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Instruction to Authors
Change is the only permanent thing on earth, we too are moving in for a change this time. After a year full of mixed issues, now we are moving to thematic issues. This issue is fully dedicated to cataract and refractive surgery, and we have carefully selected the topics to offer a great treat to all of you, be practicing physicians, bombastic surgeons or humble postgraduates. We have strived hard to include both basics as well as breakthroughs in these two subspecialties. Let me thank all my authors who had made time between their busy schedules to get the ball rolling for this issue of KJO.

Our issue, as usual, starts with the cover story, this time focussing on the most cut off part of the human body, the crystalline lens. The author has very clearly explained the anatomy, embryology and other details of the lens and I am sure this will be a collector’s item article for postgraduates, years to come.

Our Major review kickstarts with the most common surgery known to mankind, the cataract surgery. In this article, the author goes on to describe the working of the phaco machine. It is a must read article to all postgraduates as well as surgeons, and will help increase their understanding and grip on their own surgical techniques. Knowledge is power... If you master the machine, the work is half done.

After the phaco machine, comes the next review on the newer IOLs. The author has put together all the different IOLs available in Indian market for all of us to compare and contrast. He has lucidly explained the subtleties involved in choosing these IOLs for our patients, again a must read for all practicing ophthalmologists and surgeons.

Managing astigmatism during surgery is a main agenda in cataract surgery; the aims are to provide an uncorrected best visual acuity of 6/6 after every surgery. The author in the third major review speaks about the various techniques which we adopt to manage astigmatism during cataract surgery. A class article, which I am sure, will receive great appreciation.

One of the most difficult cataracts to manage is a posterior polar cataract and our fourth major review is on the management of posterior polar cataract. With the help of diagrams, the author has tried to explain the best techniques for managing this difficult surgical topic.

Pediatric cataract may be due to multitude of reasons and many a time, the operating surgeon may not be able to actually find out the cause for the lenticular opacity. In our problem oriented ophthalmic diagnosis column, we are trying to find an aetiology for the pediatric cataract. There are many clues that we have to hunt to make an earnest effort in finding out the actual cause of the cataract in these small children.

Our biostatistics column continues to form a strong basement in research methodology for practicing ophthalmologists. The ophthalmology examples make it very readable for all. Once again we have to thank the author in making this difficult topic palatable.

Femtosecond laser has taken the cataract and refractive surgery by storm and this time, we have added a new column on the breakthroughs. Refractile lenticule extraction in Femtosecond LASIK and Femtosecond assisted cataract surgery are the two major changes occurring in this area and we have spared no effort to maximally cover these two topics.

Our surgical corner this time looks at the evergreen topic- complications during cataract surgery. This column has been getting a lot of appreciation from our younger colleagues, who open the you tube video and read the stimulating text within our journal for a complete understanding of the surgical situation.

A new column on frequently asked questions completes the list, this time, it is on the favourite topic, operation theatre asepsis. Compressed information which is very simple and matter of fact, they may answer a lot of queries that you had in the back of your mind, but were unaware, whom to ask.

The regular columns on case reports, original articles, journal review, book review and spot diagnosis are all retained. The PG corner this time is on IOL power calculations, a must know for all PGs.

Hope to have the next issue up early, work is already on. Please contribute freely in terms of articles, case reports and reviews in cornea and glaucoma as early as possible.

Jai KSOS
Dr Gopal S Pillai
Editor
Lenses and Zonules

Human crystalline lens is a transparent, biconvex, elliptical semisolid avascular structure located between iris and vitreous, and bathed by aqueous humour on both sides. It has anterior and posterior surfaces and equator.

It enables the eyes to focus images of objects lying at distance and near on the retina and for this the lens must be transparent and elastic. The lens has cells of single type in various stages of cytodifferentiation. As the cells get older they are embedded within the lens and become metabolically inert. Zonules connect the equator of lens to ciliary body.

Dimensions of lens:
- Equatorial diameter:
  - Birth: 6.5mm
  - Adult: 9.0-10mm
- A-P diameter:
  - Birth: 3.5-4mm
  - Adult: 4.5-5mm
- Radius of curvature:
  - Anterior surface: 10mm
  - Posterior surface: 6mm
- Anterior pole of lens is at 3mm from corneal endothelium.
- Equator of lens is 0.5mm from ciliary process.

Refractive index of lens: 1.39.
Refractive power: 15-17D,

Accomodative power:
- Birth: 15-16D
- 25yrs: 7-8D
- 50yrs: 1-2D

With a dilated pupil under slit lamp we can see stratifications of lens to various layers from front to back.

Capsule
- Subcapsular clear zone (cortical zone c1)
- Bright narrow scattering zone of discontinuity (c1 β)
- Subclear zone of cortex (c2)

2 deep perinuclear zones – bright scattering zone (c3) clear zone (c4)

Nucleus (prenatal lens)
- Embryonic – only primary lens fibres

Embryology of lens:
Surface ectodermal cells overlying the optic vesicle thickened to form a lens placode at 27 days of gestation. This lens placode invaginates into the developing optic cup until it pinches off as a lens vesicle. The cells approximating the retinal half of vesicle differentiate and transform to

With specular microscopy a beaten metal appearance is visible at the interface between aqueous and anterior capsule and is termed as lens shagreen.
Scanning electron microscopy reveals a pebble like appearance for anterior lens capsule.
Retroillumination lens is clear

Figure 1- Development of lens
primary fibres which elongate along the visual axis and obliterate the lumen of the vesicle. At this point lens is a ball of primary fibres overlaid by a monolayer of undifferentiated vesicular cells.

Secondary fibres are then formed from the germinative zone of anterior lens epithelium at 28mm stage of embryo. Since the 2o fibres are laid down concentrically the lens on section has a laminated appearance. Depending upon the period of development, the secondary fibres form the different layer of nucleus and cortex. Thus recently formed secondary lens fibres form the cortex. Zonules appear at 65mm stage of fetal life.

ANATOMY OF LENS:
The lens consists of:
 a) The lens capsule
 b) The lens epithelium
 c) The lens fibres or lens cells

a) The lens capsule:
Completely envelops the lens. It is the basement membrane of lens epithelium and is the thickest basement membrane in the body. It is thicker anterior compared to posterior, equator compared to the poles. Anterior capsule thickens with age since lens epithelium secret basement membrane. Zonules are attached to the anterior and posterior lens capsule at the periphery and at equator.

The capsule is transparent, homogenous, lamellar structures with fibre arranged parallel to the surface. There are about 40 lamellae each of about 40nm thickness.

It is a modified basement membranes consist of collagen embedded in glycoprotein matrix, the main collagen is Type IV and other collagens like type I and III are also present. Capsule is devoid of elastin and the configuration of collagen is in the form of superhelices which uncoil under tension. The capsule is normally under tension so when it is cut as in ECCE or Yag laser capsulotomy, the edges rolls out and curls up – Elastic recoil property. The capsule is freely permeable to water, ion and smaller molecule, whereas resistant to bacteria and inflammatory cells.

b) The lens epithelium:
It is a single sheet of cuboidal cells spread over the front of lens deep to the capsule, extends toward equator. There are about 5L cells in mature lens with increasing density towards periphery. Cell density is higher in females than males and decrease with ages. Since the posterior lens epithelium of the embryonic lens is involved in the formation of primary lens fibre, there is no posterior lens epithelium. There are 3 zones of anterior epithelium.

i) Central zone (cz): It is a stable population of polygonal cells with round apically placed nuclei. These nuclei are large, intended with numerous nuclear pores and have two nucleoli. The cells have all cellular organells and cytoskeletal protein. α-crystalline is present in the epithelium but not β and y. Heidesmosomes attach the basal aspect of cells to the lens capsule. cz cells do not mitose normally but can do so in response to injury.

ii) Intermediate zone: It is peripheral to Cz and the cells are smaller more cylindrical with central nucleus. Cells of this zone have complex basal interdigitations. Occasional mitosis can be seen.

iii) Germinative zone: is the most peripheral zone located just pre-equatorially. It is the major site of cell division. Cell nuclei are flattened, lies in the line of long axis of the cells. From this zone new cells migrate posteriorly to become lens fibre. Epithelial cells in this zone has few organelles and cytoskeletal proteins. α crystalline is present but not  β and y.

C) The lens fibres:
The transition of the epithelial cells in the gz to the elongated nucleated lens fibre cell is accompanied by

• reduction in the lateral interdigitations
• onset of pronounced elongation at the basal and apical portion of the cells which extend backwards along the inner aspects of capsule and forward under the epithelium respectively.

Figure 2-Lens fibers
The deposition of successive generation of lens fibre is associated with formation of nuclear bow, in which flattened nuclei of successive generation of lens fibres form an arch forward. The fibres are laid down in concentric layers, outermost of which lies in the cortex of lens and innermost in the nucleus. These fibres are straplike. They are hexagonal in
equatorial cross section. The lens fibres are thinner posterior that is why lens is asymmetrical in sagittal section. The lens fibres are of 3 types – elongating, cortical and nuclear fibres.

Membrane specialization of lens fibres:

1. Ball and socket and tongue and groove interdigitations: The cell membrane of lens fibres enter into a variety of association with those of their neighbours. In the superficial 8-10 layers of the anterior cortex, the short or lateral sides of the hexagon undulate and interlock with adjacent fibres by a series of ball and socket like joints arranged regularly along the length of the fibre. In this way cells in a given layer are firmly attached to each other while having only loose connection with preceding and succeeding layers. This arrangement may be important for the movement of fibres during accommodation. In the deepest layers of the cortex and in the nucleus along with ball and socket interdigitations, tongue and groove interdigitations also present. All these types of interdigitations are for maintenance of fibre order which is essential for maintaining transparency of the lens while allowing a limited degree of fibre sliding and certain amount of flexing of whole lens structure during accommodation.

Desmosomes are present between elongating fibre cells but not between mature fibre cells.

2. Gap junctions:
They are second order junctional complexes seen in human lens fibre. It has 2 important roles
- By conjoining large areas of membrane they contribute to fibre order and therefore transparency.
- They are considered to contribute to lens function by providing pathways between terminally differentiated lens fibres which lack the cellular organelle for metabolic cooperation.

Gap junction are of 2 types:
- Crystalline type – associated with lens epithelial cells
- Non-crystalline type – between lens fibres.
Gap junctions are not found at the anterior and posterior tips of lens fibres and therefore not within the sutural zone, their density increases toward equator.

The lens sutures:
The tips of lens fibres meet those of other fibres to form sutures. These lines of junctions are accompanied by expansion, flattening and curving of the tips as they insert to the suture with overlapping and interlocking below the 10th layer cortical cells. The suture arrangement of the lens become increasingly complex with the growth of lens. In fetal nucleus there is an anterior erect Y and posterior inverted Y suture. After birth more branch points are added to succeeding suture lines, so that in the adult nucleus the sutures have a stellate structure, a 9-point star of mature cortex. The suture system may be envisaged as a means of accommodating the growth and packing of the lens fibres while retaining the cross-sectional configuration of lens. They are responsible for zones of optical discontinuity. Since the suture architecture is a stable feature of the lens, and it moves outwards when lens grows while maintaining a constant distance from lens surface. The suture is a site of increased spherical aberration in the lens.
As the lens grows an increase in equatorial circumference can be achieved by increase in fibre width or by an increase in number of rows. This increase in row number is associated with site of fibre cell fusion, which are found in cortex and nucleus. They also have a role in cell-cell communication. The younger lens fibres are fine due to the presence of few cellular organelles and dense amorphous granular cytoplasm. The cytoplasmic appearance is due to higher concentration of protein in the lens fibres. Lens fibres has α, β, y crystallines. Lens fibres contain highest protein content of any cell in the body.

**PHYSIOLOGY OF LENS:**

1. Lens transparency:
   Normal lens is transparent structure which transmit almost 80% of light energy. The lens transparency is maintained by:
   1) Single layer of anterior epithelium
   2) Semipermeable nature of lens capsule
   3) Lack of organelles in the lens fibres Regular arrangement of lens fibres, homogenous structure or fibres and small site of extracellular space.
   4) Nuclei of the epithelial cells are present in monolayer and the nuclei of multilayered lens fibres are displaced to the nuclear bow of cortex.
   5) Regulation of ionic and water content of lens fibres is essential for transparency. The pump mechanisms in epithelium for these are
      - Na-K ATPase pump – transport Na outwards
      - Ca activated pump moves K into the cell
      - Passive diffusion of Na inwards & K outward - post surface
   6) Avascularity of lens
   7) Auto oxidation.
   8) There is a graded change in refractive index in the lens towards inwards, which is correlated with change in protein content and account for the overall refractive power and relative freedom from chromatic aberration.

