if the follow eye has no refractive error or is corrected by contact lenses.
7. Pre-operative cylindrical correction of less than 1.75D.Planned emmetropic; axial length < 26mm.

Contraindications

1. Absolute contraindications include the presence of ocular pathologies like age-related macular degenerations uncontrolled diabetes or diabetic retinopathy, uncontrolled glaucoma, recurrent inflammatory eye disease, retinal detachment risk and corneal disease or previous refractive surgery in the form of radial keratotomy, photorefractive keratectomy or laser assisted in situ keratomileusis.
2. Patients who have a significant requirement for night driving and in patients who are professional drivers.
3. Engineers and architects occupations that put high demands on vision and near work.
4. Patients with high visual expectations in general are not good candidates for Multifocal IOLs.
5. Irregular astigmatism.
6. Axial length > 26 mm.
7. Pupil size smaller than 2.5mm for Multifocal IOLs.

Pre-operative Measurements

1. Appropriate patient selection
2. Keratometry
3. A-scan
4. Intraocular pressure measurement
5. Sac syringing
6. Routine blood investigations, fasting sugar, postprandial blood sugar and urine tests etc.

SURGICAL TECHNIQUE

Clear Corneal Phacoemulsification Cataract Surgery with Foldable PCIOL

- Eyelids retracted with speculum.
- Side ports made with 1.2 mm side-port blade depending on the incision site.
- Anterior chamber filled with visco-elastic material.
- Continuous curvilinear Capsulorhexis carried out with a modified cystitome.
- A clear corneal self-sealing incision made with a 3.2 mm keratome.
- A clear corneal incision taken at 12 o'clock position.
- Hydrodissection and hydrodelineation performed to separate the capsule and nucleus and free rotation of nucleus ensured.
- Phacoemulsification done by chip and flip or by stop and chop procedure.
- Cortex was removed by bimanual irrigation and aspiration technique.
- Following this, capsular polishing done if required.
- A foldable intraocular lens inserted through a 3.2 mm incision with the help of an injector. Intra-ocular lens inserted within the capsular bag.
- Residual visco-elastic removed.
- The clear corneal wound and side port entries sealed by hydration.
- Sub-conjunctival injection of dexamethasone 2 mg and gentamycin 10 mg.
- Eye padded and bandaged after installing antibiotic eye drops.

COMPLICATIONS AND MANAGEMENT

- When intra operative complications develop they must be handled precisely and appropriately. In situations in which the first eye has already had a Multifocal IOL implanted, complications management must be directed toward finding any possible way of implanting a Multifocal IOL in the second eye. Under most circumstances, capsule rupture will still allow for implantation of a Multifocal IOL as long as there is an intact capsulorhexis. Under these circumstances, the lens haptics are implanted in the sulcus and the optic is prolapsed posteriorly through the anterior capsulorhexis. This is facilitated by a capsulorhexis that is slightly smaller than the diameter of the optic in order to capture the optic in essentially an “in the bag” location. If full sulcus implantation is utilized then appropriate change in the IOL power will need to be made in order to compensate for the more anterior location of the IOL within the eye. When vitreous loss occurs, a meticulous vitrectomy with clearing of all vitreous stands must be performed.
- It is important to avoid iris trauma since the pupil size and shape may impact the visual function of a Multifocal IOL postoperatively. If the pupil is less than 2.5mm, there may be near visual acuity. For patients with small post-operative pupil diameters affecting near vision, surgeon has had success utilizing the Argon laser to perform a mydriatic pupilloplasty.

POST-OPERATIVE COURSE

- If glasses are required after surgery, the spherical correction should be determined by over-plusing the patient to a slight blur and gradually reducing the power until the best acuity is reached. Patients are able to focus through the nearer portions of their IOL and thus it is possible to over-minus a patient if the case is not taken to push the plus power. When using this defocusing technique, it is critical to stop as soon as distance activity is maximized to avoid over-misusing. The cylinder power should be the smallest amount that provides the best activity. If add power is necessary, prescribe the full add power for the required working distance.
- If patients are unduly bothered by photic phenomena such as halos and glare, there symptoms can be alleviated by various techniques. Weak pilocarpine at a concentration of 1/8 percent or weaker will constrict the pupil to a diameter that will usually lessen the severity of halos without significantly effecting near visual activity.

- Another approach involves the use of over minused spectacles in order to push the secondary focal point behind the retina and thus lessen the effect of image blur from multiple images in front of the retina. Polarized lenses have also been found to be helpful in reducing photic phenomena. Perhaps the most important technique is the implantation of bilateral Multifocal IOLs as close in time as possible in order to allow patients the ability to use the lenses together, which appears to allow for improved binocular distance and near vision compared to monocular activity. Finally most patients report that halos improve or disappear with the passage of several weeks to several months.

TESTING OF VISUAL ACUITY

Distant visual acuity:

- The distant central visual acuity is usually tested by Snellen's test types. The fact that two distant points can be visible as separate only when they subtend of 1 minute at the nodal point of the eye, forms the basis of Snellen's test types. It consists of a series of black capital letters on a white board, arranged in lines, each progressively diminishing in size.
- Each letter of the chart is so designed that it fits in a square, the sides of which are five times the breadth of the constituent lines. Thus, at the given distance, each letter subtends an angle of 5 minutes at the nodal point of the eye. The letters on the top line of Snellen's chart should be read clearly at the distance of 60 m.
- Similarly the letters in the subsequent lines should be read from a distance of 36, 24, 18, 12, 9, 6, 5 and 4 m, respectively.

Procedure of testing:

- For testing distant visual acuity, the patient is seated at a distance of 6m from the Snellen's chart, so that the rays of light are practically parallel and the patient exerts minimal accommodation.
- The patient is asked to read the chart with each eye separately and the visual acuity is recorded as a fraction, the numerator being the distance of the patient from the letters, and the denominator being the smallest letters accurately read.

Near visual acuity:

- Near vision is tested by asking the patient to read the near vision chart, kept at a distance of 35cm in good illumination, with each eye separately. In near vision charts, a series of different sizes of printer type are arranged in increasing order and marked accordingly. Commonly used near vision charts are as follows:

    1. **Jaeger's chart:** In this chart prints are marked from 1 to 7 and accordingly patient's acuity is labelled as J1 to J7 depending upon the print he/she can read.
    2. **Roman test types:** According to this chart, the near vision is recorded as N6, N8, N10, N12, N18 and N36.
    3. **Snellen's near vision test type.**

- Vaggu SK, Kodepaka PN in 2016 found that there was a significant difference in the uncorrected near visual acuity. There was no difference in the corrected near visual acuity in both the groups. There is no significant difference in uncorrected distant visual acuity after 1 and 6 weeks postoperatively in both the groups. Multifocal IOLs offer best near visual acuity, good distance visual acuity in selected and motivated individuals.(19)

CONTRAST SENSITIVITY

Introduction:

- Contrast sensitivity is the ability to perceive slight changes in luminance between regions, which are not separated by definite borders, and is just as important as the ability to perceive sharp outlines of relatively small objects.

Types of contrast sensitivity:

1. **Spatial contrast sensitivity:**

- Spatial contrast sensitivity refers to detection of striped pattern at various levels of contrast and spatial frequencies. In its measurement, Patient is presented with sine wave grating of parallel light and dark bands (Arden gratings) and is asked to tell the minimum contrast at which the bars can be seen at each frequency. The width of the bars is defined as spatial frequency, which expresses the number of pairs of dark and light bars subtending an angle of one degree of the eye. A high spatial frequency implies narrow bars, whereas a low a spatial frequency indicates wide bass.

2. **Temporal contrast sensitivity:**

- Here the contrast sensitivity function is generated for time related (temporal) processing in the visual system by presenting a uniform target field modulated sinusoidal in time rather than as a function of spatial position.
- Both temporal and spatial contrast sensitivity testing yield scientifically more complete and systematic data on the status of visual performance than the conventional tests.

- Measurement of contrast sensitivity – When a subject is presented with the grating frequencies and contrast below which resolution is impossible indicates the threshold level; and the reciprocal of this contrast threshold gives the contrast sensitivity.
- Contrast sensitivity is measured as (L max – L min) / (L max + L min); where L is the luminance recorded by photocells scanning across the gratings.
- There are three variables in the measurement of contrast sensitivity:

    1. Average amount of light reflected depends on illumination of paper and darkness of ink.
    2. Degree of blackness in relation to the white background i.e. contrasts.
    3. The distance between the grating periods or cycles per degree of visual angle.

- The deficits were expressed in terms of decibel and three types of deficits were described:
    1. High frequency type characterized by increasing loss of high frequency.
    2. A level loss type characterized by a similar loss for all spatial frequencies.
    3. A selective loss type characterized by deficits in a narrow band of spatial frequencies.

In general, the methods recommended to measure contrast sensitivity include; simple plates, cathode ray tube display on a screen letter activity charts, laser interferometer which produces grating on the retina, visual field testing using low contrast rings on stimuli, pattern discrimination test, prototype for forced choice printed test visual evoked cortical potentials to checker board pattern reversal dependant contrast threshold measurement two alternative forced choice test and many more.

Five simple methods are:

1. **Arden gratings:** Arden in 1978 introduced a booklet containing seven plates – One screening plate and six diagnostic plates. The contrast changes from top to bottom and covers a range of approximately 1.76 log units. A score of 1.20 is assigned to each plate, depending upon the amount of plate uncovered. The sum of six plates with an upper limit of 82 was established for normal subjects together with interocular differences if less than 12.

2. **Cambridge low contrast gratings:** Cambridge low contrast gratings consist of a set of the plates containing gratings in a spiral bound booklet.
   - To perform the test the booklet is hung on a wall at a distance of six meters. The pages are presented in pairs one above the others. One page in each pair contains gratings and the other is blank, but have the same mean reflectance. The subject is simply required to choose which page, top or bottom, contains the gratings. The pages are shown in order of descending contrast and told to stop when the first error is made. Four descending series are shown separately to each eye, when no error is made at plate 10, then a score of 11 is given. Depending upon the total score of the patient from four series, the contrast sensitivity is noted from the conversion table.

3. **Pelli – Robson contrast sensitivity chart:** This chart consists of letters which subtend an angle of three degrees at a distance of one meter. The chart is printed on both the sides. The two sides have different letter sequence, but are otherwise identical. The letters on chart are organized as triplets, these being two triplets in each line. The contrast decreases from one triplet to the next. The log contrast sensitivity varies from 0.00 to 2.25.

- To perform the test, the chart is hung on the wall, so that its center is approximately at the level of the subject's eye. The chart is illuminated as uniformly as possible so that the luminance of the white areas is between the acceptance range of 60 to 120 cd/m, which corresponds to a photographic exposure between 1/15 and 1/30 second at f/5.6 with an ASA of 100. The luminance is determined with the help of a light meter.

- While recording, the subject sits directly in front of the chart at a distance of one meter (with the best distance correction). The subject is made to name or outline each letter on the chart, starting from the upper left corner and reading horizontally across the line. The subject is made to guess, even when he believes that the letters are invisible. The test is concluded when the subject guesses two of the three letters of the triplet incorrectly. The finest triplet indicates the subject's sensitivity incorrectly. The finest triplet for whom two of the three letters are named correctly indicates the subject's sensitivity.

4. **Halogen glare test csv – 1000 HGT (vector vision, Dayton, OH, USA):** Contrast sensitivity and glare disability were examined using the halogen glare test. The instrument contains four rows with 8 x 2 test patterns with decreasing contrast from left to right. The patient is asked to recognize the lines on the top or bottom of the test pattern. The lines encompass four spatial frequencies (3, 6, 12 & 18 cycles per degree, CPD). The halogen light source automatically measures the surrounding illumination and

calibrates the instruments testing light lends. Therefore, it is independent of room illumination contrast sensitivity was checked without glare and with moderate as well as with high glare.

5. **Bailey and Lovie chart:** This chart contains high contrast one side and lower contrast other side, each line is measured by log Mar (VAR).

   - To perform the test, the chart is hung on the wall, so that its center is approximately at the level of subject's eye. The chart is illuminated as uniformly as possible so that the luminance of the white areas is between acceptable ranges while recording the subject sits directly in front of the chart at a distance of six meters. The subject is asked to read letter, i.e. each letter on the chart, subject is made to guess ensure when he believes that the letters are invisible. The test is concluded when the subject guesses two of the three letters of the triplet incorrectly. Both high contrast and low contrast are checked in the same above manner. The subject is the finest triplet for which two of the three letters are named correctly indicates subject's sensitivity.

- Hayashi et al reported in 2009 that the diffractive multifocal IOL with a low add power (ReSTOR SN6AD1* IOL with a +3.0 D add) provided significantly better intermediate and near VA than the monofocal (AcrySof IQ SN60WF) IOL. Contrast sensitivity (CS) with and without glare was reduced with multifocal IOL, and all-distance VA was independent of pupil diameter.[(25)]

Neural Mechanisms of contrast Sensitivity:

- Campbell and green gave the concepts of different visual channels for handing information about different bonds of spatial frequencies. This concept indicates that the retina is non-uniform. Fovea is specialized for high acuity and is responsible for high spatial frequencies. In the retinal periphery, only low frequency channels are represented. For coarse grating, central and peripheral retina has an equal contrast sensitivity per unit area of retina, but larger the retinal area stimulated greater is the sensitivity. Thus, contrast sensitivity will be reduced in peripheral retinal diseases and the use of low frequency grating would provide a rapid check of peripheral retinal function.
- Further, Campbell and Robson proposed the existence within nervous system of linearly operating independent mechanisms selectively sensitive to limited range of spatial frequencies. The oriented to limited range of spatial frequencies, the orientation selectivity and the interocular transfer of the adaptation effect implicated the visual cortex as the site of their neurons. They attempted to explain the preliminary and essential role of such interactions in the recognition of complex images and generalization for magnification.

Factors affecting contrast sensitivity:

1. Refractive errors – Refractive errors affect only the higher frequencies.
2. Age – There occurs a definite decrease in contrast sensibility with increasing age. From 20 years of age, 10% decrease per decade.
3. Lenticular changes – Early lens changes can reduce contrast sensitivity essentially for low spatial frequencies
4. Ocular and systemic disease - Contrast sensitivity is decreased in cases with retinal optic nerve and visual pathway diseases, glaucoma, ocular hypertension, retro bulbar neuritis, multiple sclerosis, amblyopic, diabetes mellitus and pituitary adenoma.
5. Points with cataract extraction with Multifocal PC IOL implantation experience reduced low contrast sensitivity in the initial post – operative period.

HALOS

- Halos or the colored halos refer to entoptic visualization of colored rings around small white light viewed from a distance. These colored rings result from breaking of the white light into seven colors by the various layers of cells of the ocular media through which the light must pass on its way to retina. Halos may be either physiological or pathological.