2) Lens metabolism:
   Metabolism of lens involve two essential processes
   - Provide energy through carbohydrate
   - Provide structural materials through amino acids

   **a. Glucose metabolism:**
   Main source of energy
   i) Glycolysis – Anaerobic, 80% of lens glucose is metabolized by this provide 2 molecules of ATP.
   ii) Kreb’s cycle – Aerobic, 5% lens glucose is metabolized by this 36 molecules of ATP is formed.
   iii) Hexose monophosphate (HMP) shunt – 15% glucose is metabolized, provide pentose sugar for RNA synthesis and NADPH for many biochemical reactions.
   iv) Sorbitol pathway – not provide ATP, important role in the development of diabetic cataract.

   **b) Protein metabolism:**
   Protein synthesis take place rapidly in anterior and equatorial cortex.
   Proteolysis occur in later stages of cataract.

   **c) Transport mechanism of the lens:**
   Are essential to provide nutrients for metabolism, to dispose waste products of metabolism and to regulate water and ionic balance in the lens.
   Active transport : amino acids, K+, Na+, inositol, taurine. 90% ATP is used for this
   Passive transport : water, ions, waste product of metabolism.

   **d) Accommodation:**
   Change in shape of lens during accommodation is due to the elastic property of the capsule. During accommodation the thicker ring of anterior capsule surrounding the central region contract under lessened zonular traction, while the thinner central capsule bulges forward to have a short radius of curvature and high refraction.

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**Lens zonules:**

It is a series of fibres passing from ciliary body to lens, which holds the lens in position and enables the ciliary muscle to act during accommodation. The lens-zonules diaphragm
divide the eyeball to anterior and posterior segments. The zonules form a ring which is roughly triangular with base is concave and faces to the equatorial edge of the lens and apex is elongated and curved towards the ciliary process. This febrils composed of a noncollagenous glycoprotein containing oligosaccharides. It resembles elastin and has a susceptibility to digestion by trypsin (This property is used in ICCE, in which α-chymotrypsin dissolves zonules without any effect on collagenous capsule). The zonular fibres are immunoreactive for fibrillin. In Marfan syndrome, there is mutation of fibrillin gene. Each zonular fibre is composed of fibrils of 10nm diameter.

There are 4 main topographic zones for ciliary zonules:

- Pars orbicularis (lying on pars plane)
- Zonular plexus (between ciliary process)
- Zonular fork – point of angulation of the zonule at mid zone is the ciliary valley.
- Anterior, equatorial, posterior limbs.
- Anterior zonules run from pars plane to preequatorial lens and supplemented by fibres from pars plicate. Preequatorial insertions are dens.
- Posterior zonules run from pars plicate to post equatorial lens and supplemented by fibres from pars plane. Postequatorial insertions are in 2-3 layers.
- Equatorial fibres from pars plicate to equator – perpendicular sparse insertion.
- Hyaloid zonule is filmsier structure plastered as a thin layer deep to main suspensory apparatus run from parsplana to lens at the edge of patellar fossa and is attached to Weiger’s ligament.

Circumferential zonules girdles are flimsy circumferential structure lying in relation to ciliary body.

Aging changes of lens:
1) Increase in size, weight and thickness of lens
2) Lens become dehydrated, compact and resulting in nuclear sclerosis associated with increase in refractive index.
3) There is an accumulation of yellowish brown pigments which absorb short wavelength light.
4) Decrease the transparency of lens.
5) Proliferative capacity in lens epithelium declines with age.
6) Enzyme activity declines.
7) Age related loss of gamma crystalline
8) Zonules become fine more spares, rupture readily in old age.
9) Zonular attachment become broadened.

References:
As we all know, Dr. Charles Kelman in 1962 introduced the first phacoemulsification machine. Since then there has been many advancements in the technology and features of many generations of machines. But the basic principle remains unchanged.

This article aims at bringing out some important points about phacoemulsification systems that every phaco surgeon should be clear about, to perfect the art of cataract extraction by phacoemulsification.

All phaco machines consist of a computer to generate electrical signals and a transducer to turn these electronic signals into mechanical energy. The energy thus produced is passed through a hollow needle as it vibrates and is transmitted into the lens inside the eye to emulsify it. Once emulsified, fluidic systems remove the lens matter out of the eye, through the hollow needle.

Basically any machine will have a console with a pump (fig 1), a hand piece, and a footpedal.

To get the machine to work, one ought to depress the footpedal. It has generally 3 positions. Irrigation in position 1, irrigation & aspiration in position 2, irrigation, aspiration & Phaco power in position 3.

Irrigation is gravity dependant. The intraocular pressure during phaco is essentially determined by the height of the irrigation fluid above the eye and the rate of leakage of fluid out of the eye. Chamber stability during surgery is the balance between irrigation on the one hand and aspiration plus leakage on the other hand. Surge results when there is inflow–outflow imbalance. Irrigation bottle height can be adjusted manually or is automated in some machines.

Aspiration flow rate (AFR) is the rate (in cc/min) at which fluid exits the anterior chamber through the machine’s aspiration tubing. This rate can be set by the surgeon by adjusting the settings on the display panel. Vacuum (the force with which the nucleus material is held at the tip of the needle) control is also present on the display. These two parameters are controlled by the particular pump that machine has.

Peristaltic and Venturi pumps
In a peristaltic pump system (fig 2), depression of the foot pedal in position 2 directly controls the rate at which the pinch roller rotates. Machines offer fixed rates of flow or linear control of flow, as well as alterations in the flow rate when the machine senses an occlusion (rising vacuum). No vacuum is present in peristaltic systems until the tip begins to become occluded and resistance to flow is sensed. Vacuum pressure rises as flow is reduced by nucleus material starts occluding the tip. Aspiration flow ceases at full occlusion and the maximum vacuum is reached. The maximum vacuum level is set by the surgeon as one of the parameters of a peristaltic system. In turn, this setting specifies the vacuum level at which the pump stops. One mechanism for reducing surge involves an occlusion mode setting with reduction of maximum vacuum, so that when the occlusion breaks (as the material is emulsified and evacuated), the fall in vacuum is reduced (the fall is reduced because the vacuum level falls from a lesser height). Ultrasound power is usually necessary at the point of occlusion to emulsify material and allow evacuation.

In general, the higher the flow rate, faster the fluid and material will move towards the phaco tip and faster the vacuum will rise when material occludes the tip. Some machines offer independent control of vacuum rise time or ramp, essentially changing the pump speed as the machine first senses resistance to flow, in order to either speed up or...
slow down the process of reaching full occlusion (i.e. getting a firm hold on material more quickly or less quickly).

The concept of followability means the facility with which nuclear material flows towards, is held by, and evacuated through the phaco tip. Opposite to followability is chatter, which means that material repeatedly bounces off the phaco tip without following the aspiration flow up the tube. It is the aspiration flow that brings the material toward the tip. In coaxial phaco (with the irrigation sleeve on the phaco tip), the irrigation stream tends to push material away so that aspiration must overcome irrigation for magnetic attraction to occur. Longitudinal ultrasonic vibration of the phaco tip also acts as a repulsive force that must be overcome by aspiration flow and, during occlusion, by vacuum pressure, to bring material and hold it on the tip as it is mobilized and emulsified. Alleviating the repulsive force of longitudinal tip motion has been the impetus behind the development of nonlongitudinal sonic and ultrasonic energy delivery systems, such as oscillatory, torsional, or transverse tip motions.

In a Venturi pump (named after the Italian physicist Giovanni Battista Venturi), the foot pedal directly controls the application of vacuum; aspiration flow occurs in response to vacuum pressure. According to the classic Venturi principle, it is the flow of pressurized gas through a narrowed tube that creates the vacuum. Unlike a peristaltic pump, with which vacuum does not exist until there is resistance to flow, with a Venturi pump vacuum is always present. The surgeon sets the maximum vacuum level as one of the parameters. There is no setting for aspiration flow. The vacuum increases in a linear fashion as the foot pedal is depressed in foot position 2 Venturi pumps as more aggressive than peristaltic pumps. This perception comes about primarily because of surge. Vacuum increases as the surgeon depresses the foot pedal in order to evacuate material, and the vacuum remains high even after the material is evacuated unless the surgeon actively reduces the vacuum by moving the foot pedal. But in a peristaltic pump the vacuum will drop to zero once the occlusion has passed regardless of foot pedal action. Still, with an appropriate initial Venturi vacuum setting and a good foot pedal control, one can maintain a stable chamber. Therefore, not only do Venturi pumps have a reputation for being more aggressive, they also have a reputation for allowing exceptionally rapid clearing of material, excellent followability, and fast surgery.

**Power**

Phaco power is created by an interaction between frequency and stroke length.

**Frequency** is defined as the speed (cycles per second) of the phaco needle movement. The frequency of a particular machine is decided by its manufacturer. Most machines operate between 28 KiloHertz to 50 KHz. Lower frequencies become less efficient and higher frequencies create excess heat.

Stroke length is defined as the length of needle movement in one cycle. This length is generally 2 to 6 mils (1 mil = 1/1000
So in microns, most phaco needles travel a distance of 50 to 100 microns. The longer the stroke length, the greater the physical impact on the nucleus to cut it. Longer stroke lengths, like higher frequencies, however, tend to generate extra heat.

Stroke length is controlled by foot pedal excursion in position 3 during linear control of phaco. As the foot pedal is depressed in position 3, the stroke length and therefore the power increase to the preset maximum. Many machines have the facility to increase the throw length of the foot pedal in position 3 allowing for more control in energy delivery.

**Phaco Energy**

The actual forces that emulsify the nucleus are thought to be a combination of the jackhammer effect and cavitational energy. The jackhammer effect is the physical striking of the needle against the nucleus. To explain cavitation, it needs a bit more explanation. The phaco needle, moving through a liquid medium at ultrasonic speeds, gives rise to intense zones of high and low pressure. Low pressure, created with backward movement of the tip, pulls dissolved gases out of solution, thus producing micro bubbles. Forward tip movement then creates an equally intense zone of high pressure. This initiates compression of the micro bubbles until they implode. Of the micro bubbles created, 75% implode, creating a powerful shock wave radiating from the phaco tip in the direction of the bevel with annular spread. However, 25% of the bubbles are too large to implode. These micro bubbles are swept up in the shock wave and radiate with it. The energy created is present only in the immediate vicinity of the phaco tip and within its lumen. Cavitation is instrumental in clearing nuclear fragments within the phaco needle.

**Power delivery modifications**

Unnecessary power intensity is a cause of heat and can cause wound burn, endothelial cell damage, and iris damage with alteration of the blood-aqueous barrier. Phaco power intensity can be modified by the following:

- Controlling the foot pedal excursion in position 3 in linear mode
- Usage of pulse (fig 3) or burst mode (fig 4) phaco.

Both these modes break up continuous power delivery into constant or variable periods of on and off time (Duty cycle defined as the length of time of power on combined with power off) with linear or fixed control of energy delivery. Hyper-pulse phaco or Micro-pulsing (cold phaco) shortens the cycle of on and off time. The short bursts of phaco energy followed by a short period without phaco energy allows two important events to occur. First, the period without phaco energy permits the nuclear material to be drawn toward the phaco tip to increase efficiency. Second, the absence of power allows inflow of irrigating fluid in the micro cavity between the phaco tip and nuclear fragment.

- Torsional Phaco - Classic phaco has utilized a phaco tip that moves forward and backward, or longitudinally. Torsional phaco is defined as a 32-kHz oscillatory movement of an angled (Kelman) phaco tip. This can be combined with longitudinal movement of the needle at 44 kHz. The torsional component is linear and the longitudinal component can be micro-pulse. As the movement of the tip is side to side, there is no repulsion and increases cutting efficiency due to the continuous cutting during the movement of the tip.
- Ellips Phaco - In this system the longitudinal movement of the phaco tip at 38 kHz is combined with a transversal motion at 26 kHz. The resultant movement of the needle can be described as prolate-spheroid (shaped much like an egg cut in half).

**Phaco needles**

The emission of phaco energy is modified by tip selection. Needles may be standard (19G) or micro tips. Larger bore tips cut better and take in larger pieces of nucleus but also aspirate more fluid and can lead to more surge. Micro tips
reduce surge a lot, but the nucleus needs to be chopped into smaller pieces to be emulsified more efficiently.

The tip bevel can vary from 0 degree to 45 degrees. The lesser the bevel the better it holds and the larger the bevel the better it cuts. Newer modifications are many in the tip shape and angulations aimed to improve efficiency.

**Fluidics**

The fluidics of all machines is fundamentally a balance of fluid inflow and fluid outflow. Inflow is determined by bottle height above the eye of the patient and irrigation tubing diameter. Usually 80 to 100 cm above the eye level is the bottle height according to the level of AFR and vacuum set by the surgeon.

Outflow is determined by the sleeve-incision relationship, as well as the paracentesis size, aspiration flow rate, and vacuum level preset. The incision length selected should create a snug fit with the phaco tip selected. This will result in minimal uncontrolled wound outflow with resultant increased anterior chamber stability.

AFR, with a peristaltic pump, it is determined by the speed of the pump. AFR determines how well particulate matter is attracted to the phaco tip. Vacuum is a level measured in mmHg and is defined as the magnitude of negative pressure created in the tubing. Vacuum is the determinant of how well particulate material will be held to the tip, once occluded on the phaco tip.

**Surge**

A fundamental limiting factor in the selection of high levels of vacuum or flow is the development of surge (fig 5). When the phaco tip is occluded, flow is interrupted and vacuum builds to its preset level. Emulsification of the occluding fragment then clears the occlusion. Flow instantaneously begins at the pre-set level in the presence of the high vacuum level. In addition, if the aspiration line tubing is not reinforced to prevent collapse (a function of tubing compliance), the tubing will have constricted during the occlusion. It then expands on occlusion break. This expansion is an additional source of vacuum production. These factors trigger a rush of fluid from the anterior chamber into the phaco tip. The fluid in the anterior chamber may not be replaced rapidly enough by infusion to prevent shallowing of the anterior chamber. This can result in damage to the posterior capsule and the corneal endothelium.

Classically selecting lower levels of flow and vacuum control surge. The phaco machine manufacturers help to decrease surge by providing noncompliant aspiration tubing that will not constrict in the presence of high levels of vacuum. Also the use of high infusion sleeves, flow restrictors like Starr cruise control, surge suppressors, using micro tips (Phaco needles with lesser bore size) reduce surge. Some noteworthy new technologies are:

- **CASE**: Micro-processors sample vacuum and flow parameters 50 times a second, creating a “virtual” anterior chamber model. At the moment of occlusion, the computer senses the decrease in flow and instantaneously slows the pump to stop surge production.

- The Dual Linear foot pedal can be programmed to separate both the flow and vacuum from power. In this way, flow or vacuum can be lowered before beginning the emulsification of an occluding fragment. The emulsification therefore occurs in the presence of a lower vacuum or flow so that surge is minimized.

- **ABS** (aspiration by-pass system)—The ABS tips have 0.175-mm holes drilled in the shaft of the needle. During occlusion, the hole provides for a constant alternate fluid flow. This will cause dampening of the surge on occlusion break.

**Clinical application**

Before any phaco technique starts capsulorhexis, cortical cleaving hydrodissection, and removal of the superficial cortex and epinucleus to expose the endonucleus have to be performed well in all cases. The general principles of power management are to focus phaco energy into the nucleus, vary fluid parameters for efficient sculpting and fragment removal, and minimize surge.

Generally all phaco procedures have two phases. The first is the creation of fragments. This requires sculpting or
chopping. The second phase is the removal of the fragments in a controlled approach. Occlusion is mandatory to move fragments to the iris plane. Fragment removal is assisted by partial-occlusion phaco.

**Sculpting**
A 15-30 or 45-degree tip can be utilized. Low vacuum (depending on the manufacturer’s recommendation) is mandatory for sculpting. This will prevent occlusion and avoid excessive movement of the nucleus during sculpting. According to the hardness of the nucleus, the phaco power is adjusted so that there is no mechanical push on the nucleus while the tip moves inside the nucleus material during sculpting. The groove is judged to be adequately deep if it is about 3 phaco tip diameters deep in the center. Either continuous mode or pulse mode can be used for sculpting. If micro-pulse phaco is used for sculpting, duty cycles with longer power on than off should be selected. This will allow the phaco to proceed with clean emulsification and avoid pushing the nucleus ahead of the phaco tip, potentially damaging zonules. When the initial groove is judged adequate, the nucleus is rotated 180 degrees and completed on the other side. Similar groove can be created at 90 degrees to the original groove finally making the sculpted area look like a cross.

**Quadrant Removal**
The grooves are expanded and cracking is performed at the base of the grooves to make 4 separate nucleus fragments. Vacuum and flow are increased to reasonable limits governed by the machine being used. The limiting factor to these levels is the development of surge. Therefore, the use of micro-pulse phaco is best used at this stage. The bevel of the tip is turned toward the quadrant or fragment. Low pulsed or burst power is applied at a level high enough (in the iris plane) to emulsify the fragment without driving it away from the phaco tip.

**Phaco Chop**
Phaco chop requires no sculpting. Therefore, the procedure is initiated with high vacuum and flow and linear pulsed or micro-pulse phaco power. For a 0-degree tip, especially when emulsifying a hard nucleus, a small trough may be required to create adequate room for the phaco tip to push deep into the nucleus. For a 15- or a 30-degree tip, the tip should be rotated bevel down to engage the nucleus. The phaco tip should be encased within the endonucleus with the minimal amount of power necessary. All chopping procedures require at least 1-1.5mm of exposed phaco tip to create adequate holding power for chopping. If the phaco tip is inserted into the nucleus with excess power, the adjacent nucleus will be emulsified, creating a poor seal between nucleus and tip. This will make it impossible to remove fragments, as the tip will not hold the nucleus immobile. Additionally, the bevel should be turned toward the fragment to create a seal between tip and fragment, allowing vacuum to build and create holding power.

After the first chop, a second similar chop is performed so the heminucleus is divided into three pieces. One pie-shaped piece of nucleus thus created is elevated to the iris plane (occlusion is utilized to move fragments) and removed with low power hyper-pulsed phaco. The rest of the nucleus can be similarly chopped and emulsified.

**Irrigation and Aspiration**
Similar to phaco, anterior chamber stability during irrigation and aspiration (I/A) is due to an equilibrium of inflow and outflow. Wound outflow can be mini-mized by employing a soft sleeve around the I/A tip and a deep and stable anterior chamber should be maintained. Generally, a 0.3-mm I/A tip is used. With this orifice, a vacuum of 300 - 500 mmHg and flow of 20-40 cc/min is excellent to tease cortex from the capsular fornices. Linear vacuum allows the cortex to be grasped under the anterior capsule with low vacuum and drawn into the center of the pupil at the iris plane. There, in the safety of a deep anterior chamber, vacuum can be increased and the cortex aspirated.

Bimanual I/A is also a viable procedure. A 20 or 21-gauge irrigating cannula provides inflow through one paracentesis while an unsleeved 20 or 21-gauge aspiration cannula is used through the opposite paracentesis. The instruments can be easily switched, making removal of cortex from any location inside the capsular bag considerably easier.

**Vitrectomy**
Most phaco machines are equipped with a vitreous cutter that is activated by compressed air or by electric motor. For vitrectomy, an irrigating cannula, or chamber maintainer, inserted through a paracentesis, provides inflow. Bottle height should be adequate to prevent chamber collapse. The vitrector should be inserted through another paracentesis. Utilizing a flow of 20 cc/min, vacuum of 250 mmHg, and a cutting rate of 450 or more cuts/min, the vitrector should be placed into the area of vitreous prolapse in the anterior chamber. The foot pedal on level 1 provides irrigation, level 2 delivers irrigation and cutting and in level 3 irrigates, cuts and aspirates.

**Conclusion**
Phacoemulsification is a balance of technology and technique. Awareness of the principles that influence phaco machine settings is a prerequisite for the performance of a proficient and safe surgery. A thorough understanding of fundamental principles will enhance the capability of the
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surgeon to appropriately modify the parameters as and when required for specific situations.

Bibliography
Cataract surgery has gone through a major technological leap in terms of the visual rehabilitation it can afford since the introduction of Extra capsular extraction with Intra ocular implantation in the late 1970s. The aging of baby boomers and rising incidences of cataract in all parts of the world has accelerated the global market of intraocular lenses, projecting it to reach up to $5 billion by 2015. (Intraocular Lenses : A global strategic Business Report). Published by the Global Industry an off the shelf market research, the report states that the percentage of cataract incidence is relatively high, with an approximate 20 million cataract blinds. A majority of them are in developing countries such as India and China. Technological and surgical advances have seen a huge increase in cataract surgery rates, particularly in India. The region is projected to register a growth rate of between 11% and 17% over the period 2008-2015. The other factor fuelling further growth of IOLs are marketing campaigns by leading ophthalmic companies and enhanced training of physicians on implanting advanced IOLs, according to Global Industry. The report said hard IOL market is projected to fall at a CAGR at 7.5% over 2000-2015. PMMA IOLs, on the other hand will continually be used in developing markets, including Asia-Pacific, Latin America, and Africa due to the economic reasons and easy use (Myra Colis INSIGHT a report in Ophthalmology World Report Dec 2008 p 13). Thus we are discussing the furtherance of IOL technology that has taken place in the last decade and the implications in the present day scenario with the availability of a whole range of speciality IOLs comprising toric, aspheric, and pahkic IOLs in the Indian market.

Ophthalmology in India during the last decade has been providing the end user the best in terms of surgical procedures or the materials used, be it in departments of Cornea, Glaucoma, Cataract or posterior segment. The procedures have become less invasive with modern anaesthetic modes like topical anaesthesia, minimalistic wounds and the best of implants which can be introduced through the smallest of wounds! This has translated into early rehabilitation of Vision, shorter healing time with least morbidity – thus the patient is able to undergo surgery as a day care procedure and also return to the daily chores as early as the 4th day as in case of microincision cataract surgery.

Earlier issues like dysphotopsia, edge glare, poor UCVA after surgery due to large wounds causing high surgically induced astigmatism (SIA), delay in wound healing, posterior capsular opacity and need for early YAG capsulotomy have been addressed with the refinement that has taken place in the IOL technology, hydrophobic acrylics with the better design of the optics – square edge and bioadhesive property prevents lens epithelial cell migration and PCO formation. Hydrophylic IOLs due to its compliance can get compressed through microincisions as small as 1.7 mm. The recent market entrants amongst the implants being IOLs that can correct pre existing refractive errors – like high myopia or hypermetropia along with astigmatism (toric IOLs), And the accommodative and multifocal IOLs (multifocal torics) which afford both distance and near vision correction. Thus cataract surgery which was earlier a vision restoring surgery has improved into a refractive surgery as well because of the refinements that have taken place in the incision size, placement of incisions and the best of modifications on the IOL optic.

Sensar: a 3 piece foldable IOL hydrophobic acrylic manufactured by AMO, this was the first model in which the edge glare was corrected with a slanting edge design which helps to dispel the light incident on the optic edge and this also had a 360 degree square edge design. The material had some element of bioadhesive property and thus adding to the factors preventing an early PCO formation. This design is best for implanting the IOL in the sulcus where the PC support is very poor, that an in the bag implantation is impossible. The Sensar 1 is a single piece model of the same lens which came out a year back in India.
Acrysof: The first model was a 3-piece foldable hydrophobic acrylic lens which was brought out by ALCON—holder folder system of IOL implantation was in vogue initially, but later injector system came into being. This implant too has a square edge design with good bioadhesive nature allowing the optic to stick to the posterior capsule and the anterior capsule rim of the rhexis thus preventing PCO formation. Soon the single piece acrysof came into the market which has a very predictable unfolding property which allows these IOLs to be easily implanted in the bag despite a PC rupture.

Aspheric IOLs
Spherical aberration is a symmetrical fourth-order aberration. It is a key contributor to the deterioration of retinal image quality as a result of peripheral rays being focused anteriorly to refracted paraxial rays of light. Corneal surface analysis confirms that the prolate corneas of both young and cataract-aged patients have, on average, positive spherical aberration. In youth, the generally negative spherical aberration of the crystalline lens largely neutralizes the average positive spherical aberration of the prolate cornea and thus results in an optimized retinal image.