Physiological Halos:

Four distinct physiological halos as seen entoptically around the bright light by normal individuals have been described. There are as follows:

1. 3^0 diameter halo:
   - It is the least distinct or the four physiological halos and is probably formed by the corneal epithelial cells.
2. 4.5^0 diameter halo:
   - It is one of the more distinct halos and is most likely formed by the corneal endothelial cells and\ or lens epithelial cells.
3. 6^0 diameter halo:
   - It is the most distinct and the largest described halo. Emsley and Fincham suggested that it is formed by diffraction of the light by the radially arranged lens fibers. Simpson described that this lenticular halo is not a homogenous band of color, but is composed of innumerable radial rays of varying lengths and brightness each ray being a complete six-colored spectrum. All the rays combine to form a halo composed of concentric colored rings. In the center there is a disc of white called the ciliary corona.

4. 9^0 diameter halo :

   - This is a very indistinct halo and is believed to be a second order of diffraction from the structures that produce the 4.50 halo. Multifocal IOLs designs appear to have an incidence of patient awareness of halos or blur circles of approximately 10%. These blur circles are particularly prominent in dim light, when point sources of light will manifest as having defocused circles of light around then. This occurs because both refractive and diffractive lens optics creates two (or more) planes of focus. So that if, for example, light from a distant object is clearly focused, there will also be a defocused imaged from the same object being perceived by the retina.

Pathological halos:

1. Colored halos of corneal edema
2. Colored halos of corneal mucus
3. Colored halos of immature cataract

GLARE

- For many individuals the ability to see objects of low and moderate contrast fails in high glare situations. Such as when driving into low sun or at night on crowded roads, walking on a summer beach or even being in a white walled bathroom. Especially on the road, this is a potent cause of accidents. The problem is caused by light scattering within the eye and thereby reducing the contrast of the retinal image.
- Susceptibility can be quantified in terms of the glare susceptibility (GSR), defined as a visual activity with no glare source divided by visual activity in the presence of a standard glare source. This index provides a direct impression of the effect of glare.
- Glare can render low-contrast objects invisible while having comparatively little effect on visual activity is no more than a straightforward consequence of the shape of the contrast sensitivity function.
- The cause of glare susceptibility includes lens opacities, light entering through the iris (especially for those with blue eyes) and corneal scarring.
- Note that the slit-lamp technique for examining lens opacities is based on light scattered back from lens opacities, whereas the disabling effect of glare is caused by the light that is scattered forward into the retina. Consequently, slit lamp examination does not necessarily indicate the degree of glare disability experienced by individual patients.

MATERIALS AND METHODS

METHOD OF COLLECTION OF DATA

STUDY DESIGN

A Prospective Observational Study (one year study)

SOURCE OF DATA

All the patients attending the outpatient department of Ophthalmology at KLE'S Dr. Prabhakar Kore Hospital and Medical Research Centre, Belgaum who had pre-senile and senile cataract on the examination.

STUDY PERIOD

One year – 1st January 2015 to 31st December.

Study size: Calculated as per the given formula

$n = 2(Z\alpha + Z\beta)^2\ p*q \div (p_0-p_1)^2$

=36 (sample size)

$Z\alpha = 1.96$ $Z\beta = 0.84$

$p = 26.5$ $q = 100-p$

$p_1 = 41\%$ $p_0 = 12\%$

Power of study- 80%

SELECTION CRITERIA

Inclusion Criteria:

1) Patients with pre-senile and senile cataract without any other ocular pathology.

2) Patient's age group 40-70 years.

3) Pre-operative corneal astigmatism less than 1.0D.

4) Willingness and sufficient cognitive awareness to comply with examination procedures.

5) Who agreed to attend the scheduled follow up visits.

Exclusion Criteria:

1) Poor visual outcome expectations due to other ocular disorders.

2) Profession demanding visual precision

e.g. Architect, Driver, Pilot.

3) Psychiatric diseases.

4) Dissatisfaction with progressive glasses.

STUDY PARTICIPANT SELECTION

Once patient satisfy with inclusion criteria all the pre-operative evaluation required for the cataract surgery done. The choice of intraocular lens inserted during phacoemulsification with IOL surgery given to the patient according to their willingness. Written informed consent was taken from the patients. Participation was voluntary and participants could exercise their right to pull out of the study at any stage.

PRE-OPERATIVE EVALUATION

Data regarding demographic parameters such as name, age, sex, occupation and address noted on a predesigned proforma.

Detailed history of following symptoms noted:

- H/o diminution of vision RE/LE
- Duration
- Gradual/ Sudden
- Progressive/ Static
- Distant/ Near vision
- Visual improvement with bright light or dim light
- Painful/ Painless
- Diplopia/ Polyopia
- Photophobia
- Flashes of light
- Coloured halos

- Floaters
- Watering
- Redness
- Discharge
- Black spots in front of the eye
- H/o Curtain falling experience in front of the eyes
- H/o Wearing glasses
- H/o Diabetes Mellitus, Hypertension, Asthma.

History was followed by Systemic and Ocular examination that includes

- Vital Signs-
    - Blood Pressure
    - Pulse
    - Respiratory Rate
    - Temperature

- Systemic Examination-
    - CNS Examination
    - CVS Examination
    - Per Abdomen Examination

- Distant Visual Acuity with Snellen's chart, Near Visual Acuity with Roman vision chart.

- Ocular examination proper (adnexa, conjunctiva, cornea, anterior chamber, iris, pupil and lens).
- Detailed slit-lamp bio microscopy to grade the cataract as:-
    - Cortical Cataract
    - Nuclear Sclerosis
    - Posterior Subcapsular Cataract
- Schiotz tonometry
- Best Corrected Visual Acuity
- Retinoscopy
- Ophthalmoscopy through dilated pupil
- Pre-operative keratometry (Manual Bausch and Lomb Keratometer)
- A-scan biometry (SRK II Formula)

Routine laboratory investigations included were:-

- Routine hemogram
- Fasting blood sugar using glucometer

PRE-OPERATIVE PREPARATION

Instillation of Moxifloxacin 0.5% plus Ketorolac 0.5% eye drops started day before the surgery (8-10 times/day) and stopped one hour before surgery. The pupil was dilated with Tropicamide 0.8% with Phenylephrine 5% used 3 times in one hour for two hours before surgery. Oral Levofloxacin 500 mg once a day started a day before surgery for 5 days. Informed consent for surgery was taken.

PROCEDURE

Senior consultant performed all the surgeries under local anaesthesia by using peribulbar block. Anaesthesia and akinesia of the eyeball was obtained with a peribulbar block of 8 ml mixture of 2% Xylocaine with adrenaline, with addition of Hyaluronidase (1500IU).

A good massage was given to the eyeball for ten minutes to achieve adequate hypotony. Just before the start of the surgery diluted 5% Povidone iodine with normal saline (1:5) eye wash given. The skin around the eye was painted with 5% povidone iodine and 70% v/v isopropyl alcohol.

Clear Corneal Phacoemulsification Cataract Surgery with Foldable PCIOL

- Eyelids retracted with speculum.
- Side ports made with 1.2 mm side-port blade depending on the incision site.
- Anterior chamber was filled with visco-elastic material
- Continuous curvilinear Capsulorhexis was carried out with a modified cystitome.
- A clear corneal self-sealing incision was made with a 3.2 mm keratome.
- A clear corneal incision taken at 12 o'clock position.
- Hydrodissection and hydrodelineation was performed to separate the capsule and nucleus and free rotation of nucleus was ensured.
- Phacoemulsification was done by chip and flip or by stop and chop procedure.
- Cortex was removed by bimanual irrigation and aspiration technique.
- Following this, capsular polishing done if required.
- A foldable intraocular lens was inserted through a 3.2 mm incision with the help of an injector. Intra-ocular lens inserted within the capsular bag.
- Residual visco-elastic was removed.
- The clear corneal wound and side port entries were sealed by hydration.
- Surgery was concluded with a sub-conjunctival injection of dexamethasone 2 mg and gentamycin 10 mg
- Eye was padded and bandaged after installing antibiotic eye drops.

POST-OPERATIVE EVALUATION

On the first post-operative day, all the patients were submitted to detailed slit-lamp examination, distant visual acuity, near visual acuity, contrast sensitivity testing and fundus examination. All the patients were put on topical corticosteroid (Difluprednate 0.05%) and antibiotic (Gatifloxacin 0.3%) combination 6 times daily, which was then tapered and stopped over a period of 6 weeks. The patients were also given topical mydriatic/cycloplegic (Tropicamide 0.8% with Phenylephrine 5%) at bedtime to prevent posterior synechiae formation and to diminish ciliary spasm. Oral Levofloxacin 500 mg had continued for another 3 days. The patients were asked to come for review on the end of 1st week, 3rd week and 6th week of postoperative day.

At all subsequent visits, the patients were submitted to the following examinations:

1. Slit-lamp examination
2. Visual acuity:
    - Uncorrected distance visual acuity (UDVA)
    - Uncorrected near visual acuity (UNVA)
3. Wound healing
4. Corneal clarity
5. Intraocular lens placing
6. Contrast sensitivity: High & Low
7. History of Subjective symptoms:
    - Halos
    - Glare
    - Difficulty in night driving
8. Fundus examination
9. Patient satisfaction evaluation by Visual Function Questionnaire at the end of 6 weeks.

STATISTICAL ANALYSIS

Statistical analysis done by CHI-SQUARE Test.

RESULTS

The present study is a prospective observational study. It was conducted on 40 patients with pre-senile or senile cataract, meeting the inclusion criteria, who presented to the ophthalmology department of KLES Dr. Prabhakar Kore Hospital and Medical Research Centre between 1st January 2015 to 31st December 2015.

In this study, distant vision, near vision, contrast sensitivity, refractive changes and also subjective symptoms like halos, glare and difficulty in night driving were compared post-operatively at 3 weeks and 6 weeks between the two IOL groups and were statistical analysed by Chi-square test with $p < 0.05$ indicating statistical significance.

Table 1: Study Inclusion Data

Parameters	Observation
Total number of patients	40
Monofocal IOL Group	20
Multifocal IOL Group	20
Total number of eyes included	40

Table 2: AGE DISTRIBUTION

Age Groups	Mono Focal Group	%	Multi Focal Group	%
41-50	2	10.00	2	10.00
51-60	8	40.00	6	30.00
61-70	10	50.00	12	60.00
Total	20	100.00	20	100.00
Mean age	60.55 ± 7.06		61.15 ± 7.75	
Chi-square=0.4682 p = 0.7922				

Out of the 40 patients included in this study, 20 cases were allocated to each of the two groups according to their desire for type of IOL. The mean age of the patients was 60.55 ± 7.06 years in the monofocal group and 61.15 ± 7.75 years in multifocal group as shown in table-2 and graph-1.

Graph 1: Age Distribution

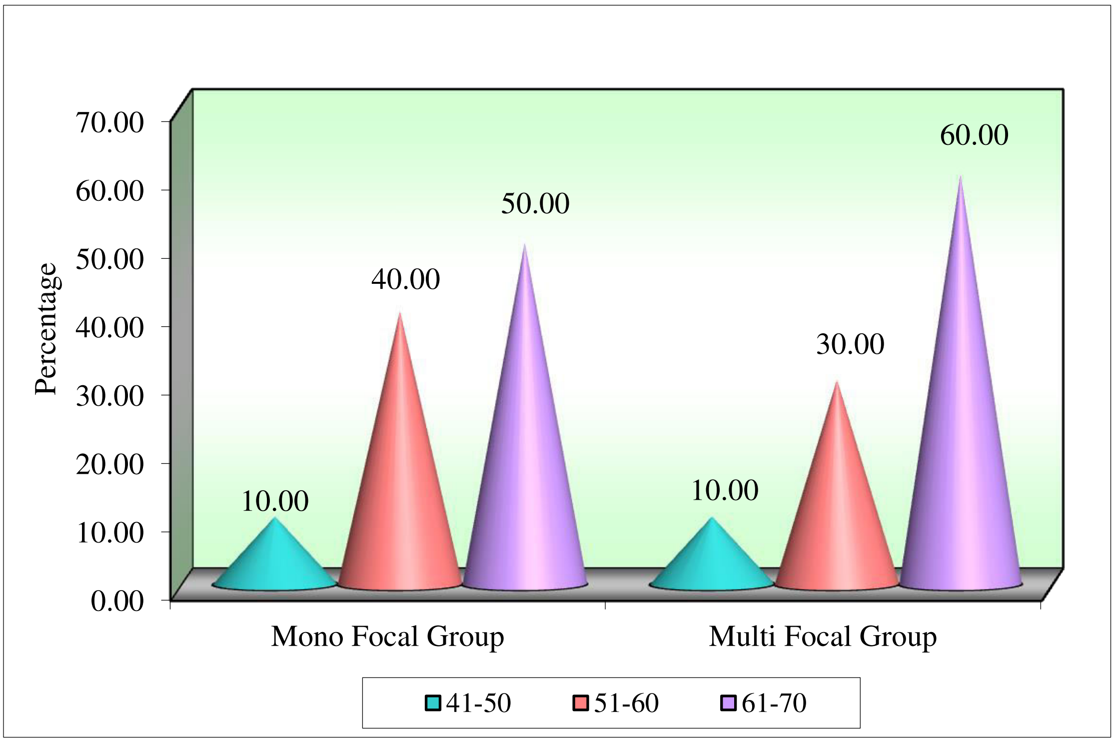


Table 3: GENDER DISTRIBUTION

Sex	Monofocal Group	Multifocal Group
Male	11	13
Female	9	7
Total	20	20
Chi-square=0.4172 p = 0.5191		

In our study, Out of 20 patients in monofocal group 11 were male and 9 were female; out of 20 patients in multifocal group 13 were male and 7 were female.