As the eye ages, it loses this cornea/lens coupling. The crystalline lens grows, becomes rounder, and therefore develops positive spherical aberration itself, which adds to rather than offsets the average positive corneal spherical aberration. Similarly, conventional spherical IOLs, with their equibiconvex or convex-plano design, augment rather than offset positive corneal spherical aberration. Their implantation results in suboptimal visual quality due to increased spherical aberrations with poor point spread and modulation transfer functions (MTFs). The goal of aspheric IOLs is to minimize the aforementioned spherical aberrations and optimize image quality and contrast, while minimizing the induction of asymmetrical aberrations (eg, coma) and mitigating adverse effects on the depth of field and relative MTF. The decentration of an IOL with negative or positive spherical aberration may induce defocus, astigmatism, and coma, which would degrade the optical transfer function and retinal image quality.

AcrysofIQ: was one of the first aspheric IOLs to be introduced into the Indian market by 2005. With an asphericity of -0.1 micron and a yellow chromophore which is supposed to block the blue light thus aiding in preventing ARMD. The D cartridge allows injection through a 2.2 mm incision.

Tecnis1: (Tecnis ZA9003) is yet another aspheric single piece clear hydrophobic acrylic (AMO) with glistening free optic incorporating an asphericity of -0.27 micron, which has showed a lot of promise providing trouble free vision especially in mesopic conditions. The screw type of injector and cartridge allows injection through a 2.2 mm incision.

MIL: The Akreos Micro-Incision Lens is a single-piece, biconvex, hydrophilic acrylic IOL consisting of a central optic and four flexible haptics (Figure 1). The optic and haptics have square edges, and the haptics are angulated (approximately 11°), which helps to push the lens against the posterior capsule after its implantation in the capsular bag and thus increase its stability. The lens is available in three diameters—10.5, 10.7, and 11.0mm—depending on the power, ranging from 10.00 to 30.00D. Like other IOLs in the Akreos line, the Akreos Micro-Incision Lens has a continuous 360 degree barrier edge to limit PCO, which is designed for implantation in the capsular bag of the posterior chamber after phacoemulsification. The IOL is designed for insertion with a 1.8 Viscoglide cartridge and the Viscoject Lens Injection System.
Envista: is the latest entrant (2011) into the Indian market, a Bausch & Lomb product which provides zero asphericity—a single piece hydrophobic acrylic IOL which comes in a saline bath package thus claiming prevention of glistening on the optic surface. This is the only IOL material labeled as glistening-free by the USFDA. Lens is packaged in physiologic saline to establish equilibrium prior to implantation. This IOL can be implanted through a 1.8 mm incision using a disposable injector.

Besides the above mentioned IOLs there are a whole plethora of Indian manufacturers of IOLs who claim good design, equal or better optical qualities and affordable foldable and rigid implants suiting our community needs where the backlog of cataract also needs to be attended to.

TORIC IOLs:
IOL technology designs for monochromatic and chromatic aberration correction have undergone important advances, at the same time lower order aberrations need correction to provide the best optical quality and thus visual quality. Here the toricity is incorporated onto the posterior surface of the optic and thus preexisting corneal regular astigmatism ranging from 1 to 4.5 cylinder can be corrected. The lens material being hydrophobic acrylic, the bioadhesive nature and tachiness of the IOL helps maintain the stability of the implant in the capsule bag. Toric IOLs with Z-design haptics have good stability compared to C-loop or plate haptic designs. The anterior surface of the lens has markings which are aligned to the steepest meridian of the cornea. Toric IOLs have been made available in India by Alcon, AMO and Zeiss.

MULTIFOCAL IOLs
The past decade has seen many properties of physics being engaged involving light ray splitting and getting these to focus at two different focal lengths within the eye allowing the brain and the sensory optic pathways to preferentially pick up the near and far focal points thus enabling the patient to visualize objects that are distant and near without the help of spectacle correction post operative. These IOLs provide nearly 80 to 90 percent functional vision which comes with a few downsides and at the same time requires a period of adaptation from the patients part to imbibe the new visual faculty that they have acquired after bilateral implantation of these IOLs. The intermediate vision though provided by these implants, is not as sharp as the images formed for distance or near.

The two major principles incorporated into multifocal IOLs were based on refractive and diffractive theories. Amongst which the former involved 5 (as in the FDA approved silicon AMO Array lens – SA40N) or less number of zones in the anterior optic surface of the lens which could alternately focus either for distance or near. E.g. zone 1, 3 and 5 for distance dominant whereas 2 and 4 for near dominant or vice versa. The 5 zone lens provided varying optical powers such that light distribution with a typical pupil size is approximately 50% for distance 37% for near and 15% for intermediate vision. But these lenses when implanted were met with high level of disturbances as complained by the patients regarding the glare, halos, ghost images, poor contrast sensitivity, difficulty in colour hue differentiation. The Array lens had a near addition of 3.5 at the IOL plane and 2.1 D at the spectacle plane. This lens is pupil dependent (ideal size – about 3-3.5mm). The average pupil size in Indian eyes being
small aggravated with age, these lenses did not suit Indian eyes as reported in the study by SenH.N et all. Though the diffractive MF IOLs too had the same issues to a lesser extend the former technology has taken a rebuttal from the feedback that has been collected from the patients. Considering the advantages provided by each of these optical principles – a combination of these have been also introduced in a few of the present day MF IOL designs. In diffractive MFs each diffractive ring splits the light into half and the rays that split are brought to focus at two points – near and distance and the brain adapts to perceive the distant foci or the near by selectively switching from one to another as per the requirement. The latest generation diffractive IOLs (Tecnis 1 &ReSTOR) offer excellent near and distance as well as good reading speed. As these are pupil independent, patients experience fewer night vision disturbances. However, there is a gap in intermediate vision as well as a loss of transmitted light and thereby a loss in contrast sensitivity with these lenses. The limitations of multifocals mentioned earlier is seen to be overcome to a large extend by encouraging patients to undergo bilateral implantation, because of “a bilateral summation” effect. Lately the toricmultifocals have entered the market thus allowing surgeons to implant these implants in eyes with pre existing astigmatism between 1 to 3 cylinder caused at the corneal plane. PiyushKapur et al DOS times Vol 12 No.7 Jan 2007 p.572-579

The most popular of the multifocals being:

Rezoom :this is a foldable acylic MF IOL from AMO,here the design in the former model Array was modified by expanding the first and third zones for distance such that 60% of incoming light is for distance and 40% for near and intermediate distances. The near add was increased. Aspheric transition between the 5 ones provides a better intermediate vision and also reduces glare and halos. These IOLs are pupil dependent and near vision is not as strong with these lenses as with some other technologies. They are ideal for light to moderate readers who drive mostly during the day.

ReSTOR (SN6AD1&SA6AD3) these are diffractive – refractive multifocals where the central 3.6 to 4mm of the optic is rendered diffractive by a technology called apodisation on the anterior surface of the optic – progressively decreasing heights of steps (1.3 – 0.2 microns) of diffractive rings from center to periphery in the zone mentioned and beyond that the optic is refractive in nature thereby decreasing the night glare and halos in mesopic vision and also contributing to distant vision. They come on the same platform as the acrysof IQ thus aspheric and can be implanted through a 2.2 mm incision. These come in three different near vision adds affording +4, +3 or a +2.5 add at the lenticular plane. The latter provides good intermediate vision compared to the other two. Toric MFs have been available during the past 2 years.
Tecnismultifocals – ZM001 (Advanced Medical Optics, Inc., Santa Ana, DA) represents the first IOL that has a wavefront designed, modified prolate, anterior surface optic that neutralizes the positive spherical aberration of the human cornea. Its design is based on the average corneal-surface wavefront-derived spherical aberration in a group of patients, and the optic neutralizes this aberration. This diffractive multifocal IOL has 32 concentric rings with equal step heights of 0.25 microns - all through to the periphery on the posterior surface of the optic and the advantage claimed by the manufacture being that even during night time the reading is better (acuity and speed) even in dim light, again supported by a prospective study conducted at Augenklinik, Bad Hersfeld, and Gutenberg University, Mainz, Germany which compared the performance with 3 types of MF IOLs under different lighting conditions based on reading acuity and reading speed tests, where they implanted the Array MF, Tecnis, and RESTOR. The near vision addition at the lens plane is +3.75 D. This IOL can pass through the 2.2 mm incision making use of the screw type of injection system.

Acri.LISA366D marketed by Zeiss is a bifocal refractive-diffractive aspheric with 4 point in the bag fixation as these are plate haptic IOLs made of hydrophilic material with hydrophobic surface and these come with disposable injectors which can introduce the IOL through 1.8 mm MICS.SMP-Technology (smooth micro phase technology) is a worldwide unique patented technique to create a lens surface. The lens surface does not exhibit any square edges or right angles. AT.LISA – has a combination of diffractive and refractive optic Refractive zones, which are designed so that they also have a diffractive function. At the same time there is no topographical structure (e.g. steps) on the lens surface thereby refractive and interference constraints are simultaneously fulfilled.

Total diameter of the IOL is 11.0 mm, the optic being 6 mm with square edge, the refractive distance focus with 65 % light intensity and the diffractive near focus with 35% light intensity. It offers a +3.75 D power addition for near at the lens plane. The toric form of the lens is also available in the Indian market for the past 1 year.

Accommodative IOLs: in an attempt to replicate the human crystalline lens there have been various attempts to design implants which would change configuration or shape once it is implanted into the capsule bag taking advantage of the residual ciliary muscle action, the anterior vitreous phase push and the dynamic nature of the implant as such – on one side there are the IOL optics which shift to and fro on hinges and yet others which are made of gels which shift in and out of chambers thus changing the shape of the implant and thereby creating an increment in power.

CrystalensHD: is the only accommodative IOL in the Indian market which increases the depth of field and creates a central power gradient affording a +1.5 to 2 add. the former is by induction of spherical aberration during the accommodating process. Vector forces are transferred from the ciliary body through the lens haptics. Then the lens vaults forward and arches, the change in shape creates spherical aberrations which in turn creates depth of field. Though it doesn’t provide the near vision add that the diffractive MF IOLs provide, it doesn’t cause the visual disturbances and the drop in quality of vision in extremes of light exposure and even in dim light. These implants provide clear distant vision as well as intermediate. Reading may still require spectacle correction.

SULCOFLEX: is a product of Reiner – a sulcus fixated IOL used for implantation in the ciliary sulcus of pseudophakic eyes as piggyback lenses.

These single-piece hydrophilic acrylic IOLs can be inserted...
through a 3-mm incision. The 6.5-mm optic and haptic edges are round. The haptics are angulated and have an undulated design to preclude the IOL’s rotation.

Spherical, toric, multifocal and aspheric versions available

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Dr. Jacob, after finishing his training from RIO Trivandrum and Aravind Eye Hospital, is now the senior consultant & CMO, Vasan Eyecare, Kochi.
Options in Astigmatism Management in Cataract Surgery

Approximately 70% of the general cataract population has at least 1.00 D of astigmatism, and approximately 33% of patients undergoing cataract surgery are eligible for treatment of preexisting astigmatism. The main parameters to be considered before astigmatism correction include the location of the cylinder, the patient’s age, and the status of the fellow eye. Most patients with age-related cataract have against-the-rule astigmatism. Residual with-the-rule astigmatism may favor better distance UCVA, and residual against-the-rule cylinder may improve near UCVA.

The surgical correction of astigmatism is becoming increasingly more important as we strive to improve visual results in our cataract patients. Many times a patient will return post-cataract surgery unhappy that they need to use bifocals to see clearly. “But my friend had cataract surgery and only needs glasses for reading,” is often heard. Certainly a pre-operative discussion and education of astigmatism with the patient is helpful, but being able to appropriately correct astigmatism is of equal importance.

PREOPERATIVE PREPARATION

Whichever method is selected, it is extremely important to establish a surgical plan for each patient. This entails obtaining accurate measurements from multiple sources preoperatively. Old refractions may help to confirm preexisting corneal astigmatism and keratometry and corneal topography measurements should be consistent with respect to the magnitude and orientation of the astigmatism.

Keratometry- I like to obtain keratometry data with manual and auto K readings, the measurements should be in agreement. Videokeratography is the probably is among the most appropriate method of measuring astigmatism and should be done in patients who are likely have surgical correction of the astigmatism. Sources of error include dry eye, contact lens warpage, and ectatic corneal disease.

Surgically Induced Astigmatism (SIA) You should know how much surgically induced astigmatism your wound causes, ideally a review of your previous at least 50 cases would give you the answer. Once all the numbers have been collected, the desired correction is calculated using various nomograms or online calculators, which exist for both LRIs (www.lricalculator.com, maintained by AMO) and Toric IOLs

Marking the Patient It is essential to mark the patient’s eye in an upright position prior to surgery because the eyes can cyclotort when the patient reclines to the supine position. This allows correct identification of the steep corneal meridian and ensures proper alignment of the astigmatic correction. Numerous markers and gauges are available for this (Figure 1 A). I simply use a marking pen to place dots at the limbus at the 3, 6, and 9 o’clock positions, and then use a Mendez degree gauge intraoperative (Figure 1 B). There sophisticated devices that can be incorporated into the microscope which enables the surgeon to instantly measure intraoperative refraction and thereby refine the results by adjusting the astigmatic correction if necessary.

Management of astigmatism in these patients can be broadly divided into intraoperative or postoperative methods.

A. Intraoperative
1. Clear Corneal Incision
2. Incisional corneal techniques such as limbal or corneal relaxing incisions (LRIs/CRIs) or traditional astigmatic keratotomy
3. Lens based methods, namely
   - Toric IOLs for primary aphakia
   - Sulcoflex lenses for residual astigmatism

B. Post Operative
1. Laser vision correction or
2. One of the aforementioned incisional techniques like LRIs/CRIs

1. Clear Corneal Incision on the steep meridian

Preoperative astigmatism can be controlled and modified with incision parameters, including size, configuration and construction, location, and closure. Modification of the size and location of the incision is the most straightforward method to correct mild to moderate amounts of astigmatism. The technique is associated with predictable outcomes without the need for special instrumentation and is my preferred method for corrections up to 0.75 D of astigmatism. Some surgeons even suggest putting opposite paired clear corneal incisions (OCCI) for higher amounts of astigmatism. A good general rule is that a 3.2-mm clear corneal phaco incision results in surgically induced astigmatism of 0.50 D (95% confidence interval of 0.40 to 0.60 D). For patients receiving
monofocal IOLs with less than 0.50 D of preexisting corneal astigmatism, an incision on the steep axis is usually sufficient. The amount of astigmatism corrected depending upon the type of incision:
Hinged > Triplanar > Biplantar > Uniplantar

The amount of astigmatism corrected depending upon the site of incision:
Superior > Oblique > Temporal

Some right-handed surgeons prefer to make superotemporal incisions in right eyes and superonasal incisions in left eyes, you can use the online toric IOL calculator which includes the SIA vector along the corneal astigmatism to give the final anticipated astigmatism which can be then used for doing the LRI if the residual is clinically significant. There are of course surgeon’s factors like movement around the surgical table, which often produces awkward hand positions. Additionally, the surgeon must consider ergonomic issues such as wrist support, legroom beneath the operating table, and the position of the operating microscope when considering on-axis phacoemulsification.

2. Limbal Relaxing Incisions and Corneal Relaxing Incisions

Limbal Relaxing Incisions (LRI) is based on Gauss’s law of elastic domes – “for every change in curvature in one meridian there is an equal and opposite change 90 degrees away”. This phenomenon of corneal behaviour is known as the coupling effect.

Corneal coupling is ratio of magnitude of corneal flattening or steepening in axis of surgery divided by magnitude of flattening or steepening 90 degrees away.

Coupling ratio = Amount of flattening in the incision meridian
Induced steepening in the opposite meridian

If Coupling ratio = 1, indicates that the spherical equivalent is unchanged.
LRI involves making a pair of incisions at the corneal limbus just anterior to the vascular arcade. By adjusting the length, depth, and location of the arcuate incision, one can induce changes in the corneal astigmatism. Specifically, changes in corneal astigmatism are achieved by flattening the steep corneal meridian with a simultaneous increase in corneal curvature in the flat meridian. The effect of the foregoing is to alleviate the corneal astigmatism while keeping the average corneal power untouched (Figure 2 C, D).

Furthermore, they are contraindicated in ectatic corneal disorders since the results are unpredictable and they may further destabilize the cornea.

3. Toric Intra Ocular Lens- Monofocal Toric and Multifocal Toric

The concept of neutralizing congenital corneal astigmatism using a rigid PMMA Toric intraocular lens was first developed by Shimizu in 1992, the same year in which Grabow and Shepherd implanted the first foldable silicone toric plate haptic IOL.

Toric IOLs have the advantage of being precise, predictable, and require no new skills on the part of the surgeon; however, the technology is more costly. An infrequent complication is misalignment or rotation of the IOL, which results in a 3.3% loss of effect per 1 degree of rotation from the correct axis.

There are multiple available lenses for correcting the corneal...
astigmatism which are mostly in the plate haptic IOL or the 1-piece loop haptic IOL. The power of the astigmatism mentioned on the IOL and the amount it corrects at the corneal plane less. This traditional loop haptic design has fewer tendencies to rotate (average of < 4 degrees in the FDA trial).

**Contraindications for implanting Toric IOLs**
- Irregular corneal astigmatism.
- Any condition which could lead to intra or postoperative misalignment of the axis or inadequate centering of the optics such as: Evidence or suspicion of zonular instability. Crystalline lens subluxation. Sulcus implant (if specific adequate models of toric IOLs for sulcus implantation are not available).
- Important ectopic pupil (pupiloplasty should be performed intraoperatively).
- Refractive but not corneal astigmatism (lens induced preoperative cylinder).

- Extracapsular extraction or SICS surgical techniques causing unpredictable surgical induced astigmatism.

**SURGICAL TECHNIQUE**
All cataract surgeons will quickly become comfortable with implanting the Acrysof Toric IOL. Only minor modifications to a surgeon’s routine cataract procedure are required for success. Areas where modifications are necessary include (1) the IOL calculation for cylindrical power and axis of placement, (2) the marking of the eye, and (3) the on-axis placement of the IOL.

**Power Calculation**
Selecting the appropriate lens model for a particular patient begins with determining the required spherical IOL power. Surgeons should use the method and formulae they prefer for conventional monofocal IOLs to determine each patient’s spherical power requirements. They should then use the online Toric IOL calculators (Figure 5) to assist in the selection of the correct model and optimal axis location within.

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**Figure 5 - The online Toric IOL calculator from AMO for Tecnis 1 toric IOL which takes into account the SIA of the surgeon and site of incision**
the capsular bag. The calculators are unique in that they compensate for expected surgically induced astigmatism in the calculation of both the IOL’s power and the axis.

**Marking and Surgery**
Marking step should be done with the patient sitting upright to avoid the effect of cyclorotation when the patient moves to a supine position for the cataract procedure. The capsulorrhexis should be smaller in size than the size of the IOL optic, should be well centered and should cover the optic equally on all side so that IOL misalignment is reduced. If the capsulorrhexis is eccentric or irregular, it can cause decentration and misalignment of the IOL. It is always better to err on the side of a smaller CCC. An ideal size would be about 4.5-5.5 mm. Cohesive viscoelastics should be used for IOL implantation as they can be removed completely from the capsular bag at the end of surgery, thus preventing rotation of the IOL.

**Aligning the IOL With the Axis**
Precisely aligning the IOL with the predetermined axis of placement involves gross alignment, viscoelastic removal, and final alignment. The first occurs after the IOL’s implantation but before it has unfolded fully in the capsular bag. The IOL should be rotated to a point that is 15° to 20° counterclockwise of the final axis’ location. The surgeon must ensure that the IOL does not rotate beyond the final axis during the viscoelastic’s removal. It is important to remove all of the viscoelastic, including on the posterior side of the lens, because remnants could cause rotation of the IOL postoperatively.

There are various techniques and instrumentation that a surgeon may use to achieve precise on-axis alignment of the IOL. My preferred technique (Figure 6 A-D) is to use an I/A tip and a Sinskeyhook through the sideport incision to achieve gross alignment. I then use the Sinskey hook to hold the implant in place while I remove the viscoelastic with the silicone I/A tip. Then, I use the Sinskey hook once again to carefully nudge the IOL into the final alignment with the axis. Regardless of which surgical technique a surgeon chooses to employ, the precise alignment of the IOL is critical to achieving excellent outcomes with the Toric IOL. The advantages of the plate haptic IOLs from Zeiss include the BiToric Design hence can be implanted either way and that it can be rotated clockwise and counterclockwise unlike the C or J Looped single piece lenses.

**MODELS OF PSEUDOPHAKIC TORIC IOLS**

There are two models of toric IOLs with fixed toricity available for the surgeon on the market. However, this obviously limits the accuracy for correcting, with precision, the huge amount of possible spherocylindrical combinations.

We have been able to use TORIC IOLs in a patient with post LASIK ectasia and post Keratoplasty patients cataract with excellent results (Figure 7 A-E).

**Figure 6** Shows the keys aspects of the Toric IOL. Fig 6 B-D The toric IOL is held with the sinkeys/chopper securely in correct alignment while the irrigation and aspiration probe is used to remove viscoelastic from behind the IOL; the toric IOL is then properly aligned with the 90° marking at the limbus. Note that the capsulorrhexis is well-sized and completely overlaps the optic edge, further adding to stability of the lens. Post Operative picture of the patient shows a perfectly aligned lens with UCVA of 6/6.

**Figure 7 A, B** Pre and postoperative slit lamp photos of a 47 yrs old patient with Post LASIK ectasia and cataract(Preop vision 6/60).Inset shows the LASIK flap edge (arrowheads). Post Op UCVA 6/9. Fig 7 C-E show the topography, posterior float and the pachymetry map of the patient.
**Tecnis T (Abbot Medical Optics, US)**

This lens uses the Tecnis 1 platform for toric IOLs which has the following advantages:
- Tri-Fix 3-Point fixation designed for excellent stability
- The precision and predictability of the proven TECNIS® IOL platform
- Sharper vision due to spherical aberration correction
- Proprietary hydrophobic acrylic material for reduced chromatic aberration

Tecnis- Thas 4 models ZCT series which corrects Cylinders from 1 D to 4 D at the IOL plane (0.69 D to 2.74 D) at the corneal plane (Figure 5)

**Acrysof Toric IOL (Alcon Laboratories Inc., Fort Worth, Texas)**

The Acrysof Toric lens is composed of an acrylic polymer that has UV and blue-light absorbers and is built on the same platform as the Acrysof Single-Piece monofocal models SA60AT and SN60AT IOLs (Alcon Laboratories Inc.) and can be folded or injected to be inserted inside the eye.

Currently, the IOL is available in powers of +1.50D (SN60T3), +2.25D (SN60T4) and +3.00D (SN60T5), which are supposed to correct 1.03, 1.55 and 2.06 dioptres respectively at the corneal plane. Greater magnitude of astigmatism can be corrected with SN60T6, SN60T7, SN60T8 and SN60T9 (which would correct 3.75, 4.5, 5.25 and 6 D at the plane of the IOL and thus 2.57, 3.08, 3.60 and 4.11 respectively at the corneal plane). The Acrysof IQ Toric IOL has recently been designed with an aspherical profile. Rotational stability has been demonstrated for the different models of the Acrysof Toric IOL with the mean IOL misalignment being estimated at 2.5 ± 2.1 degrees after implanting SN60T3; 3.5 ± 2.3 degrees for SN60T4; and 4.1 ± 3.5 degrees for SN60T5.

Staar Toric IOL STAAR AA4203TF (StaarSurgical, Monrovia, California)

Not commonly available in India

**Toric Customized IOLs**

These toric IOLs are an alternative for the correction of high corneal astigmatism. Most of them offer both standard stocks for usual spherocylindrical combinations and customized fabrications for special ones.

**Acri.Comfort 646TLC, Acri.LISAtoric 466TD, AT Torbi® 709M (Carl Zeiss Meditec)**

The Acri.Comfort 646TLC is an asphericalbitoric IOL. It was the first designed to be inserted through incisions smaller than 2 mm and so is thought to minimize the surgically induced astigmatism (SIA).

Its technical features are:
- Hydrophilic acrylic polymer containing 25% water with Hydrophobic surface
- Plate design with square edges in haptic and optic.
- Total diameter 11 mm, Optic diameter 6.0 mm
- A-constant of 118.0
- Spherical powers available from -10.0 to +32.0D and a cylinder powers from +1.00 to +12D (cylinder values outside the standard range are manufactured individually).