Graph 2. Male: Female

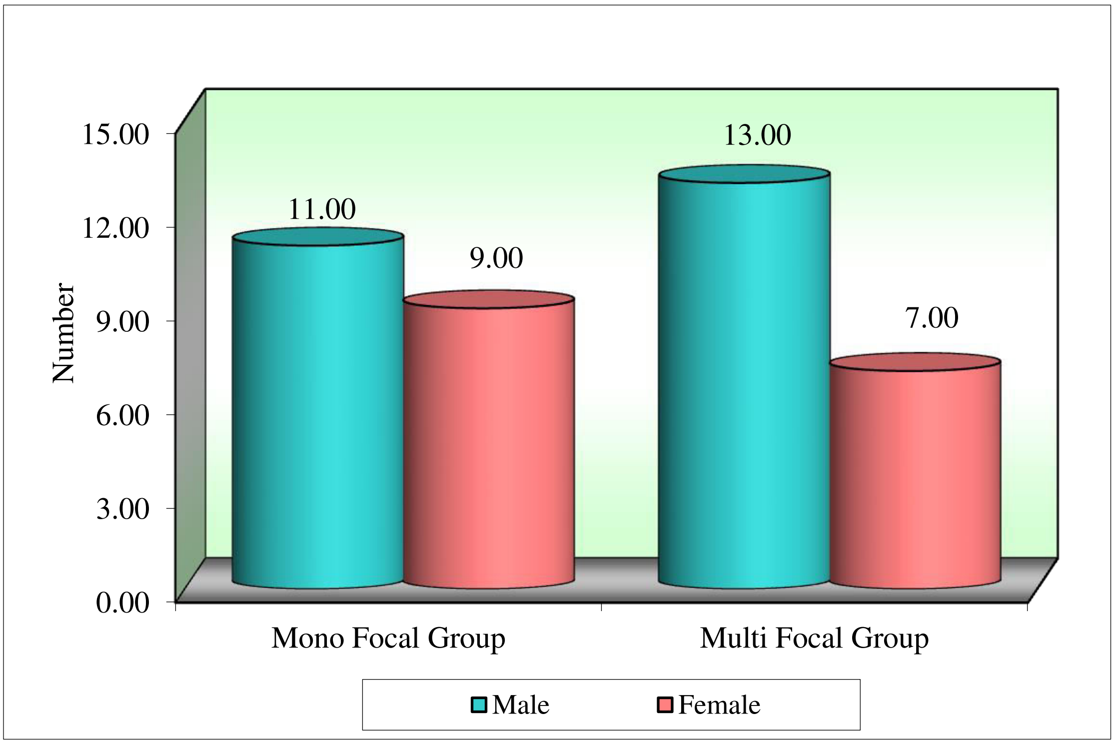


Table 4: PRE-OPERATIVE DISTANT VISION ACUITY

Distant Vision Acuity	Mono Focal Group	%	Multi Focal Group	%	Total	%
6/ 18 – 6/24	1	5.00	6	30.00	7	17.50
6/ 36 – 6/60	11	55.00	8	40.00	19	47.50
CF 4M – CF 3M	1	5.00	2	10.00	3	7.50
CF 2M – CF 1M	7	35.00	3	15.00	10	25.00
HMCF	0	0.00	1	5.00	1	2.50
Total	20	100.00	20	100.00	40	100.0
Chi-square=6.9782 p = 0.1371						

Pre-operative distant vision acuity was almost similar in both the groups (p = 0.1371).

Graph 3: Pre-operative distant vision acuity

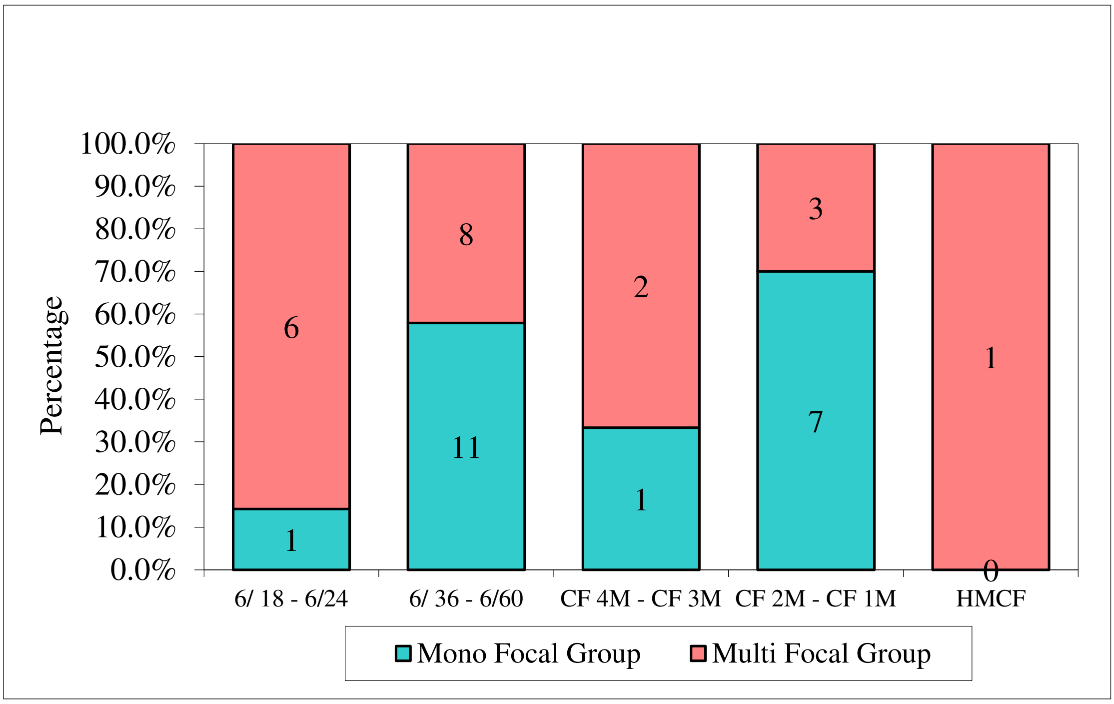


Table 5: PRE-OPERATIVE NEAR VISION ACUITY

Near Vision Acuity	Mono Focal Group	%	Multi Focal Group	%	Total	%
N8 – N10	2	10.00	5	25.00	7	17.50
N12 – N18	10	50.00	7	35.00	17	42.50
N24 – N36	6	30.00	4	20.00	12	30.00
N36	2	10.00	4	20.00	4	10.00
Total	20	100.0	20	100.0	40	100.0
Chi-square= 2.8828 p = 0.4102						

Table 5 shows that pre-operatively all the patients were spectacles dependent for near work activities. 50% of patients of monofocal group and 35% of patients of multifocal group had pre-operative near vision N12 – N18. This difference of pre-operative near vision acuity doesn't make any significance for post-operative visual outcome ($p < 0.05$).

Graph 4: Pre-operative near vision acuity

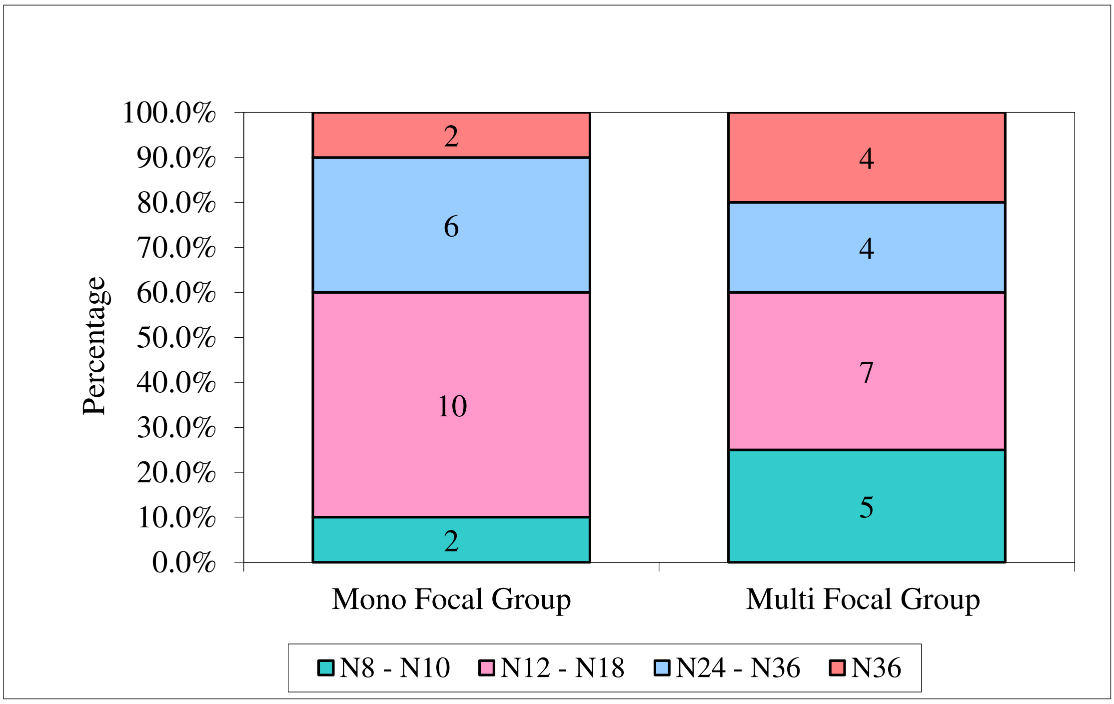


Table 6: 3rd WEEK DISTANT VISION ACUITY

Distant Vision Acuity	Mono Focal Group	%	Multi Focal Group	%
6/6 – 6/9	6	30.00	5	25.00
6/12 – 6/18	13	65.00	14	70.00
6/24 – 6/36	1	05.00	1	5.00
Total	20	100.0	20	100.0
Chi-square=0.1282 p = 0.9381				

Distant vision acuity found to be almost similar in both the groups by the end of the 3rd week. 30% of patients with monofocal group had 6/6 – 6/9 vision compared to 25% of patients in multifocal group had 6/6 – 6/9 vision and remaining patients in both the groups had slightly reduced vision in Snellen's vision chart as shown in table 6 and graph 5 (p = 0.9381).

Graph 5: 3rd week distant vision acuity

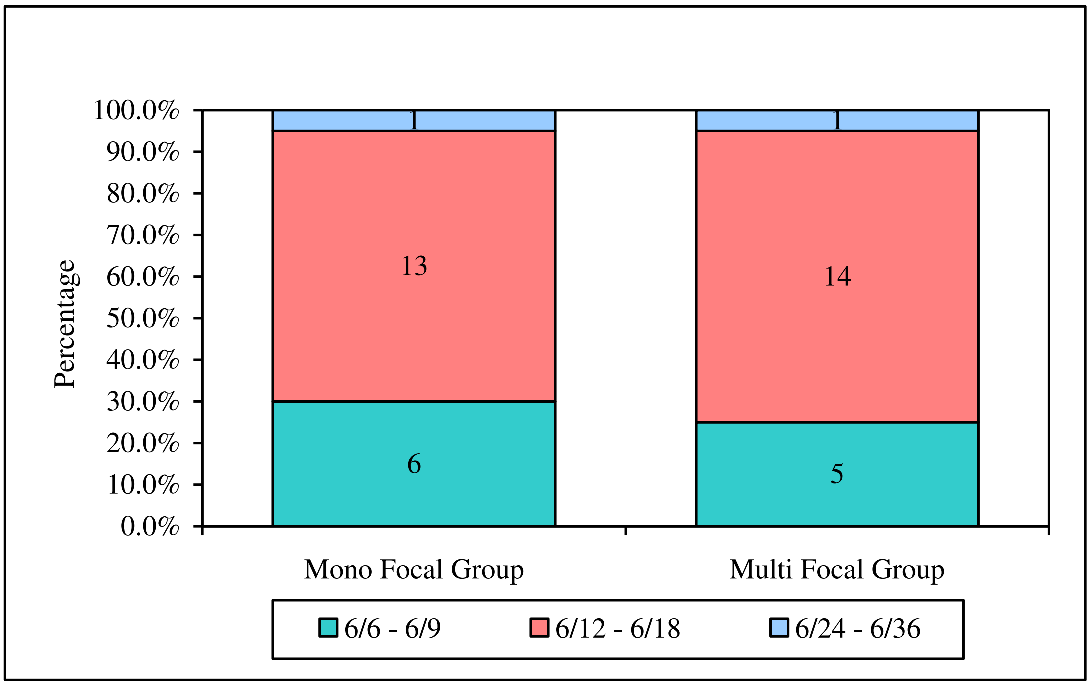


Table 7: 3rd WEEK NEAR VISION ACUITY

Near Vision Acuity	Mono Focal Group	%	Multi Focal Group	%
N6 – N8	0	0.00	13	65.00
N10	2	10.00	6	30.00
N12	8	40.00	1	5.00
N18	10	50.00	0	0.00
N36	0	0.00	0	0.00
Total	20	100.00	20	100.00
Chi-square= 25.5914 p = 0.0001*				

*p < 0.05

Multifocal group had better uncorrected near vision acuity by the end of 3rd week of the study. 65% of the patients in multifocal had N6 – N8 vision. Remaining 35% in multifocal and 100% in monofocal had reduced vision in Snellen's near vision chart ($p < 0.005$) as shown in table 8 and graph 7.

Graph 6: 3rd week near vision acuity

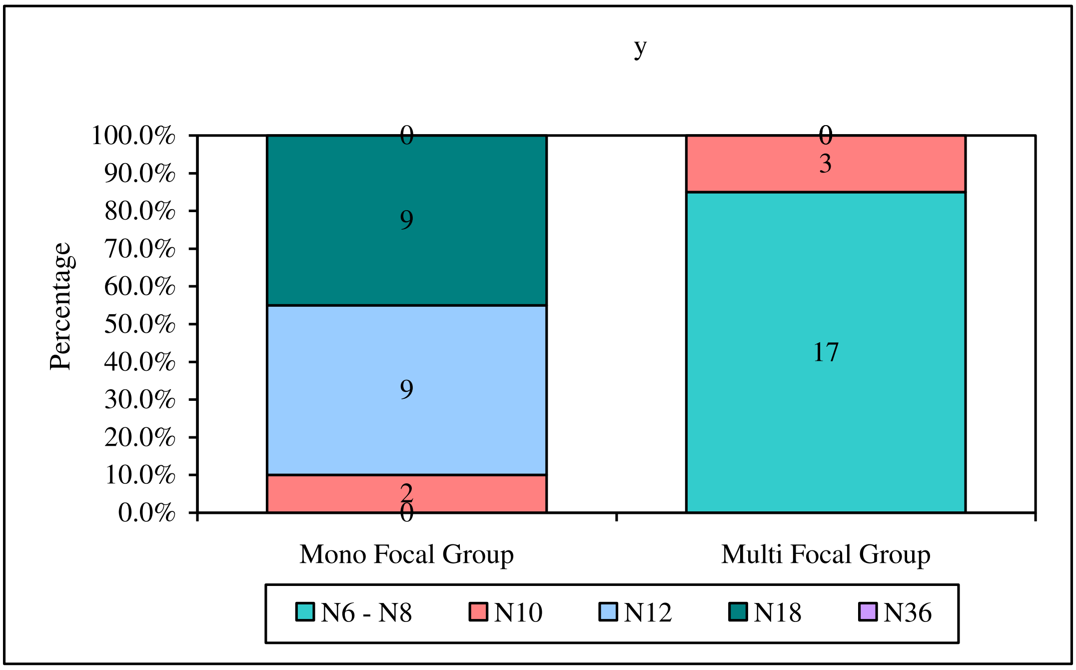


Table 8: 3rd WEEK CSH AND CSL SCORES

Variables	Mono Focal Group	Multi Focal Group	t-value	p-value
	Mean	Mean		
CSH	0.24 ± 0.12	0.34 ± 0.12	-2.4892	0.0173*
CSL	0.30 ± 0.10	0.48 ± 0.14	-4.7367	0.0001*

In ETDRS contrast sensitivity chart mean contrast sensitivity at low contrast level was significantly reduced in multifocal group patients ($p < 0.001$).