AT TORBI® 709M is intended for the correction of astigmatism. Its cylinder refraction is symmetrically distributed amongst the front and the back surface of the IOL. Due to the reduction of the difference of the two radii, imaging quality is said to surpass traditional monotoric intraocular lenses.

Further the online Toric IOL calculator is uses a different software than others in the market.

**Rayner T-flex toric 573T and 623T**

This British company offers a wide range of toric IOL models with different features:
- Rayacryl hydrophilic acrylic co-polymer.
- One piece injectable design with C-haptics.
- Square edge on the posterior side of the lens for avoiding posterior capsule opacities.
- Customized toric power implemented on the anterior surface of the optic and radial marks along the steepest axis.
- Designed to provide torsional stability thanks to an “anti-vaulting” haptic system (AVH technology)
- The model 623T is especially suitable for myopic eyes and designed for low and medium power lenses. The model 573T on the other hand, is used for normal and hyperopic eyes and for higher power lenses.

MicroSiltoric IOL MS6116TU and the MS6116T-Y (HumanOptics AG) and LENTIS Unico (LU, Oculentis) are not discussed here since they are not available in India.

**Multifocal TORIC IOLs**

Standard multifocal IOLs are often contraindicated for patients with >1.5D of corneal astigmatism. The combination of multifocal and toric optical components in multifocal IOLs allows the potential benefit of reduced spectacle dependence to be extended to patients with significant corneal astigmatism.

Some lenses are based on a multi-zoned refractive aspheric optic technology, with either 4 or 5 annular zones (depending on IOL base power) providing +3.0D or +4.0D of additional refractive power at the IOL plane (equivalent to +2.25D or +3.0D at the spectacle plane).
Some diffractive IOLs are associated with a significant loss of light transmission (typically 18 – 20%) resulting in a corresponding reduction in contrast sensitivity.

The commonly available models are RayneM-flex® Multifocal IOLs (588F and 638F) AcrySof® IQ ReSTOR® Multifocal Toric IOL (not approved in the U.S. Market) Acri.LISAtoric466TD.

We have been able to use these lenses in special post refractive surgery cataract situations with excellent results (Figure 8 A-D)

4.Sulcoflex IOLs

The new sulcoflex intraocular lens (IOL), which has been designed for sulcus-implantation in the pseudophakic eye ("piggy back"), is safe and well-tolerated, according to Michael Amon, MD from the University of Vienna Medical School, Austria. Since surgeons often want to avoid IOL exchange at all costs, hence the implantation of a pseudophakic lens is appealing.

RaynerSulcoflextoric 653T (Piggy back sulcus lens)

Conceived for correcting post-surgical or residual ametropia, Rayner has designed one of its Sulcoflexpseudophakic supplementary IOLs for correcting refractive cylinders using piggy-back techniques.

The lens offers the following features:

- One piece foldable design with modified undulated C haptics
- Large optical zone designed to reduce the contact between lenses with round optic edge to decrease disphotopsia.
- Customized cylinder range of +1.00D to +6.00 D in 0.5D increments.

Complications Management

Complications with the Toric IOLs are rare. One potential problem is that the implant may rotate beyond the desired axis of alignment during the removal of viscoelastic. In such cases, the surgeon can reinflate the capsular bag with additional viscoelastic, reposition the implant to achieve gross alignment, and then proceed through the remainder of the procedure to attain final alignment. It is important to note that the lens cannot be easily rotated counterclockwise without the risk of damaging or ripping the capsular bag.

In contrast to normal methods for the correction of astigmatism during cataract surgery, such as limbal relaxing incisions in which many variables are involved in the outcome and are not precise enough, toric IOL implantation offers a predictable, stable and safer way to reduce pre-existing astigmatism. Combined with small incisions, cataract surgery techniques can provide a greater opportunity to correct cylindrical errors intraoperatively, thus improving visual quality leading to spectacle independence.
Suggested indications include correction of postoperative ametropia, astigmatism (toric IOL), paediatric cataract and aphakia as possible indications for the lens. Recent studies indicate that postoperative refraction is stable with good predictability and rotation stability.

**Sulcoflex® Multifocal (653F)**
This lens give the option of multifocality along with correcting any residual ametropia. These are available from -9.50 D to +5.5 D in 0.5D increments with +3.5D add (equivalent to +3.0D at the spectacle plane).

**4. Laser Vision Correction (LVC)**
Originally termed ‘Biopics’, the technique involved raising the Lasik flap preoperatively, performing the phacoemulsification with IOL implantation and then treating the residual refractive error about 4 weeks postoperatively by lifting the Lasik flap and performing the LVC.
I reserve laser vision correction for patients following premium IOL implantation who need further refining of the refractive error after surgery; however a surface ablation suffices to correct these errors. Laser vision correction, if selected to correct post-operative astigmatism, should be performed after the cataract wounds have healed and the refraction has stabilized.

**Conclusions**
Refinement of the refractive outcome is one of the most important challenges faced by cataract surgeons. Along with spherical error, preexisting astigmatism may now be safely and effectively reduced at the time of cataract surgery. The on-axis approach appears simple; however, it presents logistical challenges. Toric IOLs, which have been shown to be safe and accurate for treating astigmatism during cataract surgery for toric IOLs to be safe, effective and convenient though rotational stability must be enduring. Newer developments like sulcoflex lenses are used for residual errors after pseudophakia. Laser vision correction is accurate and safe but may be inconvenient and costly for patients.
References:


Dr. Anand Parthasarathy, is presently the Senior Consultant, Cataract, Cornea and Refractive Surgery & the Head, Corneal Services Vasan Eye Care Hospital Group, Chennai
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Management of Posterior Polar cataract

Introduction
The posterior polar cataract is a clinically distinctive cataract that consists of a white, well-demarcated, disk-shaped opacity with typical onion peel appearance located on the central posterior capsule. They are generally bilateral without any sexual predilection and are relatively uncommon. Frequently this condition does not become problematic until the patient is entering young adulthood and become troubled by glare and other disturbing visual images especially when driving at night. During diagnosis it is confused with posterior subcapsular cataract. The indication for surgery consists of visually significant cataract impairing the patients quality of life and activities of daily living. PPCs are both a diagnostic and surgical challenge.

Posterior polar cataract presents a special challenge to the surgeon because of its predisposition to posterior capsular dehiscence during surgery. The defect in the posterior capsule may cause rupture of the capsule during hydrodissection, nucleus removal, posterior capsule polishing, or the rupture may occur spontaneously.

Morphology
Posterior polar cataracts are associated with remnants of the hyaloid system or the tunica vasculosa lentis. These cataracts may also occur without any relation to hyaloid remnants and appear as circular or rosette shaped opacities; they are hereditary and usually transmitted as a dominant trait. The gene for this has been mapped to chromosome 16q22.2

Classification of posterior polar cataracts
Type 1 Opacity associated with posterior subcapsular cataract.
Type 2 Opacity with ringed appearance like an onion.
Type 3 Opacity with dense white spots at the edge often associated with thin or absent posterior capsule.
Type 4 Combination of the above 3 types with nuclear sclerosis.

Though no studies are available, it is our experience that PC rupture is noticed in type 3 & 4 while rarely noted in type 1.

Incidence of PC rupture
Various authors have reported an incidence of posterior capsular rupture from 7.1% to 36%.
Osher et al. report on 26% incidence of posterior capsular rupture during surgery in eyes with posterior polar cataract, Vasavada and Singh report 36%, Lee and Lee report 11%, Stanić et al. report 28.5% and Hayashi et al. report 7.1%.

Various strategies have been recommended to prevent posterior capsular rupture in posterior polar cataracts. Osher et al. recommended using slow-motion phacoemulsification with a low aspiration flow rate, a low level of vacuum, and infusion pressure. Fine et al. avoided overly pressurizing the anterior chamber with viscodissection to mobilize the epinucleus and cortex, Allen and Wood performed viscodissection, and Lee and Lee preferred a lambda technique with dry aspiration while Vasavada favors inside-out delineation. Modern instrumentation, refined surgical strategies, a better understanding of phacodynamics, and cumulative surgical experience, has reduced the incidence of posterior capsular rupture to 8%.

Summing up the strategy revolves around the following steps:
1. Avoiding over pressuring the chamber
2. Closed chamber Procedure
3. Adequate capsulorhexis – 5mm, so that a sulcus positioning of the lens can be attempted with optic capture in case of rupture with vitreous loss
4. No Hydrodissection
5. Slow motion Phacoemulsification – no jerky movements
6. Prevent Fluctuation of the chamber – no sudden shallowing
7. Frequent injection of viscodispersive viscoelastic while withdrawing probe from AC

Counselling
Surgical planning starts with extensive counselling the patient should be informed of the possibility of the nucleus dropping intraoperatively due to a posterior capsular rupture, a relatively long operative time, secondary posterior segment intervention, and a delayed visual recovery. In addition, the surgeon should discuss Nd:YAG capsulotomy.
for residual plaque and emphasize the possibility of pre-existing amblyopia, especially in cases of unilateral posterior polar cataract.

**Anesthesia**

With increasing experience, one may use topical anesthesia in a selective manner. In case of topical anesthesia extra caution is necessary as the patient is able to move and squeeze his eye increasing the risk of forward bulging of the iris lens diaphragm. It is important to have a standby anesthetist, in case the patient requires any additional sedation.

**Capsulorhexis**

An attempt is made to make the continuous curvilinear capsulorhexis diameter no larger than 5.0 mm so that if the posterior capsule is compromised during the procedure, an intraocular lens (IOL) can be implanted in the ciliary sulcus with capture of the optic though the capsulorhexis. This provides IOL stability and centration in the short and long term.

**Hydroprocedures**

Hydrodissection can lead to hydraulic rupture and is avoided. It is logical instead to perform hydrodelineation to create a mechanical cushion of epinucleus. Hydrodelineation is performed with a small amount of fluid. Approximately < 0.1 cc of a balanced salt solution is used for hydrodelineation. The nucleus is neither rotated nor rocked. The soft cushion of the epinucleus against the posterior capsule protects the posterior capsule during this maneuver. In case of nuclear sclerosis it is better to use Vasavada inside out delineation which involves creation of a small crater in the centre before hydrodelineation.

**Nucleus removal**

It is advisable to avoid rotating the nucleus, because this maneuver can rupture the posterior capsule. All the techniques are geared toward facilitating the removal of the nucleus while it is cushioned by the epinucleus. For nuclear sclerosis greater than +2, a combination technique of slow motion phacoemulsification and lateral separation is used. Optimum power setting is achieved when minimal movement of the nucleus occurs while sculpting. The final aim is to create multiple fragments with least movement of the nucleus & then removed.

For less dense nuclei, the entire nucleus can be emulsified within the epinuclear shell or a plain aspiration would suffice. Traction of posterior lenticular fibers and posterior polar opacity during surgery are sufficient to break the weak posterior capsule. Thus, the slow-motion technique reduces turbulence in the anterior chamber. Similarly, injecting viscoelastic prior to removing the instrument prevents the anterior chamber from collapsing and the posterior chamber from bulging forward.

**Epinuclear removal**

Epinuclear removal is done from periphery to centre stopping short of the central disc which is removed at last. Various authors have suggested performing viscodissection of the epinucleus by injecting viscoelastic (Healon5 or Healon4 under the capsular edge to mobilize the rim of the epinucleus. The surgeon then removes this rim with a coaxial I/A handpiece. Alternatively one may perform manual dry aspiration with a Simcoe cannula.

**Cortical removal**

An efficient way of cortex removal is to occlude it in the fornix and, as vacuum rises, pull it tangentially to detach it from the anterior capsule and finally aspirate it. Flower petal peeling – where in the cortex is pulled to the centre from multiple places, but stops short of the central disc which is aspirated in the end is the preferred technique. Alternatively dry aspiration /simcoe assisted manual aspiration has been suggested by Lee et al. There is also no “after aspiration” effect which in the automated unit can continue for several milliseconds even after the foot has been taken off the pedal. The disadvantage of manual aspiration is the increased surgical time.

Do not polish the capsule in case of residual plaque.

**Posterior capsular dehiscence**

If a defect is present in the posterior capsule, viscodispersive viscoelastic (Viscoat) is injected over the area of defect before withdrawing the phaco or I/A probe from the eye. If the vitreous face is intact, cortex is aspirated with dry I/A. A posterior capsulorhexis may be performed if the rupture is confined to a small central area. In the case of a vitreous disturbance a two port, limbal anterior vitrectomy is performed. Once the anterior chamber is free of vitreous, the remaining cortex is aspirated.

**IOL Implantation**

A single piece acrylic hydrophobic IOL is preferred choice for the simple reason as the implantation of the same is smooth & controlled. Also its slow unfolding time allows sufficient time for manipulation of the IOL. If the posterior capsular defect is larges – sulcus implantation of the IOL with optic capture can be done.

**Follow up.**

It is imperative to periodically evaluate these eyes for retinal break, cystoids macular edema, and raised IOP.
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Dr Elankumaran P completed his MD from the prestigious Dr RP Centre of ophthalmic Sciences, AIIMS, New Delhi & senior residency in cornea & refractive surgery. Currently he is Medical director of Navashakthi Nethralaya Pvt ltd . His areas of interest are cornea & refractive surgery.
Etiological diagnosis of Pediatric cataract

Introduction:
In India, childhood cataract accounts for 7.4 - 15.3% of childhood blindness and is the commonest preventable cause of childhood blindness 1,2,3. The population-based studies have estimated the prevalence of cataract in children between 1-15/10,000 children.4,5

By definition, congenital/infantile cataracts manifest either at birth or during first year of life. Developmental cataract manifests after age of one year.6

In this article, we would discuss about how to arrive at an etiological diagnosis when we see a child with cataract.

Embryology of human lens:
The morphology of congenital cataract is largely determined by the timing and nature of the insult that affects the embryogenesis of lens at different stages. So a quick revision of embryological development of human lens is helpful to understand the morphological types of congenital/developmental cataract.

The events can be summarized as follows:7,8,9
The developing lens is nourished by the tunica vasculosa lentis. By term birth, only wispy remnants of the pupillary membrane are left.

<table>
<thead>
<tr>
<th>Sr no</th>
<th>Event</th>
<th>Gestational age</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Formation of lens placode</td>
<td>Day 28</td>
<td>Surface ectodermal cells overlying the optic vesicle (which arises from developing forebrain) thicken to form lens placode (Figure 1b)</td>
</tr>
<tr>
<td>2</td>
<td>Formation of lens pit</td>
<td>Day 29</td>
<td>This is a central depression in the lens placode. (Figure 1c)</td>
</tr>
<tr>
<td>3</td>
<td>Formation of lens vesicle</td>
<td>Day 33</td>
<td>The central stalk connecting the lens pit to the surface ectoderm disappears and a sphere is formed consisting of a single layer of cuboidal cells encased within a basement membrane. This is called lens vesicle. (Figure 1d)</td>
</tr>
<tr>
<td>4</td>
<td>Formation of embryonic nucleus</td>
<td>Day 45</td>
<td>Cells from the posterior surface of the lens vesicle elongate to form the primary lens fibers obliterating the lumen of lens vesicle. These fibers ultimately form the embryonic nucleus. (Figure 1e)</td>
</tr>
<tr>
<td>5</td>
<td>Formation of fetal nucleus</td>
<td>Week 7</td>
<td>The anterior lens epithelial cells multiply and elongate forming the secondary lens fibers, which comprise the fetal nucleus.</td>
</tr>
<tr>
<td>6</td>
<td>Formation of sutures</td>
<td>Month 3</td>
<td>The interdigitation of the lens fibers creates the erect Y suture anteriorly and inverted Y suture posteriorly.</td>
</tr>
</tbody>
</table>

Table 1 summarizing various events in embryogenesis of human lens
Clinical approach to etiological diagnosis of cataract in a child:

History:
1. Antenatal history:
   a. History of any febrile illness with skin rash in mother may point towards an infective etiology like ToRCH group of infections.
   b. History of any drug intake, alcohol, tobacco intake
   c. History of exposure to ionizing radiation
2. Family history: History of any other family members with similar problem should be asked for. If possible, both parents and siblings should be examined under slit lamp with dilated pupil.

This is important because almost 30% of bilateral cataracts are hereditary in nature (Figure 2).

3. History of any eye injury: Especially for unilateral cataracts, careful history should be taken to rule out any possibility of eye injury. In bilateral cases, battered baby syndrome may be considered in appropriate circumstances. In this article, we will concentrate mostly on non-traumatic cataracts.

4. History of developmental delay may point towards metabolic disorder as etiology of cataract.

Systemic evaluation: When and how much?

<table>
<thead>
<tr>
<th>Sr no</th>
<th>Clinical signs and symptoms</th>
<th>Likely systemic disorder</th>
<th>Investigations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Hepatomegaly, failure to thrive, Jaundice, diarrhea, ‘oil droplet’ nuclear cataract</td>
<td>Galactosemia</td>
<td>Urine for reducing substances after milk feeding</td>
</tr>
<tr>
<td>2</td>
<td>Hypotonia, frontal bossing, chubby cheeks, metabolic acidosis, congenital glaucoma, mental retardation</td>
<td>Lowe’s syndrome</td>
<td>Urine for amino acids</td>
</tr>
<tr>
<td>3</td>
<td>Microphthalmos, microcephaly, congenital heart disease, deafness</td>
<td>Congenital rubella syndrome</td>
<td>ToRCH titers in serum</td>
</tr>
<tr>
<td>4</td>
<td>Polydypsia, polyphagia, polyurea</td>
<td>Type 1 DM (Figure 2)</td>
<td>FBS, PPBS</td>
</tr>
</tbody>
</table>

Table 2: summarizes clinical signs and symptoms of various systemic diseases associated with congenital / developmental cataract
Typical physical appearance in Down’s syndrome, Patau syndrome helps make quick diagnosis of the etiology of cataract in some patients. But, rather than searching for these diseases in those who have cataract, even more important is to screen those children for cataract, who are already known to have these diseases.12

Important etiological entities in congenital/developmental cataract:

1. Congenital rubella syndrome (CRS):
Although CRS has been eliminated from most of the developing world, it continues to be an important cause of blindness, deafness, congenital heart disease and mental retardation.13 Several hospital-based studies have shown 10–15% of congenital cataract in infants is due to maternal rubella in India.14,15,16 The importance of CRS lies in the fact that it is a preventable. The ophthalmic clinical signs include: microphthalmos, cloudy cornea, cataract (nuclear, membranous), iris hypoplasia, pupil rigidity (figure 3), salt and pepper retinopathy.17

Other systemic associations include microcephaly, mental retardation, low birth weight and hepatosplenomegaly.

2. Microphthalmos: 18,19
Microphthalmos is defined as a developmental ocular disorder in which the axial length (AL) is more than 2 standard deviations smaller than normal for that age group. At age less than 1 year, AL less than 19.2mm may be considered as microphthalmic (figure 5).18,19

When other major ocular malformations are absent, it is called simple microphthalmos, while in presence of associated abnormalities like unival coloboma, cataract, corneal opacity, persistent fetal vasculature, retinal dysplasia, it is called complex microphthalmos.

It can be unilateral or bilateral, sporadic or familial. It may also have significant systemic associations in the form of CHARGE syndrome. The acronym CHARGE stands for:
- C - Coloboma of the eye, central nervous system anomalies
- H - Heart defects
- A - Atresia of the choanae
- R - Retardation of growth and/or development
- G - Genital and/or urinary defects (Hypogonadism)
- E - Ear anomalies and/or deafness

2. Persistent fetal vasculature (PFV)9:
Earlier referred to as persistent hyperplastic primary vitreous (PHPV), this is basically a developmental abnormality of the primary vitreous and hyaloid vascular system where they fail to involute completely.

Key features of PFV include (figure 6):
- a. Unilateral in 90% cases
- b. Microphthalmos: 2/3rd of cases
- c. Retrolenticular fibrovascular tissue
- d. Cataract: Initially lens may be clear, in most of the cases it opacifies over time. Even when clear, the retrolenticular membrane is sufficiently opaque to obstruct visual axis.
- e. Elongated ciliary processes

Associated features include:
- f. Persistent pupillary membrane, iridohyaloid blood...
vessels
g. Persistence of the posterior fetal fibrovascular sheath of the lens, a Mittendorf dot
h. Persistent vasa hyaloidea propria and hyaloid artery
i. Bergmeister’s papilla
j. Congenital non-attachment of the retina
k. Macular abnormalities
l. Optic nerve hypoplasia and dysplasia

3. Peter’s anomaly: This rare anomaly consists of congenital central corneal opacity with underlying defects of the posterior corneal stroma, Descemet’s membrane and endothelium. It is usually bilateral but assymetrical. There may be adhesions between iris and cornea, keratolenticular contact and cataract.

5. Aniridia: There is bilateral absence of iris tissue either partly or completely. There may be associated corneal neovascularization, scarring, foveal hypoplasia and systagmus. While operating for cataract, guarded visual prognosis in view of other factors like possible foveal hypoplasia, nystagmus should be considered.

How does cataract morphology aid in arriving etiological diagnosis?
A thorough eye examination with dilated pupil is necessary to identify morphological type of cataract. Following morphological types have been described:

<table>
<thead>
<tr>
<th>Sr no</th>
<th>Morphological type</th>
<th>Morphological description</th>
<th>Possible etiology/association</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Total</td>
<td>Opacification of all lens fibers</td>
<td>Familial, Down’s syndrome, CRS, acute metabolic cataracts</td>
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<tr>
<td>2</td>
<td>Membranous cataracts</td>
<td>Represent varying stages of reabsorption of the lens, leaving behind a disk anterior and posterior capsules fuse together</td>
<td>CRS, PFV, Aniridia, Lowe’s syndrome, Hallermann-Streiff syndrome, Pierre Robbin syndrome</td>
</tr>
<tr>
<td>3</td>
<td>Zonular/Lamellar (Figure 5)</td>
<td>Bilateral, one or more layers of the lens as a zone of opacity sandwiched between clear nucleus and cortex, representing secondary lens fibers, which become opacified in response to an insult when metabolically most active. May have ‘riders’, become dense over time</td>
<td>Familial (AD, AR, chromosome 1q)</td>
</tr>
<tr>
<td>4</td>
<td>Central Pulverulent Cataracts (figure 6D)</td>
<td>Composed of myriad (pulverized) tiny dots, nonprogressive, bilateral, usually not affecting vision</td>
<td>Familial, AD</td>
</tr>
<tr>
<td>5</td>
<td>Nuclear cataract</td>
<td>Affect embryonic and fetal nucleus, may be associated with opacities of cortical and sutural fibers</td>
<td>Familial AD (most common type), CRS,</td>
</tr>
</tbody>
</table>

(a) shows right eye microphthalmos, cataract
(b) Total cataract, tunica vasculosa lentis, neovascularization of iris
(c) Ultrasound B scan shows retrorenal fibrovascular membrane and persistent hyaloid artery
Table 3: Morphological Type of Cataracts

<table>
<thead>
<tr>
<th>Sr no</th>
<th>Morphological Type</th>
<th>Morphological Description</th>
<th>Possible etiology/association</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Total Opacification</td>
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<td>Familial, Down’s syndrome, CRS, acute metabolic cataracts</td>
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<td>Composed of myriad (pulverized) tiny dots, nonprogressive, bilateral, usually not affecting vision</td>
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</tr>
<tr>
<td>5</td>
<td>Nuclear cataract</td>
<td>Affect embryonic and fetal nucleus, may be associated with opacities of cortical and sutural fibers</td>
<td>Familial AD (most common type), CRS, Galactosemia</td>
</tr>
<tr>
<td>6</td>
<td>Oil drop cataract</td>
<td>Central area of different refraction to the surrounding lens that looks like an oil droplet floating on water.</td>
<td>Galactosemia</td>
</tr>
<tr>
<td>7</td>
<td>Cortical cataract</td>
<td>Restricted to outer cortex</td>
<td>Rare, AD</td>
</tr>
<tr>
<td>8</td>
<td>Cerulean cataract (Figure 6A)</td>
<td>Bilateral, stationary, visually insignificant in peripheral cortex, colored hue</td>
<td>Familial, AD</td>
</tr>
<tr>
<td>9</td>
<td>Coronary cataract (Figure 6B)</td>
<td>Club shaped cerulean opacities in a crown-like ring around the equator</td>
<td>Familial, AD</td>
</tr>
</tbody>
</table>

Figure 5: A shows zonular cataract in retroillumination, B. shows 'riders'

Figure 6: Few examples of visually insignificant cataracts
A. Cerulean cataract, B. Coronary cataract in retroillumination, C. Sutural cataract, D. Cataracta centralis pulverulent
Table 3: summarizes morphological types of congenital/developmental cataracts and their likely etiologies