Graph 7: 3rd week CSH and CSL scores

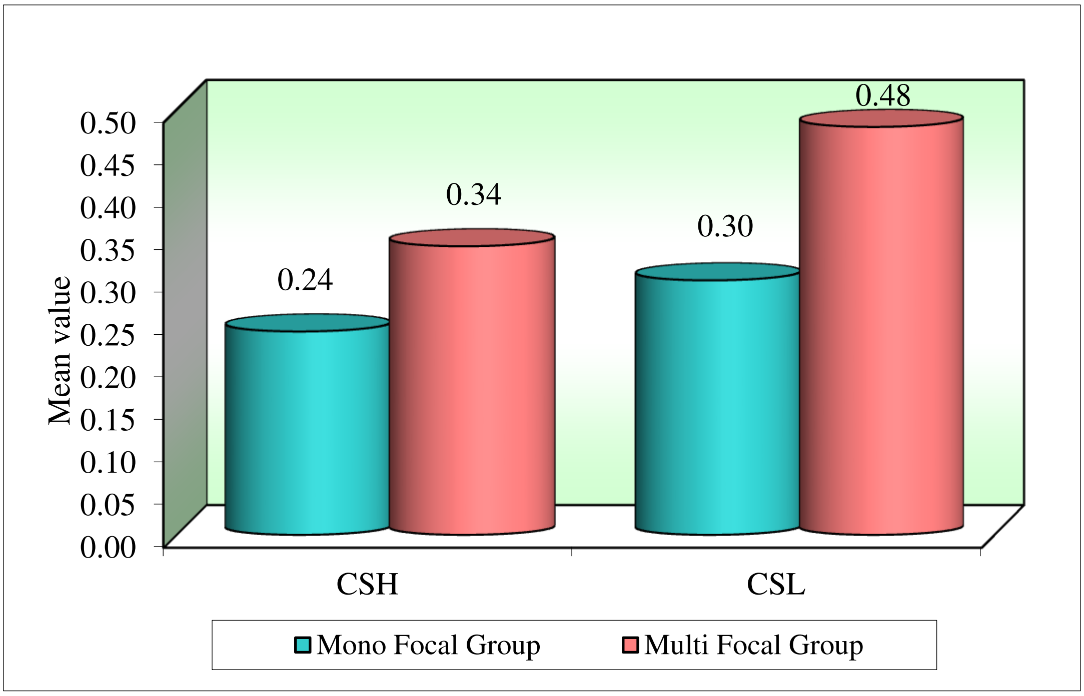


TABLE 9: 3rd WEEK GLARE AND HALOS

G and H	Mono Focal Group	%	Multi Focal Group	%
Positive	1	5.00	5	25.00
Negative	19	95.00	15	75.00
Total	20	100.00	20	100.00
Chi-square with Yates's correction = 3.6572 p = 0.0567				

1 patient in monofocal group and 5 patients in multifocal group had complained of glare and halos in 3 weeks post-operative follow up period.

Graph 8: 3rd week Glare and Halos

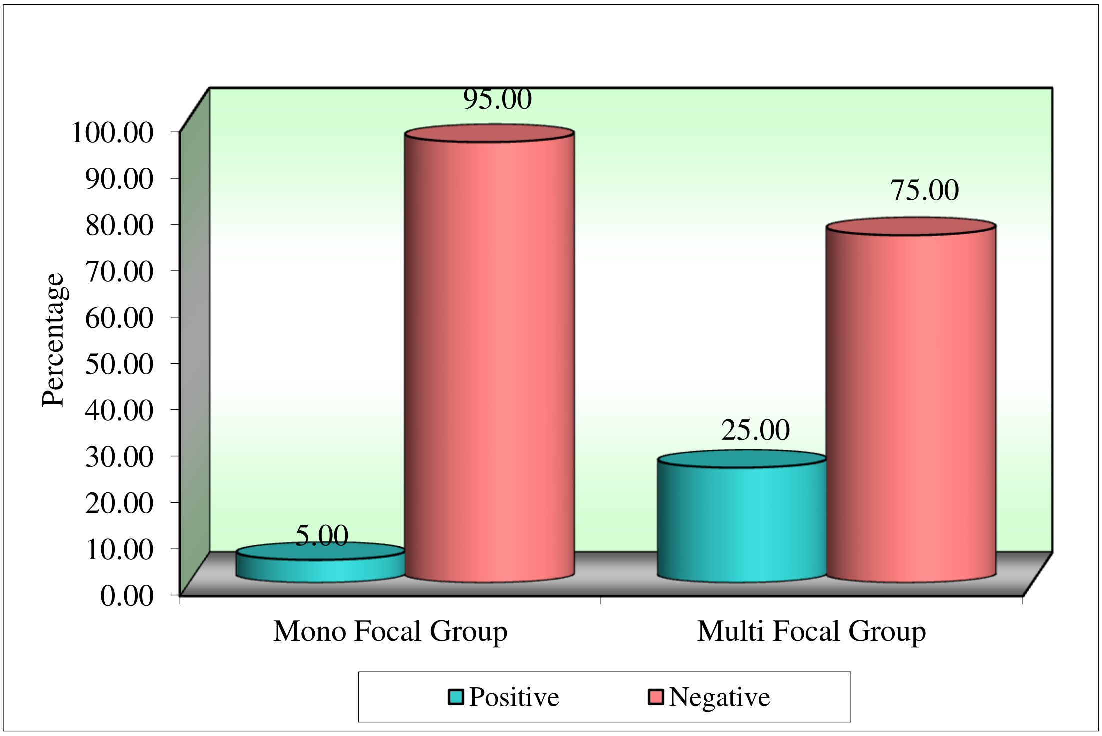


Table 10: 3rd WEEK DND

DND	Mono Focal Group	%	Multi Focal Group	%	Total	%
Positive	0	0.00	1	5.00	1	2.50
Negative	20	100.0	19	95.00	39	97.50
Total	20	100.0	20	100.0	40	100.0
Chi-square with Yates's correction = 0.0000 p = 1.0000						

None of the patients in monofocal group had difficulty in night-time driving whereas 1 patient in multifocal group found difficulty in night-time driving which is statistically insignificant.

Graph 9: 3rd week DND

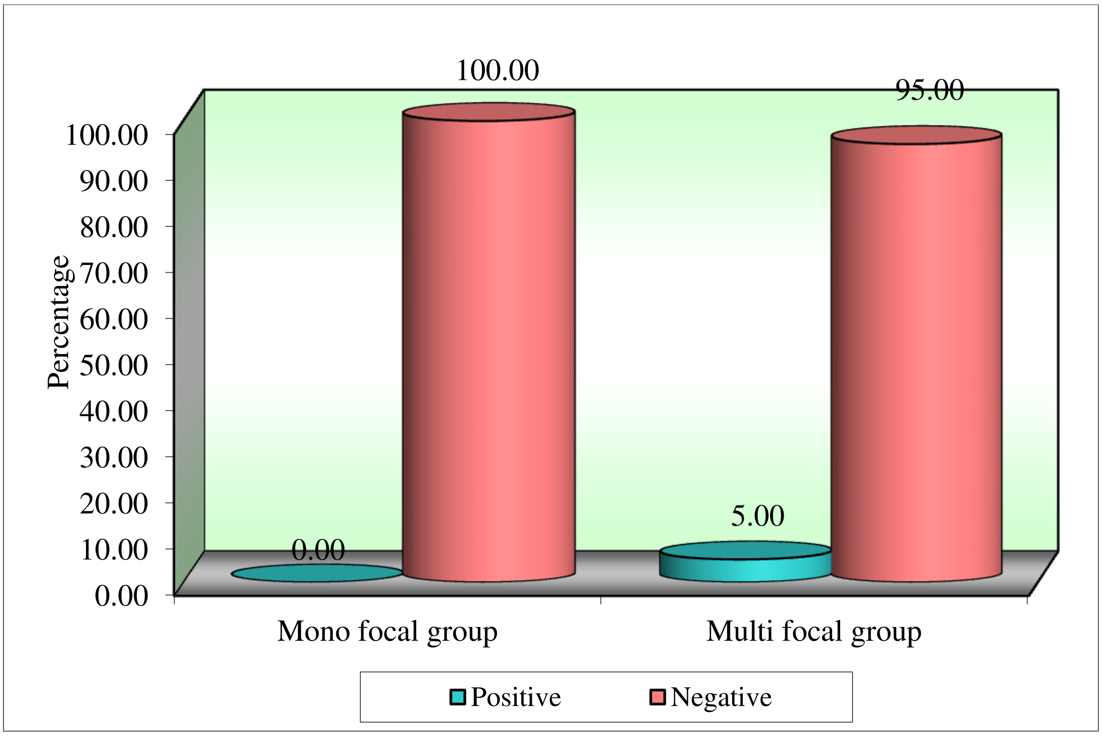


Table 11: 6th WEEK DISTANT VISION ACUITY

Distant Vision Acuity	Mono Focal Group	%	Multi Focal Group	%
6/6 – 6/9	15	75.00	16	80.00
6/12 – 6/18	5	25.00	4	20.00
6/24 – 6/36	0	0.00	0	0.00
Total	20	100.0	20	100.0
Chi-square=0.1433 p = 0.7057				

Distant vision acuity found to be almost same in both the groups by the end of 6th week. 75% of patients had 6/6 – 6/9 vision and remaining 25% had 6/12 – 6/18 vision in monofocal group. 80% of patients had 6/6 – 6/9 vision and remaining 20% had 6/12 – 6/18 vision in multifocal group in Snellen's test chart as shown in table 11 and graph 10.

Graph 10: 6th week distant vision acuity

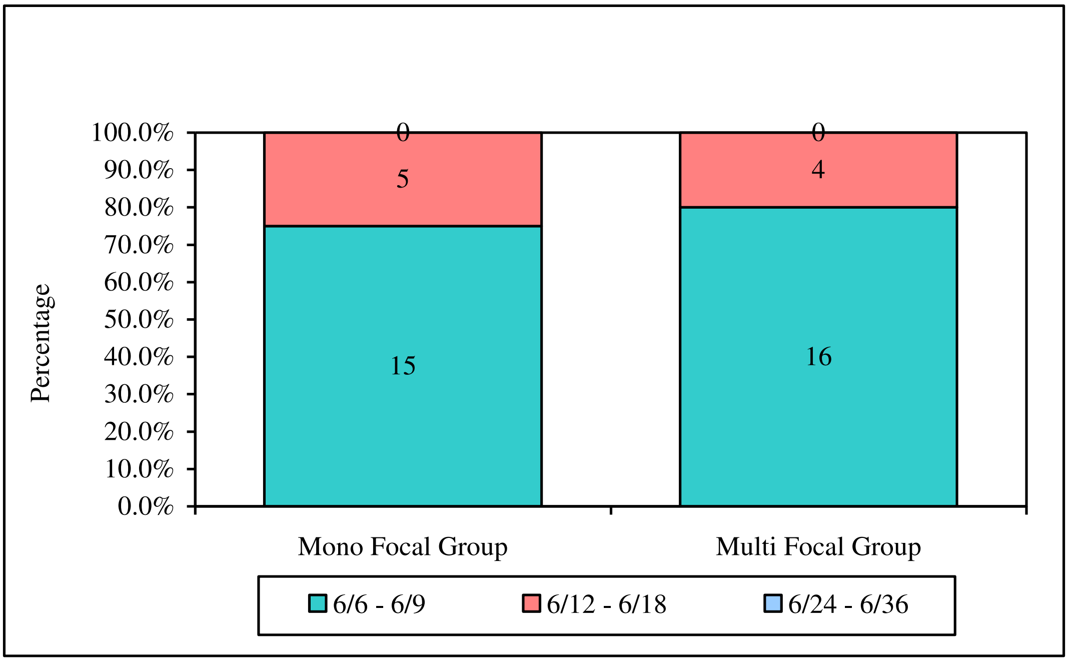


Table 12: 6th WEEK NEAR VISION ACUITY

Near Vision Acuity	Mono Focal Group	%	Multi Focal Group	%
N6 – N8	0	0.00	17	85.00
N10	2	10.00	3	15.00
N12	9	45.00	0	0.00
N18	9	45.00	0	0.00
N36	0	0.00	0	0.00
Total	20	100.00	20	100.00
Chi-square=35.2001 p = 0.0001*				

*p<0.05

Multifocal group had better uncorrected near vision acuity by the end of 6 weeks of the study. 85% of the patients in multifocal had N6 – N8 vision ($p<0.05$). Remaining 15% in multifocal and 100% in monofocal had reduced vision in Roman near vision chart as shown in table 12 and graph 11.

Graph 11: 6th week near vision acuity

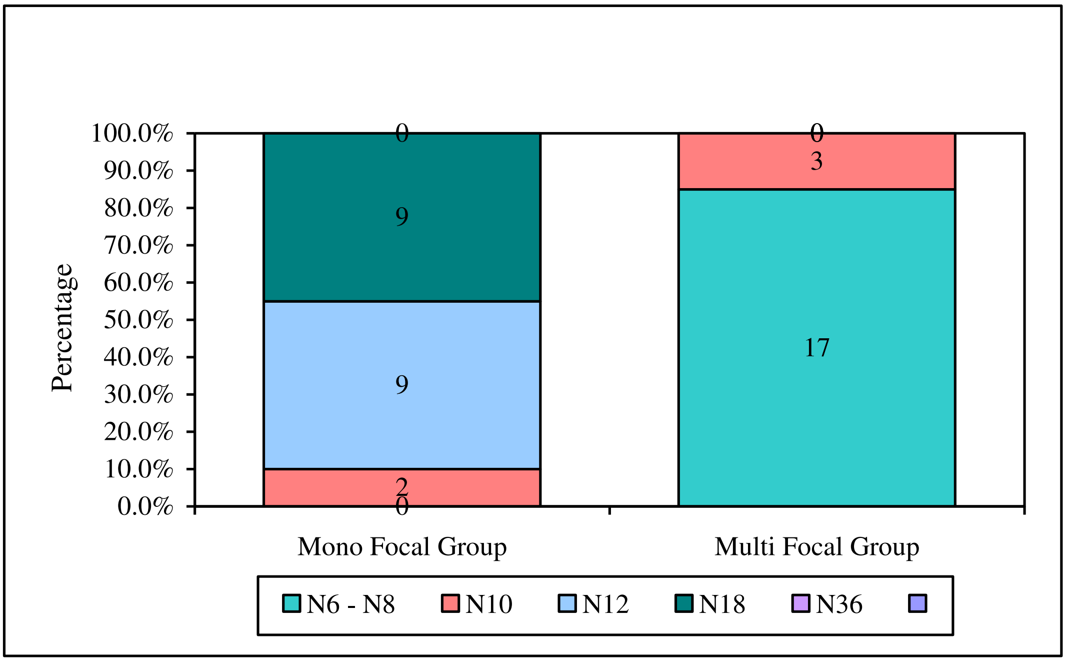


Table 13: 6th WEECSH AND CSL SCORES

Variables	Mono Focal Group	Multi Focal Group	t-value	p-value
	Mean	Mean		
CSH	0.20 ± 0.08	0.24 ± 0.09	-1.6652	0.1041
CSL	0.25 ± 0.09	0.35 ± 0.09	-3.2763	0.0023*

Even though the initial post-operative follow up in multifocal group showed reduced contrast sensitivity but by end of the 6th week showed almost similar to monofocal group at high contrast level but low contrast sensitivity was significantly reduced in multifocal group in ETDRS contrast sensitivity chart.

Graph 12: 6th week CSH and CSL scores

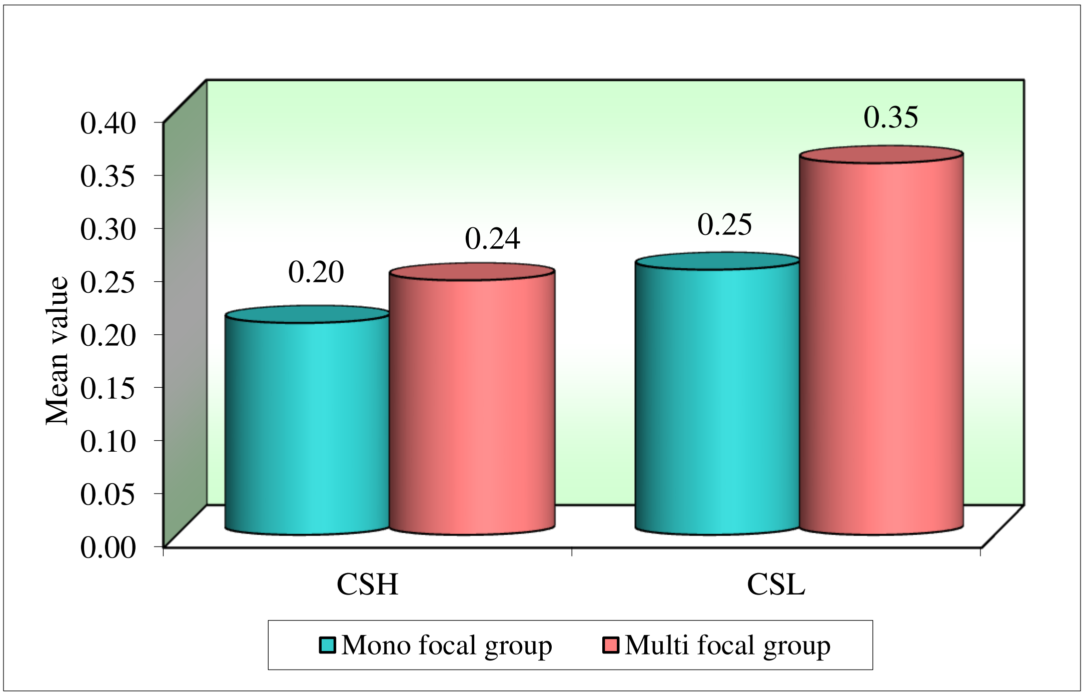


Table 14: 6th WEEK GLARE AND HALOS

G and H	Mono Focal Group	%	Multi Focal Group	%
Positive	0	0.00	3	15.00
Negative	20	100.00	17	85.00
Total	20	100.00	20	100.00
Chi-square with Yates's correction = 1.4417 p = 0.2306				

3 patients in multifocal group had complained of mild to moderate experiences of photic phenomena as shown in table 14 and graph 13.

Graph 13: 6th week Glare and Halos

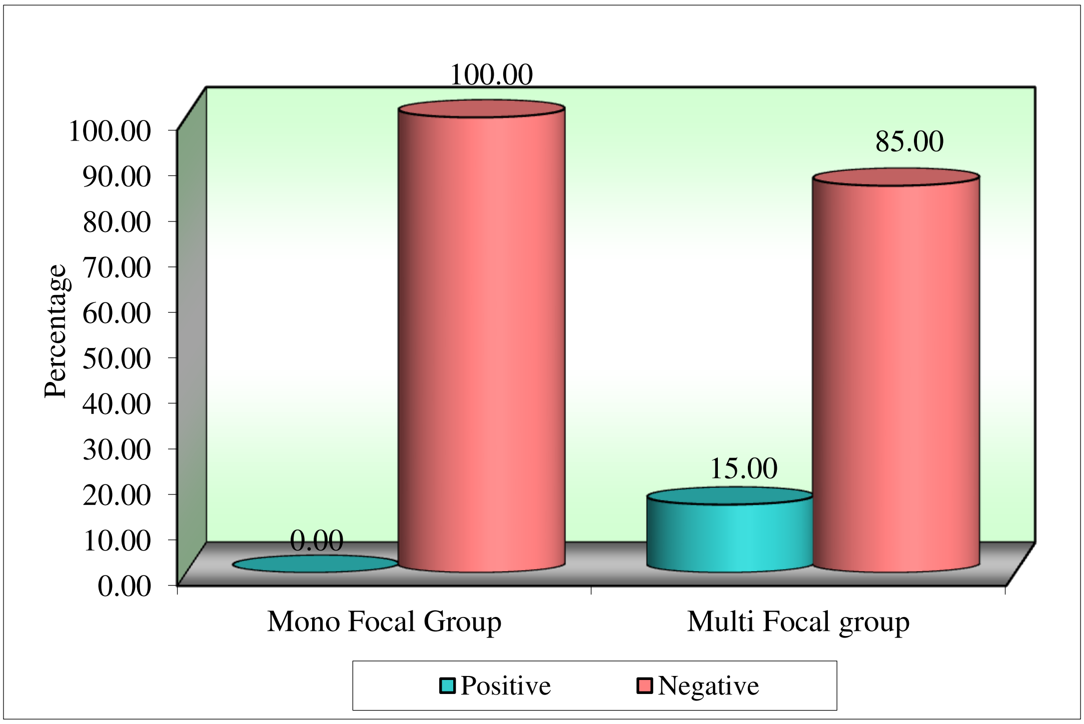


Table 15: 6th WEEK DND

DND	Mono Focal Group	%	Multi Focal Group	%	Total	%
Positive	0	0.00	1	5.00	1	2.50
Negative	20	100.00	19	95.00	39	97.50
Total	20	100.00	20	100.00	40	100.00
Chi-square with Yates's correction = 0.0000 p = 1.0000						

Only 1 patient of multifocal group had difficulty in night-time driving in throughout study period compared to monofocal group none had difficulty in night-time driving.

Graph 14: 6th week DND

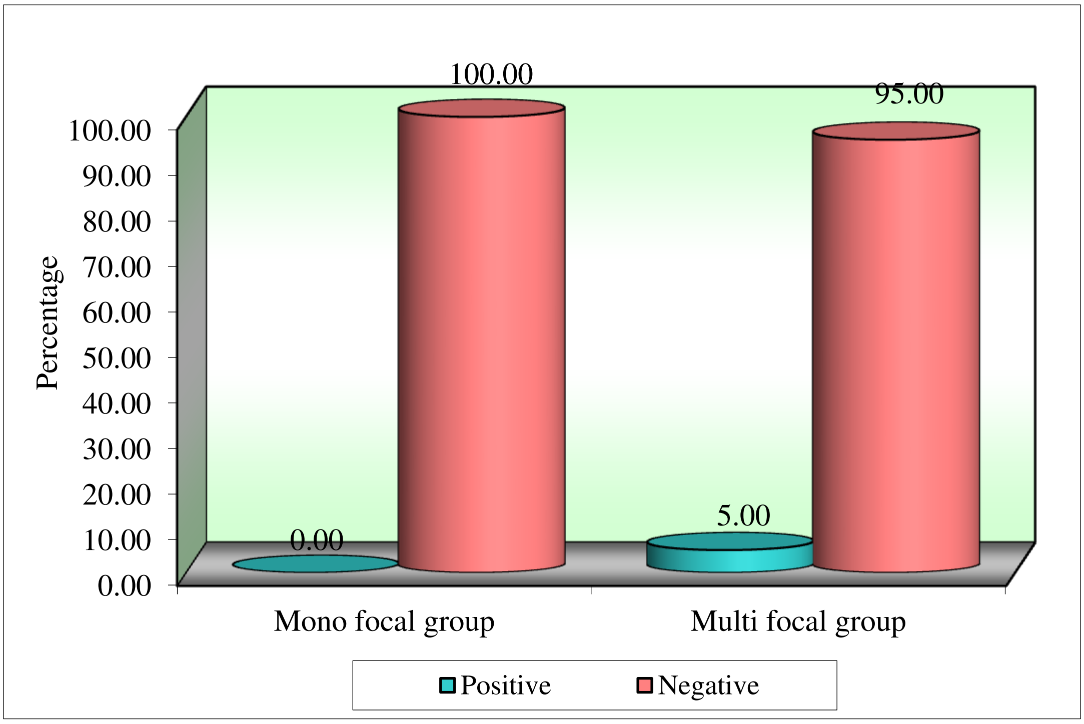


Table 16: STATUS OF SPECTACLES INDEPENDENCE

Status of Spectacles Independence	Mono Focal Group	%	Multi Focal Group	%
Yes	8	40.00	16	80.00
No	12	60.00	4	20.00
Total	20	100.00	20	100.00
Chi-square= 6.6673 P = 0.0102*				

*p<0.05

Patients were asked how often they wore glasses. Possible responses were: always, occasionally, and never. Patients with multifocal IOLs wore glasses less often than patients who had received monofocal IOLs, with 80% of patients who had received multifocal IOLs (16/20) and 40% of patients who had received monofocal IOLs (8/20) never wearing glasses. This difference was statistically significant (p = 0.0102).

Graph 15: Status of Spectacles Independence

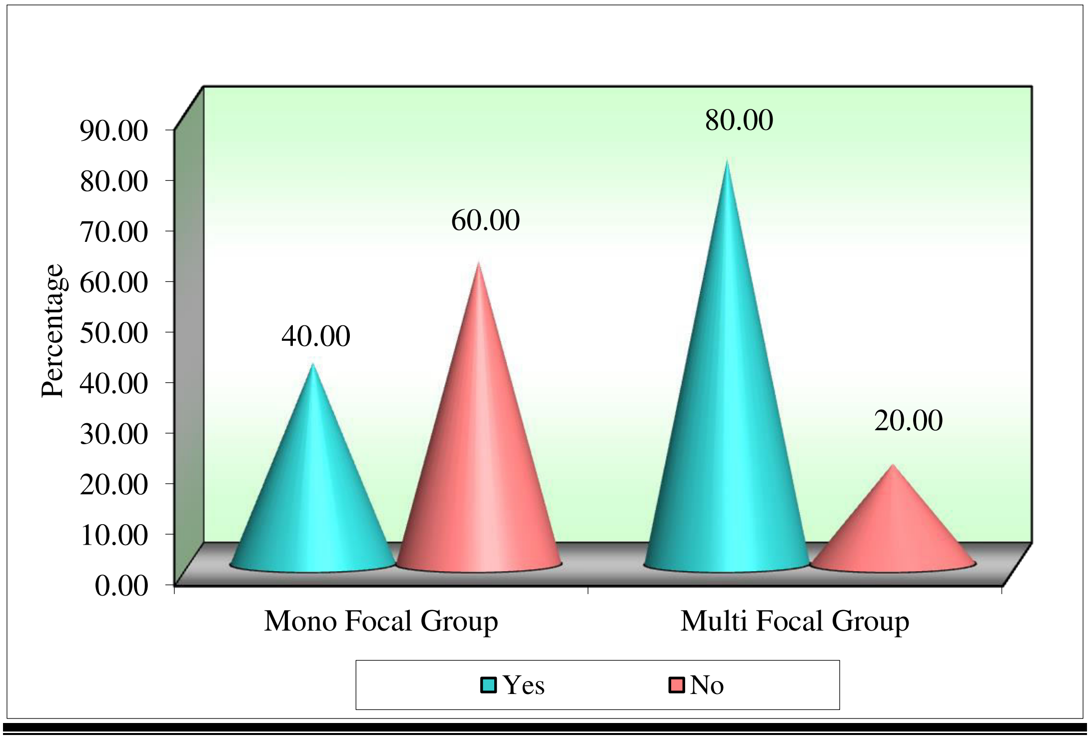


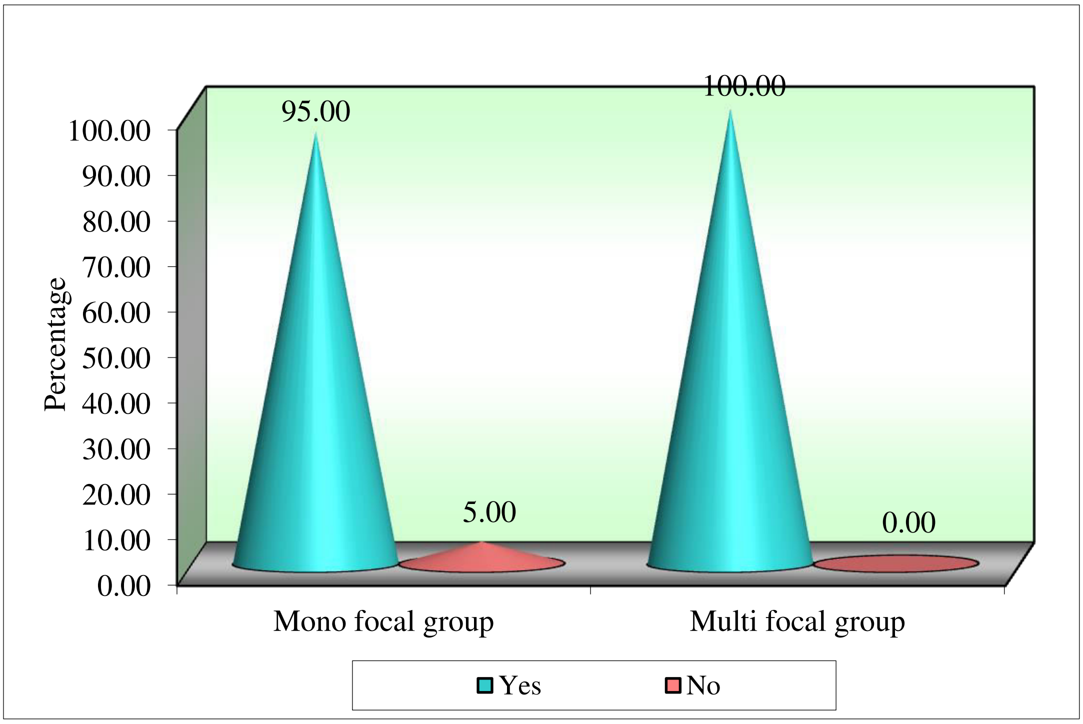
Table 17: STATUS OF SATISFACTION

Status of Satisfaction	Mono Focal Group	%	Multi Focal Group	%
Yes	19	95.00	20	100.00
No	1	5.00	0	0.00
Total	20	100.00	20	100.00
Chi-square=0.0000 p = 1.0000				

All 40 patients completed the questionnaire on visual symptoms and satisfaction. Despite the superiority of the multifocal IOL in primary outcome measures and spectacle dependence, overall patient satisfaction using the fulfilment theory (subtraction of preoperative expectations from postoperative evaluations) was similar in the 2 groups and the number of patients who were satisfied with the outcome of their surgery did not differ among groups. Perceived quality of vision showed high ratings (approximately 95% satisfied about aided near and distance vision in both groups).

Patient satisfaction is predicted by aided quality of near vision. Table 17 indicates that patients do not mind wearing reading glasses as long as near vision is good according to their own standards.

Graph 16: Status of satisfaction



DISCUSSION

Accommodation is the eye's ability to change its refractive power by altering its focal length. The ability to focus over a range of distances is essential in humans although this facility to accommodate reduces with increasing age and the amount of ciliary muscle contraction or accommodative effort unchanged. Once cataract develops transparency of lens is lost and it hardens.[44]

Age-related cataracts represent the most common cause of blindness in the world.[45]

Currently, the goal of cataract surgery is to provide fast and complete visual rehabilitation without surgical complications with minimal postoperative refractive errors. The available treatment option is surgical extraction of cataract and implantation of IOL to replace the focusing power of the natural lens. IOLs used in cataract surgery are either monofocal or multifocal. The former can be used to give clear point of focus for distance or near, but can choose only one point of focus. Spectacles provide extra lens power, which enables focusing at other points whereas multifocal IOL can correct both distant and near vision, which eliminates near vision addition.

So, this study was conducted to compare the visual outcome after cataract surgery with Multifocal Intraocular Lenses and Monofocal Intraocular Lenses and also to assess functional status and quality of life.

The study is a prospective observational study. It was conducted on 40 patients with cataract, meeting the inclusion criteria, who presented to the ophthalmology department of KLES Dr. Prabhakar Kore Hospital and Medical Research Centre between 1st January 2015 to 31st December 2015.

In this study all the 40 patients underwent clear corneal phacoemulsification cataract surgery with intraocular lens implantation under local anaesthesia. Choice of the lens inserted was given to the patients according to their willingness.

In the present study, the mean age was 60.55 ± 7.06 and 61.15 ± 7.75 years in monofocal and multifocal group respectively. All of the patients were in the range of 40 – 70 years as cataract is more common in this age group. We included younger age group because this age demands good near vision. So according to their willingness for spectacle independence they underwent multifocal or monofocal lens implantation. In older age group as even the other eye might have almost lost accommodation because of loss of elasticity of lens due to aging process or cataractous changes. As an alternative to this lost accommodation after cataract surgery, either multifocal lens or monofocal lens with near addition spectacles was used according to their desire.

The difference in age group is statistically insignificant ($p = 0.7922$) in both the groups. This indicates both the groups have age matching.

In this study, 55% and 65% patients were male, whereas 45% and 35% patients were female, in monofocal group and multifocal group respectively. We tried to match the gender distribution in both the IOL groups. This difference in the gender distribution of both the groups has no statistical significance ($p = 0.5191$). Gender distribution difference doesn’t make any significance on post-operative visual outcome.

Similarly, Kumare D, Benurwar C, Tumram NK in their study found no significant difference between the two groups in term of age and gender distribution.[26]

Yamauch T et al in 2013 in their study also found that there is no statistically significance in difference in terms of age and sex distribution ($p = 0.7442$).[27]

In the present study, majority of the patients that is 55% had pre-operative distant visual acuity in the range of 6/36 to CF 3 meters, followed by 28% patients with pre-operative visual acuity in the range of CF 2 meters to HMCF in both the groups. 30% of patients who had pre-operative visual acuity in the range of 6/18 – 6/24 opted multifocal lens suggested that these patients would be more conscious of their visual outcome. The difference in pre-operative distant visual acuity of both the groups is statistically not significant ($p = 0.1371$).

Our study data showed that pre-operatively majority of the patients were spectacles dependent for near work activities. 50% of patients of monofocal group and 35% of patients of multifocal group had pre-operative near vision N12 – N18. 10% of patients of monofocal group and 25% of patients of multifocal group had pre-operative near vision N8 – N10 indicated that these patients were more dependent on spectacles for distant vision pre-operatively. The difference of pre-operative near vision acuity in both the groups is not significant ($p = 0.4102$).

The study done by Sun Y, Zheng D, Ling S, Song T, Liu Y in 2012 and Yamauch T et al in 2013 also stated that the difference in pre-operative distant and near vision is statistically insignificant.[27] [28]

All the patients under the study were examined post-operatively at 3 weeks and 6 weeks.

In every follow up we had examined uncorrected distant visual acuity (UDVA), uncorrected near visual acuity (UNVA), contrast sensitivity high & low, wound healing, corneal clarity, intraocular lens position, and fundus visibility.

In present study, uncorrected distant visual acuity was found to be almost similar in both the groups by end of 3 weeks. 30% of patients with monofocal group had 6/6 – 6/9 vision compared to 25% of patients in multifocal group had 6/6 – 6/9 vision and remaining patients in both the groups had slightly reduced vision in Snellen's vision chart. There was no difference in gaining distant visual acuity in patients of both the groups (p = 0.9381).

Cionni RJ et al in their study found that uncorrected distant visual acuity was similar across monofocal and multifocal groups post-operatively. Group 1 had mean LogMAR value 0.05 and group 2 had mean value LogMAR 0.06 with p = 0.67 which showed no significance.(29)

Javitt J et al had concluded that there was no statistical significant difference between two groups in mean uncorrected binocular distance visual acuity. Mean uncorrected binocular distance visual acuity was 1.0 (20/21) in the multifocal group and 0.9 (20/22) in the monofocal group (p = 0.446).(30)

Uncorrected near visual acuity was better in multifocal group by the end of 3rd week of the study. 65% of the patients in multifocal group had N6 – N8 vision. Remaining 35% in multifocal and 100% in monofocal had reduced vision in Roman near vision chart. Thus there is a highly significant difference between the two groups in terms of the uncorrected near visual acuity ($p < 0.0001$). 2 patients of monofocal group had developed near vision upto N10. On examination these patients found to be more myopic than others, having an axial length of 24.53 mm and 24.10 mm respectively. So we concluded that being a myopic, these patients gained slightly better near vision acuity than others.

Kumare D, Benurwar C, Tumram NK in 2015 in their study found that the post-operative uncorrected near visual acuity in the multifocal IOL versus monofocal IOL is 75% and 0% respectively for N6 near vision ($p = 0.0000$). So post-operative near vision result of this study is highly supporting to our study.[26]

Vaggu SK, Kodepaka PN in their recent study in 2016 concluded that 15 (60%) patients had UCNVA ≥N12 (mean 0.2 LogMAR) in the monofocal IOL group and 25 (100%) patients had UCNVA ≥N12 (mean 0.01 LogMAR) in multifocal group postoperatively, which was statistically significant $p < 0.001$.[19]

Cilino S et al. stated that mean UCNVA in monofocal and multifocal groups were 0.61 and 0.7 decimal respectively. The difference was statistically significant and they concluded that multifocal IOLs are better capable of correcting NVA.[31]

At 6 weeks uncorrected distant visual acuity analysis in our study showed almost 80% of the patients in both the IOL groups, that is monofocal as well as multifocal group achieved 6/6 - 6/9 vision and remaining 20% of the patients achieved 6/12 – 6/18 vision 6 weeks post-operatively. In period of 6 weeks distant vision was improved in both the groups which states that factors like corneal wound healing, post-operative corneal oedema, post-operative mydriasis and cycloplegia are responsible for reduced distant vision in immediate post-operative period.

In multifocal group the mean monocular UDVA result which is similar to the values reported by Voskresenskaya A et al. (mean UDVA 0.13 LogMAR) where predominantly multifocal IOL is implanted monoocularly.(32)

Furthermore, in our study visual acuity outcomes are comparable to those achieved with several bifocal-design diffractive IOLs. However, in our study mean UDVA in multifocal group is lower than reported by Lesieur (mean 0.00 ± 0.01). It is likely that this difference is due to the older population examined in the present study (61.15 ± 7.75 years). The optical performance of the human eye is known to decline with age, with a resultant reduction in visual acuity for both elderly phakic and pseudophakic individuals. (33)

At end of the 6 weeks uncorrected near visual acuity in multifocal group had N6 – N8 vision in 85% ($p < 0.0001$). Remaining 15% in multifocal and 100% in monofocal had reduced vision in Roman near vision chart.

The visual cortex contains no prewired circuitry that allows it to digest information from multifocal lenses, the brain requires a period of adjustment known as *Neuroadaptation* that involves suppressing near vision when gazing at distant objects and restricting distance vision when focusing up close. So the improvement in near vision acuity is due to neural adaptation that patients developed in this period of 6 weeks.

The study done by Hashemi H et al. showed that at 3 months after surgery the UCNVA in monofocal and multifocal groups were mean 0.22 LogMAR and mean 0.14 LogMAR respectively after correction of DVA and the intergroup difference was statistically significant. Findings in other studies support our result and they agree that multifocal IOLs improve UCNVA.(34)

Gimbel HV in his study he compared the results of implantation of monofocal IOL versus multifocal IOL and found that 91% of patients in multifocal group achieved good near vision compared to 35% of patients of monofocal IOL group.(35)

Steinert RF et al in their study showed that uncorrected distance visual acuity was similar between the multifocal and monofocal implants in the subset with 85% and 91% of eyes achieving 20/40 or better visual acuity. 86% eyes developed better uncorrected near vision for multifocal lens compared to 49% of monofocal eyes achieving J3 or better.(36)

Brydon KW et al in their study found that multifocal group had better visual acuity than the monofocal group at near with distance correction in place (70% versus 43% achieved J3 or better). The multifocal group also had significantly better depth of focus. Subjectively both groups indicated high levels of satisfaction during the day, at night, and over all without spectacles in multifocal groups.(37)

In present study, 20% of patients in multifocal group and 60% of patients in monofocal group require spectacles for their near work activities. With correction near vision acuity were similar in both the groups. This 20% of patients in multifocal group had near vision N10 in Roman near vision chart. Less near vision in this patients is due to post-operative astigmatism and mostly due to these patients require more time neuroadaptation to develop. Because multifocal lenses require greater adaptation, the amount of adjustment the brain needs to make between images can be pushed to the limit of its capability.

In the report by Chiam PJ et al., mean UCNVA were 0.34 and 0.7 decimal in their monofocal and multifocal groups respectively. The evidence on NVA was in favour of multifocal IOLs. In our study, CNVA was similar in both monofocal and multifocal IOL groups. Other similar studies have demonstrated that there are no significant differences between these groups in relation to CNVA.(38)

CONCLUSION

This present study was done for post-operative analysis of differences in distant vision, near vision and contrast sensitivity, and also about subjective symptoms like halos, glare and difficulty in night-time driving encountered over 6 weeks follow-up in Phacoemulsification with monofocal PCIOL and Phacoemulsification with multifocal PCIOL groups.

A successful refractive outcome can be obtained with proper patient selection, motivation and expectation; accurate pre-operative biometry, IOL power calculation; and also good surgical technique.

Over all the patients in our study were satisfied with their distant and near vision and with surgery, although 15% of patients reported mild to moderate halos, glare and difficulty in night driving post operatively. Good evidence exists that use of multifocal IOLs improves near vision in 85% 0f patients without any major adverse effects on distant vision.

Our study results also showed that patients were pleased with their IOL performance, and most would have multifocal IOLs implanted again. The frequency of spectacle wear was greatly reduced for both distance and near vision, with 80% of patients having rated their vision without spectacles to be noticeably better after each successive surgery. These findings suggest that multifocal IOLs can improve the quality of life in active patients who wish to reduce their dependence on glasses. This technology offers surgeons a feasible way of meeting patient’s expectations of an improved lifestyle as the result of reduced spectacle dependence compared with the standard practice of monofocal IOL implantation.

In this context, Multifocal IOL's are obviously better option in most of the cases except professional drivers, commercial airline pilots, architects etc. Multifocal IOLs provide higher subjective satisfaction which overshadowed the minor side effects like glare and halos seen in our patients. Careful patient selection is the determining factor to achieve better proper functional visual outcome and patient satisfaction. The use of multifocal IOLs in cataract surgery also resulted in a significant reduction in costs for patient's post-operative spectacles.

SUMMARY

Over the past decade, refractive surgical procedures have been rapidly evolving especially for myopic and astigmatic eyes. Correction of presbyopia has remained somewhat elusive. However, cataract surgeons have been making steady progress in improving near vision IOL's and newer operative techniques with improvements in IOL power calculations and the reduction of postoperative astigmatism. Patients are now enjoying and even expecting better unaided distance and near vision after cataract removal.

The study titled "The visual outcome after cataract surgery with Multifocal intraocular lenses and Monofocal intraocular lenses at tertiary care hospital - a Prospective observational study" was conducted in KLES Hospital and MRC, Belagavi in J.N. Medical College during the period of 01^{st} January 2015 to 31^{st} December 2015.

The summary of the results obtained is as follows:

The study was done to compare and assess the effect of multifocal and monofocal IOL with reference to visual acuity both distant and near, contrast sensitivity, spectacle independence, complaints of glare and halos, difficulty in night driving and patient's visual satisfaction.

This prospective observational study was conducted on 40 eyes of 40 patients who underwent phacoemulsification cataract surgery with 20 monofocal posterior chamber intraocular lens implantation and other 20 with multifocal posterior chamber intraocular lens.

The patients were evaluated postoperatively at 3rd week and 6th week where measurements of visual acuity for distance and near, assessment of contrast sensitivity for distance and also subjective symptoms of halos, glare and difficulty with night-time driving were considered.

Distant Visual acuity analysis in our study showed almost 80% of the patients in both the IOL groups, achieved 6/6 – 6/9 vision and remaining 20% of the patients achieved 6/12 – 6/18 vision 6 weeks post operatively. Near visual acuity in multifocal group had N6 – N8 vision in 85% ($p < 0.0001$) of patients. 80% in multifocal group and 40% in monofocal group were free from spectacles (spectacle independence) and 60% in monofocal group were dependent on spectacles for near vision.

Contrast sensitivity (for distance) was almost similar in both the groups for high contrast sensitivity but reduced low contrast sensitivity in multifocal group as compared to monofocal group.

15% of patients with multifocal group complained of glare, halos and 1 patient had difficulty with night driving compared to monofocal group who never experienced these type of visual sensations.

80% of patients in multifocal group and 40% in monofocal group become spectacle independent. So 60% in monofocal group must require to use spectacles routine life activities.

Both monofocal and multifocal implant patients were very much satisfied with the results of their cataract extraction with posterior chamber IOL implantation surgery. Distance visual acuity and contrast sensitivity (high) was same in both the groups by the end of the study but reduced contrast sensitivity at low contrast levels in multifocal IOL group experienced for distant vision. Multifocal IOL group experienced reduced spectacle dependency for near vision and had a high level of satisfaction despite some reports of halos and glare. Monofocal IOL group experienced spectacle dependency for near vision.

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ANNEXURE I - INFORMED CONSENT

CONSENT FOR PARTICIPATING IN A RESEARCH STUDY

J.N. Medical College

K.L.E. University

Belagavi- 590010

Mr./Ms./Mrs.____

You are invited to participate in our research study titled **"THE VISUAL OUTCOME AFTER CATARACT SURGERY WITH MULTIFOCAL INTRAOCULAR LENSES AND MONOFOCAL INTRAOCULAR LENSES AT TERTIARY CARE HOSPITAL - A PROSPECTIVE OBSERVATIONAL STUDY"** conducted by **Dr.____________**, Post Graduate in M.S. Ophthalmology under the guidance of **Dr.______________,** Professor in the department of Ophthalmology, Dr. Prabhakar Kore Hospital & Research Centre, Belagavi.

Respected Sir/Madam we request you to enrol 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: In cataract surgery the crystalline lens is removed and replaced by an artificial intraocular lens (IOL), usually with only one focal point (monofocal). Because the natural process of accommodation is not restored, a monofocal IOL needs complementary reading or multifocal glasses to create good vision at more than one distance. The implantation of lenses with more than one focal point (multifocal), which has beneficial effect of better uncorrected near visual acuity

(UCNVA), resulting in reduced spectacle dependence relative to patients with monofocal IOLs. The present study will be initiated to compare visual outcome with multifocal IOLs and monofocal IOLs after cataract surgery, and to identify predictors of patient satisfaction.

Procedure Involved: If you agree to enrol 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, A-scan ultrasonography and investigations like Blood Pressure measurement, Random Blood Sugar will be done. Then you will be undergoing phacoemulsification cataract surgery with multifocal or monofocal lens implantation as per your choice. You will be asked to follow up on specified dates when your visual outcome would be monitored and documented.

Risks and Benefits: Rare complications of cataract surgery includes endophthalmitis, vitreous loss, globe perforation, retro bulbar haemorrhage, expulsive choroidal haemorrhage 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 due to enrolment in my study. The participant however will have to pay for the multifocal IOL in case if patient desires for multifocal IOL.

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 the 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 Dr. Prabhakar Kore Hospital & MRC, Belagavi. There is no compensation or payment for such medical treatment by law.

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

1) **Dr.____________**, Post Graduate Student, Department of Ophthalmology, JNMC, Belagavi.

2) **Dr._____________**, Professor, Guide, Department of Ophthalmology, JNMC, Belagavi.

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

3) **Dr.______________**, Chair Person, JNMC, Belagavi and chairman of Institutional Ethics Committee.

Consent Statement

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: __________________________

Date: ____________

Place: ____________

ANNEXURE II – PROFORMA

KLE UNIVERSITY'S

J.N. MEDICAL COLLEGE, BELAGAVI

<u>Department of Ophthalmology</u>

<u>TITLE OF THE STUDY</u>: "THE VISUAL OUTCOME AFTER CATARACT SURGERY WITH MULTIFOCAL INTRAOCULAR LENSES AND MONOFOCAL INTRAOCULAR LENSES AT TERTIARY CARE HOSPITAL- A PROSPECTIVE OBSERVATIONAL STUDY"

<u>Data collection Instrument</u>

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 RE [ ]

Duration: ________ days/ months/years

LE [ ]

Duration: ________ days/ months/years

HISTORY OF PRESENT ILLNESS:

1 .DIMINUTION OF VISION	1- Gradual; 2- Sudden	[ ]
	1- Progressive; 2- Static	[ ]
	1- Painless; 2- Painful	[ ]
	1- For distance; 2- For near	[ ]
2. DIPLOPIA/POLYOPIA	1- Present; 2- Absent	[ ]
3. COLOURED HALOS/GLARE	1- Present; 2- Absent	[ ]
4. BLACK SPOTS FRONT OF THE EYES	1- Present; 2 - Absent	[ ]
5. REDNESS	1- Present; 2 - Absent	[ ]
6. WATERING	1- Present; 2 - Absent	[ ]
7. DISCHARGE	1- Present; 2 - Absent	[ ]
8. H/O WEARING GLASSES	(1-Distance; 2-Near; 3-Both)	[ ]

Duration: [|] months/years

PAST HISTORY:

TRAUMA TO THE EYE:	1- Present; 2- Absent	[ ]
OCULAR SURGERY:	1- Present; 2- Absent	[ ]

Type of surgery: ____________________

Duration: [ ][ ] months/years

DIABETES: 1- Present; 2- Absent [ ]

Duration: [ ][ ] months/years

HYPERTENSION: 1- Present; 2- Absent [ ]

Duration: [ ][ ] months/years

ANY OTHER MEDICAL DISORDERS: ______________________________

PERSONAL HISTORY:

SMOKING: 1- Present; 2- Absent [ ]

Duration: [ ][ ] months/years

ALCOHOLISM: 1- Present; 2- Absent [ ]

Duration: [ ][ ] months/years

ANY OTHER ADDICTIONS: ______________ [ ]

Duration: [ ][ ] months/years

GENERAL PHYSICAL EXAMINATION:

General Appearance:

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

Pallor: 1- Present; 2- Absent [ ]

If present 1- Mild 2- Moderate 3- Severe [ ]

Pulse: [ ][ ][ ] /minute

BP: [ ][ ][ ] / [ ][ ][ ] mm of hg

Temperature: [ ][ ][ ] degree Fahrenheit

Respiratory rate: [ ][ ] /minute

SYSTEMIC EXAMINATION:

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

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

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

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

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				

	R.E	L.E
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		
BLOOD VESSELS		
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

E) A SCAN BIOMETRY : SRK II FORMULA

	R.E	L.E
KH		
KV		
AXL		
AC DEPTH		
PCIOL		

OPERATIVE PROCEDURE: PHACOEMULSIFICATION CATARACT SURGERY WITH FOLDABLE IOL IMPLANTATION

DATE: _____/______/________

OPERATING EYE: ________________________

ANAESTHESIA: PERIBULBAR BLOCK/ TOPICAL

INCISION: 1. Superior ☐

2. Temporal ☐

3. Superior Temporal ☐

4. Inferior Temporal ☐

INTRAOCULAR LENS TYPE: _______________________________

Intra-operative Complications: 1. Present, 2. Absent ☐

If present- specify

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

If present- specify

FOLLOW UP PLAN: **3 week** post-operatively

1. Conjunctiva (1- Normal; 2- Conjunctival Congestion; 3- Ciliary Congestion; 4- Chemosis)	☐
2. Section/Suture Site (1-Edges Opposed; 2- Edges Gaping)	☐
3. Cornea (1- Clear; 2- Hazy/descemets Folds)	☐
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		
NEAR		

ETDRS Contrast Acuity Chart:

EYE: ☐

LOGMAR	HIGH CONTRAST (26%)
0 - 0.1	
0.2 - 0.4	
0.5 - 0.7	

LOGMAR	LOW CONTRAST (7%)
0 - 0.1	
0.2 - 0.4	
0.5 - 0.7	

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 Folds)	☐
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		
NEAR		

ETDRS Contrast Acuity Chart:

EYE: ☐

LOGMAR	HIGH CONTRAST (26%)
0 - 0.1	
0.2 - 0.4	
0.5 - 0.7	

LOGMAR	LOW CONTRAST (7%)
0 - 0.1	
0.2 - 0.4	
0.5 - 0.7	

REFRACTION:

Prescription	Spherical	Cylindrical	Axis	BCVA
RE				
LE				

Visual Function Questionnaire (VFQ):

1. Are you satisfied with your distance vision? _______

2. Are you satisfied with your near vision? _______

3. Any difficulties in going up or down stairs? _______

4. Are glasses necessary for your near vision? _______

5. Are glasses necessary for your daily life activities? _______

6. Daytime glare? _______

7. Sunglasses required during day to decrease glare? _______

8. Night-time glare? _______

9. Difficulty in night driving? ________

10. Any rings or halo around light? _______

11. Excessive tearing? _______

Over All Patient's Satisfaction:

Very Satisfied	
Satisfied	
Not Satisfied	

Photo 1. Keratometry

Photo 2. A-scan Biometry

Photo 3a. Multifocal Lens

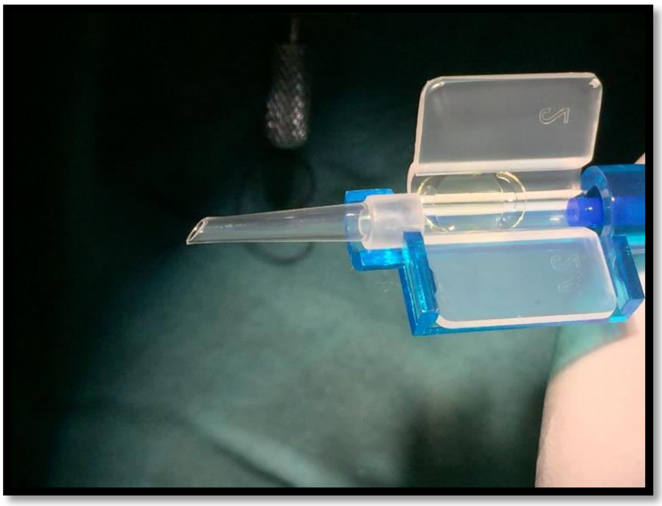

Photo 3b. Multifocal Lens

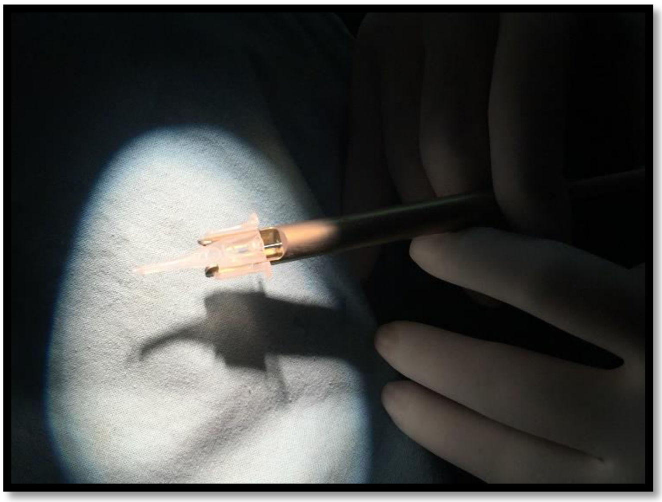

Photo 4. Monofocal Lens

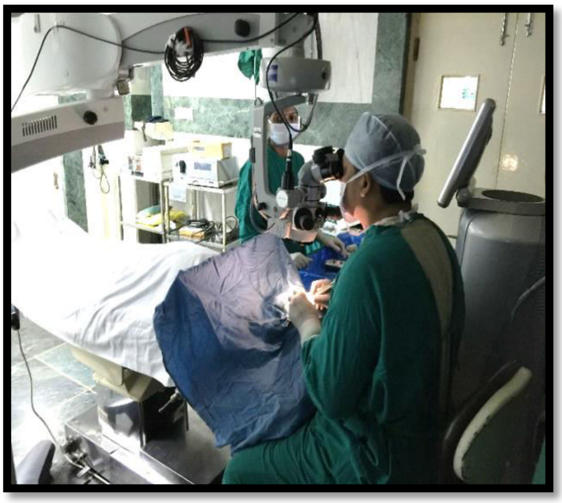

Photo 5. Intra-operative

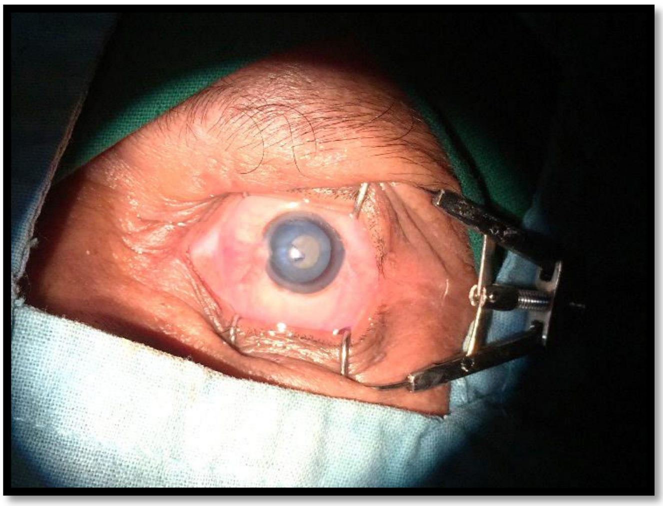

Photo 6. Capsulorhexis

Photo 7. Phacoemulsification

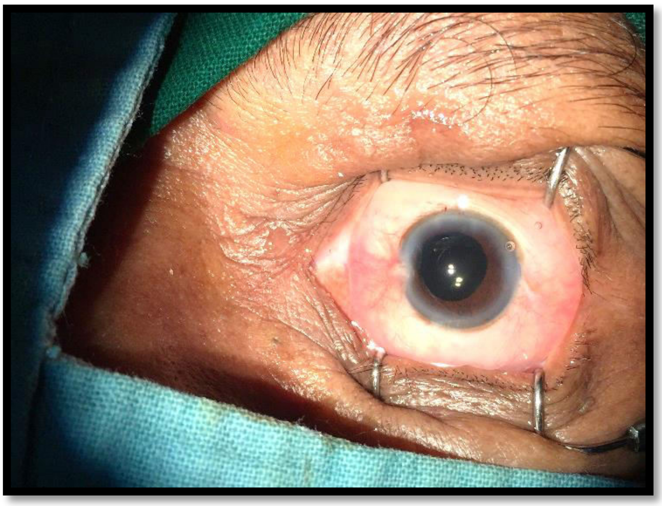

Photo 8a. Before inserting Multifocal IOL

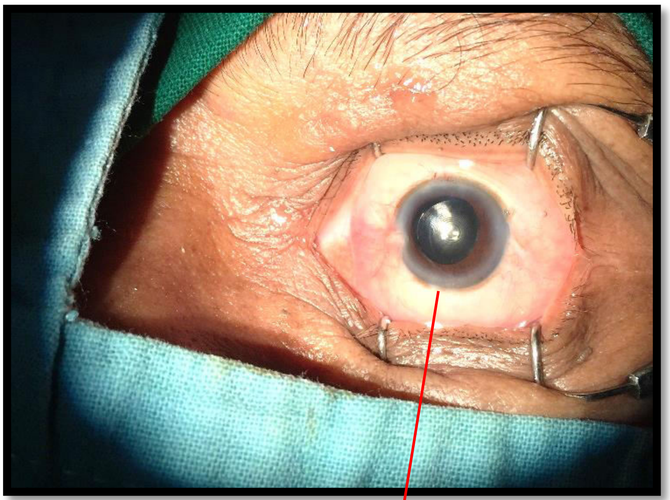

Photo 8b. After inserting Multifocal IOL

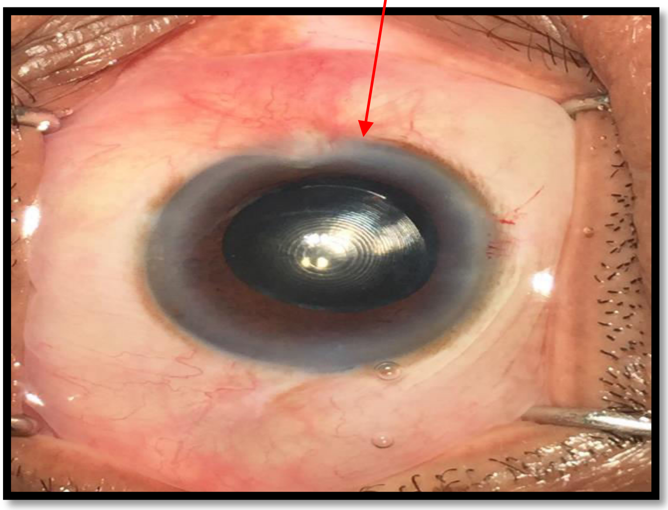

Photo 8c. Well centered Multifocal Lens

Photo 9a. Post-operative distant vision testing

Photo 9b. Post-operative near vision testing

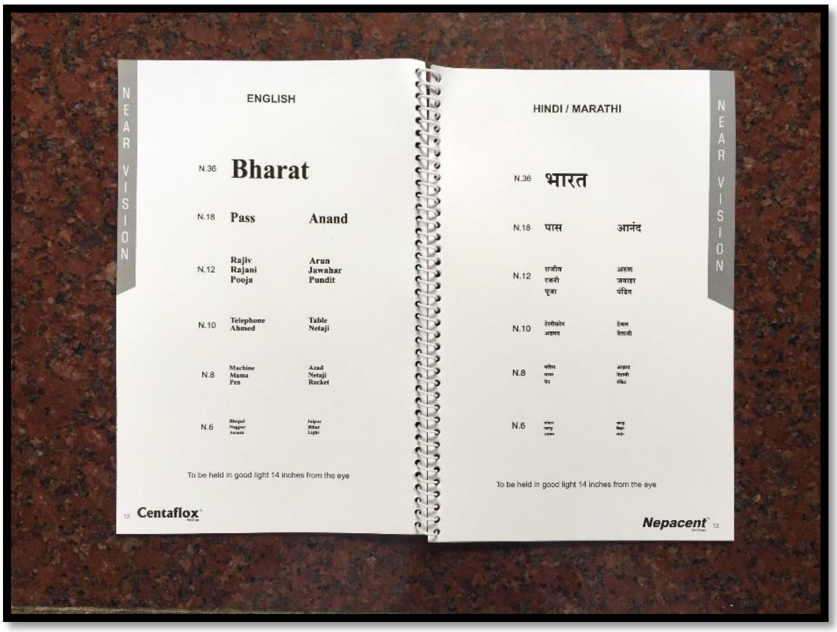

Photo 10. Near vision chart: Roman Test Type

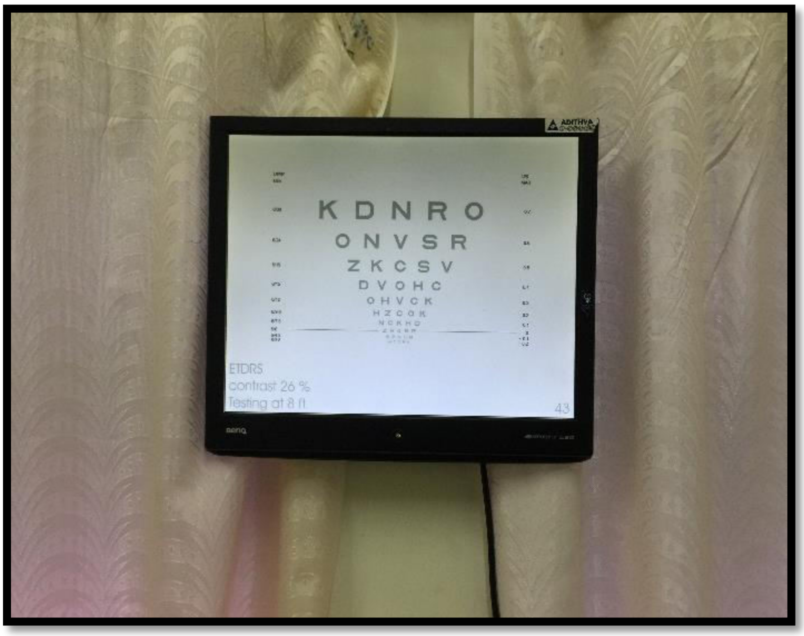

Photo 11a. High contrast sensitivity for distant vision (ETDRS chart)

Photo 11b. Low contrast sensitivity for distant vision (ETDRS chart)

SL NO.	IP NO.	Gender	Age (Years)	Eye	PRE OPERATIVE						POST OPERATIVE													
											3rd Week						6th Week							
					DV	NV	KH	KV	PCIOL Power	PCIOL Type	DV	NV	CSH	CSL	G&H	DND	DV	NV	CSH	CSL	G&H	DND	Specctacles independence	Satisfaction
1	652551	M	70	Left	6/36	N12	43.00	43.25	22.5	Multifocal	6/9	N8	0.3	0.5	-	-	6/9	N8	0.3	0.4	-	-	Y	Y
2	655960	M	63	Left	6/60	N12	45.00	45.00	22	Multifocal	6/12	N10	0.3	0.5	-	-	6/9	N8	0.2	0.4	-	-	Y	Y
3	663873	F	48	Right	6/60	N18	43.50	44.75	23.5	Multifocal	6/18	N8	0.5	0.7	-	-	6/9	N8	0.2	0.4	-	-	Y	Y
4	671935	M	52	Right	6/18	N10	43.75	44.75	22.5	Multifocal	6/9	N8	0.2	0.4	+	-	6/6	N8	0.1	0.3	+	-	Y	Y
5	673516	M	62	Right	CF 2 M	<N36	42.50	43.25	22	Multifocal	6/12	N8	0.4	0.5	-	-	6/9	N6	0.2	0.3	-	-	Y	Y
6	673397	M	57	Left	CF 1 M	<N36	46.75	45.75	21	Multifocal	6/12	N10	0.4	0.5	-	-	6/9	N8	0.3	0.3	-	-	Y	Y
7	674718	F	70	Right	CF 4 M	N36	42.50	43.50	21.5	Multifocal	6/18	N10	0.5	0.7	-	-	6/12	N10	0.3	0.4	-	-	N	Y
8	674817	F	56	Right	6/18	N12	41.50	42.00	22	Multifocal	6/12	N12	0.5	0.7	+	-	6/9	N10	0.3	0.5	-	-	N	Y
9	681628	M	60	Right	6/24	N10	42.25	42.50	19.5	Multifocal	6/12	N6	0.2	0.4	-	-	6/9	N6	0.1	0.3	-	-	Y	Y
10	682751	M	41	Right	6/18	N10	42.75	43.25	19	Multifocal	6/6	N8	0.1	0.3	-	-	6/6	N8	0.1	0.2	-	-	Y	Y
11	683083	M	56	Right	HMCF	<N36	41.25	41.25	20.5	Multifocal	6/24	N10	0.5	NR	+	+	6/18	N10	0.4	0.5	+	+	N	Y
12	683871	M	70	Right	6/60	N12	42.75	42.00	20.5	Multifocal	6/12	N8	0.3	0.5	-	-	6/9	N8	0.3	0.4	-	-	Y	Y
13	685424	M	64	Left	CF 3 M	N36	43.00	43.75	22.5	Multifocal	6/18	N10	0.4	0.7	-	-	6/12	N8	0.3	0.5	-	-	N	Y
14	688639	M	60	Left	CF 2 M	<N36	45.25	44.00	22.5	Multifocal	6/12	N10	0.3	0.4	+	-	6/9	N8	0.2	0.2	+	-	Y	Y
15	696521	F	68	Right	6/18	N24	42.50	43.25	21.5	Multifocal	6/9	N8	0.2	0.3	+	-	6/9	N8	0.2	0.3	-	-	Y	Y
16	697714	M	64	Right	6/60	N18	40.75	40.00	21.5	Multifocal	6/18	N8	0.5	0.6	-	-	6/12	N8	0.4	0.4	-	-	Y	Y
17	702998	F	63	Left	6/36	N24	41.00	40.25	18	Multifocal	6/12	N8	0.3	0.4	-	-	6/9	N8	0.2	0.3	-	-	Y	Y
18	708350	F	69	Right	6/18	N12	46.25	47.25	23.5	Multifocal	6/12	N8	0.3	0.3	-	-	6/9	N8	0.2	0.2	-	-	Y	Y
19	702998	F	63	Right	6/36	N8	43.25	43.25	17.5	Multifocal	6/12	N8	0.3	0.4	-	-	6/9	N8	0.2	0.3	-	-	Y	Y
20	684451	M	67	Left	6/36	N10	42.75	43.25	23	Multifocal	6/9	N8	0.2	0.4	-	-	6/9	N8	0.3	0.3	-	-	Y	Y

ANNEXURE IV - MASTER CHART

SL NO.	IP NO.	Gender	Age (Years)	Eye	PRE OPERATIVE DV	PRE OPERATIVE NV	PRE OPERATIVE KH	PRE OPERATIVE KV	PRE OPERATIVE PCIOL Power	PRE OPERATIVE PCIOL Type	POST OPERATIVE 3rd Week DV	3rd Week NV	3rd Week CSH	3rd Week CSL	3rd Week G&H	3rd Week DND	POST OPERATIVE 6th Week DV	6th Week NV	6th Week CSH	6th Week CSL	6th Week G&H	6th Week DND	Specctacles independence	Satisfaction
1	649098	F	60	Left	CF 1 M	N18	43.00	43.50	19.5	Monofocal	6/18	N12	0.5	0.5	-	-	6/9	N12	0.3	0.3	-	-	N	Y
2	649286	F	65	Left	6/36	N12	45.75	44.75	22	Monofocal	6/9	N18	0.2	0.3	-	-	6/9	N18	0.2	0.2	-	-	N	Y
3	649285	M	62	Right	CF 3 M	N18	44.00	43.00	24.5	Monofocal	6/18	N18	0.3	0.4	-	-	6/12	N18	0.3	0.4	-	-	N	Y
4	649284	F	45	Left	6/36	N18	43.00	44.00	24	Monofocal	6/6	N18	0.2	0.3	-	-	6/6	N18	0.2	0.3	-	-	N	Y
5	649283	M	58	Left	6/24	N10	41.00	41.50	22	Monofocal	6/9	N12	0.1	0.2		-	6/9	N12	0.1	0.2	-	-	N	Y
6	649864	F	70	Left	CF 1 M	N36	45.25	44.75	22.5	Monofocal	6/18	N12	0.3	0.3	+	-	6/18	N12	0.3	0.3	-	-	Y	Y
7	651729	F	61	Left	6/36	N24	43.75	44.75	22.5	Monofocal	6/18	N18	0.4	0.4	-	-	6/9	N18	0.3	0.4	-	-	N	N
8	651727	M	68	Left	6/36	N12	45.00	45.00	22	Monofocal	6/12	N18	0.2	0.2	-	-	6/9	N18	0.2	0.2	-	-	N	Y
9	654591	M	70	Left	6/36	N24	44.50	44.00	21.5	Monofocal	6/9	N18	0.2	0.3	-	-	6/9	N18	0.1	0.2	-	-	N	Y
10	654441	F	62	Right	6/36	N12	41.00	41.50	22	Monofocal	6/9	N18	0.1	0.2	-	-	6/9	N18	0.1	0.2	-	-	Y	Y
11	655990	M	70	Left	6/60	N12	44.00	43.75	22	Monofocal	6/18	N12	0.2	0.2	-	-	6/12	N12	0.2	0.2	-	-	Y	Y
12	666449	M	51	Right	6/36	N24	41.00	41.50	22	Monofocal	6/12	N12	0.1	0.1	-	-	6/9	N12	0.1	0.1	-	-	N	Y
13	666430	F	66	Right	CF 2 M	N12	42.50	43.50	18.5	Monofocal	6/18	N10	0.3	0.4	-	-	6/12	N10	0.2	0.2	-	-	Y	Y
14	666404	M	60	Left	6/60	N10	42.75	43.00	18	Monofocal	6/12	N10	0.2	0.2	-	-	6/9	N12	0.1	0.2	-	-	Y	Y
15	667691	M	67	Left	6/36	N18	46.75	45.75	21	Monofocal	6/24	N12	0.4	0.4	-	-	6/18	N10	0.3	0.3	-	-	N	Y
16	676614	F	55	Left	CF 1 M	<N36	45.75	46.25	23	Monofocal	6/12	N12	0.3	0.4	-	-	6/9	N12	0.2	0.3	-	-	Y	Y
17	671991	M	59	Right	6/60	N18	43.00	43.75	22	Monofocal	6/6	N18	0.1	0.2	-	-	6/6	N12	0.1	0.3	-	-	Y	Y
18	671990	M	53	Right	CF 1 M	N36	42.75	43.00	24	Monofocal	6/12	N12	0.1	0.3	-	-	6/9	N12	0.1	0.1	-	-	Y	Y
19	671803	F	51	Right	CF 1 M	N36	45.25	45.75	25.5	Monofocal	6/12	N18	0.2	0.3	-	-	6/9	N18	0.2	0.2	-	-	N	Y
20	674816	M	58	Left	CF 1 M	<N36	43.75	42.75	21.5	Monofocal	6/18	N18	0.4	0.4	-	-	6/9	N18	0.3	0.4	-	-	N	Y

ANNEXURE V - MASTER CHART KEY

DV – Distant Visual Acuity

NV – Near Visual Acuity

KH – Keratometry reading in horizontal meridian

KV – Keratometry reading in vertical meridian

PCIOL – Posterior Chamber Intraocular Lens

CSH – High Contrast Sensitivity

CSL – Low Contrast Sensitivity

G & H – Glare and Halos

DND – Difficulty in Night Driving

CF – Counting Fingers

HMCF – Hand Movements Close to Face

M – Male

F – Female

NR – Not Recordable

Y – Yes

N - No