<table>
<thead>
<tr>
<th>Sr</th>
<th>Cataract Type</th>
<th>Morphological Description</th>
<th>Possible etiology/association</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Dot/plaque-like Cataracts</td>
<td>Tiny white dots on the anterior surface in the axial area, may be associated with refractive errors, Amblyopia, strabismus</td>
<td>Familial, AD</td>
</tr>
<tr>
<td>11</td>
<td>Anterior Subcapsular Cataracts</td>
<td>Basement membrane disorder Usually no cataract</td>
<td>Uveitis, trauma, irradiation, or atopic skin disease (shield like)</td>
</tr>
<tr>
<td>12</td>
<td>Anterior Lenticousus</td>
<td>Basement membrane disorder Usually no cataract</td>
<td>Alport’s syndrome (10-30%) Lowe’s syndrome Waardenburg’s syndrome</td>
</tr>
<tr>
<td>13</td>
<td>Posterior Lenticousus</td>
<td>Thinning and posterior bowing of the posterior lens capsule (high astigmatism, variable opacification)</td>
<td>Familial (XL/AD), microcornea, hyperglycinuria, Duane’s syndrome</td>
</tr>
<tr>
<td>14</td>
<td>Posterior Subcapsular Cataracts</td>
<td>Plaque-like opacities</td>
<td>Steroid intake, trauma, NF II Congenital cataract, myotonic dystrophies, Turner’s syndrome, Fabry’s disease</td>
</tr>
<tr>
<td>15</td>
<td>Mittendorf’s Dot</td>
<td>Remains of the anterior end of the hyaloids artery, appears as a small axial grey-white dot opacity at the posterior apex of the lens</td>
<td>Persistent hyaloid artery</td>
</tr>
<tr>
<td>16</td>
<td>Sutural cataract (Figure 6C)</td>
<td>Around or involving the suture, visually insignificant, bilateral, stationary</td>
<td>Familial, AD</td>
</tr>
<tr>
<td>17</td>
<td>Wedge shaped cataract</td>
<td>Occupy a sector of the lens</td>
<td>Stickler syndrome, Conradi syndrome, Fabry disease</td>
</tr>
</tbody>
</table>

Abbreviations: CRS: congenital rubella syndrome, AD: Autosomal dominant, AR: Autosomal recessive, PFV: Persistent fetal vasculature, NF II: Neurofibromatosis type II,

Table 3: summarizes morphological types of congenital/developmental cataracts and their likely etiologies

**Summary:**
Following tips may be helpful while arriving at etiological diagnosis in a child with cataract
1. History taking with special emphasis on antenatal, developmental, and family history
2. Comprehensive ocular examination especially in unilateral cases
3. Careful examination of the morphology of the cataract
4. For bilateral cases: examine family members, get a complete physician examination by a competent pediatrician and then perform tailored systemic investigations

**References**


After finishing his training in ophthalmology from Amrita Institute of Medical Sciences, he is now Chief Consultant and Pediatric Ophthalmologist at LV Prasad Institute, Vijayawada.
In the earlier chapter, measures of central tendency and variation (dispersion, scatter) were discussed. We have seen how to summarize a single quantitative (measurable) variable in terms of its central tendency and dispersion. In practice, we may have to work on more than one variable at a time. In such situations, apart from computing mean & standard deviation of the two variables, we may be interested to study whether these two variables are correlated or not and if they are correlated, to study the type and amount of their relationship (dependence of one variable on another variable). For example, the Ophthalmologist may want to know the relationship or association between Thickness of retina and the duration of diabetes in Diabetic patients or between Retinal Nerve Fibre Layer (RNFL) and age of the patients reporting to the Ophthalmology OPD. In this chapter we shall discuss how to assess the type and amount of relationship between two quantitative variables (correlation) and if there does exist a good relationship how to build up a mathematical equation (regression) for predicting the value of one of the variables (dependent variable) based on the values of the other variable (independent variable).

**CORRELATION**

**Scatter Diagram**

When we have to assess the relationship between two measurable variables, each observation has a pair of values. The first value indicates the level of the first variable, while the second indicates that of the second variable on the same subject. For instance, let us consider Thickness of retina and the duration of diabetes in 20 Diabetic patients. The data are shown in Table 1.

![Fig. 1: Scatter diagram of Duration of diabetes and Thickness of Retina and the Linear Regression line of Thickness of Retina on Duration of diabetes](image)

We can see from the scatter diagram in Fig. 1 that as the duration of diabetes increases the Retinal thickness tends to increase, thereby showing a relationship or association between the two variables. Since the relationship is like a line, it is called a linear relationship. Two variables may also be related in such way that the form of the relationship may not be linear. These types of relationships are called non-linear associations. They are more complicated to study and quantify as compared to linear relationships.

There could be a linear relationship, which is different from the one seen in Fig. 1. Instead of the values of one variable increasing with an increase in the values of the second, the values of one variable could be decreasing while the values of the other is increasing, as shown in Fig. 2. The type of relationship shown in Fig. 1 is referred to as a positive relationship.
correlation as the change in both the variables is in the same direction (either both increase or both decrease together). The type of relationship shown in Fig. 2 is referred to as a negative correlation because the direction of change in one variable is opposite to that in the second. If there is no association between the two variables, we would expect the points plotted to scatter randomly without revealing any pattern, as shown in Fig. 3.

Correlation Coefficient

The scatter diagram no doubt helps us to visualize the type of relationship between the two variables, but it does not help us to quantify the relationship between the two variables. If the relationship appears linear, it can be quantified by a measure called the correlation coefficient proposed by Karl Pearson (1902). This is called Pearson’s product moment correlation coefficient.

The correlation coefficient \( r \) is defined as the measure of the linear relationship between two quantitative variables and is given by:

\[
 r = \frac{\sum_{i=1}^{n} X_i Y_i - \left( \sum_{i=1}^{n} X_i \right) \left( \sum_{i=1}^{n} Y_i \right) / n}{\sqrt{\left( \sum_{i=1}^{n} X_i^2 - \left( \sum_{i=1}^{n} X_i \right)^2 / n \right) \left( \sum_{i=1}^{n} Y_i^2 - \left( \sum_{i=1}^{n} Y_i \right)^2 / n \right)}}
\]

Table 2. shows the details of the calculation of \( r \) using the data shown in Table 1.

We have \( n = 20 \), \( \sum_{i=1}^{n} X_i = 232 \), \( \sum_{i=1}^{n} Y_i = 3133 \), \( \sum_{i=1}^{n} X_i Y_i = 39650 \).

\[
\sum_{i=1}^{n} X_i^2 = 3392 \quad \sum_{i=1}^{n} Y_i^2 = 539295
\]

Substituting these values in the equation of correlation coefficient,

\[
 r = \frac{39650 - (232)(3133)/20}{\sqrt{3392 - (232)^2 / 20} \sqrt{539295 - (3133)^2 / 20}}
\]

\[
= \frac{3307.2 \pm 5830.625}{5994.40} \approx 0.5672
\]

Therefore, the two variables, Thickness of retina and the duration of diabetes in Diabetic patients, are positively correlated, the correlation coefficient being 0.5672. Using computers software, we can get the same result very quickly.

Interpretation of \( r \)

It should be noted that the value of the correlation coefficient can never be more than 1 and can also never be less than –1. A value close to +1 indicates a perfect or near-perfect positive relationship between the two quantitative variables considered and a value close to –1 indicates a perfect or near perfect negative relationship between them. A value close to zero indicates that the two variables are not related. It may be mentioned here that perfect correlation (+1 or -1) can be obtained only in mathematical or physical sciences. For example, the relationship between the pressure and volume of a gas at normal temperature are perfectly correlated. Generally, biological or physiological variables do not exhibit perfect linear relationships and may have at most a close-to-perfect correlation.

Examples of positive correlation include the height and weight of children, age and height of children, age and weight of children, systolic BP and age, thickness of retina and duration of diabetes, Retinal Nerve Fibre Layer (RNFL) and Ganglion cell layer thickness, etc. Negative correlation can be expected between age and peak expiratory flow rate in adults aged above 45 years, RNFL thickness and Endothelial cell count, Ganglion cell layer thickness and duration of diabetes, RNFL and age, etc. Examples of no correlation could be height and Intelligence Quotient, height of smokers and the number of cigarettes smoked per day, etc.
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assumption may not be seriously violated, often a bivariate population can be far from normal. If so, the computation of $r$ as an estimate of the population correlation coefficient may not be valid, especially when the sample size is small. In such situations, we can try with the transformed data (say, log values), so that the joint distribution of the two transformed variables will become at least approximately bivariate-normal and then compute the correlation coefficient in the new scale of measurements.

If the sample size is large, even if the distribution is not normal, we can assume normality. But, if any transformation fails to bring normality to the data and the sample size is small, Pearson’s correlation coefficient should not be calculated. In such situations, correlation coefficient can be calculated on the ranks of the measurements of the two variables. In this method, there is no requirement for a bivariate normal distribution of the two variables being considered. This method, proposed by Spearman (1904) is called rank correlation. Instead of the actual measurements, we use the ranks. Rank correlation can be computed by the following formula:

$$r_s = 1 - \frac{6 \sum d_i^2}{n(n^2 - 1)}$$

<table>
<thead>
<tr>
<th>Serial no.</th>
<th>Duration of diabetes (years)-$X_i$</th>
<th>$X_i^2$</th>
<th>Thickness of retina ($\mu m$)-$Y_i$</th>
<th>$Y_i^2$</th>
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</table>

Total: 232 3392 3133 539295 39650

Table 2: Calculation of the correlation coefficient between Duration of diabetes and thickness of retina in Diabetic patients

Another useful interpretation of the correlation coefficient $r$ is that the square of the correlation coefficient ($r^2$) is the proportion of variance in one variable that can be explained by the other. If $r^2$ is close to one, it implies that the total variation in one variable can be explained by the other. By taking the square of $r$ in the example data on the Thickness of retina and the duration of diabetes, we get $r^2 = 0.3217$ or $32.17\%$, which implies that $32.17\%$ of variation in thickness of retina (dependent variable) can be explained by the duration of diabetes (independent variable) in Diabetic patients. The remaining $67.83\%$ of variation in retinal thickness may be explained by other variables which are not studied here. If information on the other independent variables which are correlated with retinal thickness is available they also can be included in the regression analysis. This regression analysis is called Multivariate linear regression analysis. By doing this analysis the strength of prediction of retinal thickness will be increased.

**Correlation coefficient based on rankings**

The calculation of Pearson’s product–moment correlation coefficient requires the condition that both the variables together follow a distribution called a bivariate normal distribution (symmetric & bell-shaped curve). While this assumption may not be seriously violated, often a bivariate population can be far from normal. If so, the computation of $r$ as an estimate of the population correlation coefficient may not be valid, especially when the sample size is small. In such situations, we can try with the transformed data (say, log values), so that the joint distribution of the two transformed variables will become at least approximately bivariate-normal and then compute the correlation coefficient in the new scale of measurements.

If the sample size is large, even if the distribution is not normal, we can assume normality. But, if any transformation fails to bring normality to the data and the sample size is small, Pearson’s correlation coefficient should not be calculated. In such situations, correlation coefficient can be calculated on the ranks of the measurements of the two variables. In this method, there is no requirement for a bivariate normal distribution of the two variables being considered. This method, proposed by Spearman (1904) is called rank correlation. Instead of the actual measurements, we use the ranks. Rank correlation can be computed by the following formula:
where \( d_i \) is the difference in the two ranks of the \( i \)th observation in the data and \( n \) is the total number of observations.

We will use the data on Thickness of retina and duration of diabetes, given in Table 1 which was used to calculate the Pearson’s correlation coefficient, for calculating Spearman’s rank correlation coefficient.

We have given the ranks in the ascending order, but it does not matter whether they are in ascending or descending order. Notice that when a value is repeated, an average rank is given for the repeated observations. For example, there are three subjects with the duration of diabetes as 20 years. The ranks 1, 2 & 3 will be equally given to these three subjects as an average \((1+2+3)/3 = 2\).

Similarly, there are three subjects with the duration of diabetes as 17 years. The rank of the previous value (18) is 4. Hence the average rank of the 3 subjects with value equal to 17, will be \((5+6+7)/3 = 6\). Same approach is also adopted for ranking the values of the variable, thickness of retina. After appropriate ranks have been assigned to the two variables, we obtain the difference between the ranks of the two variables for each subject. These differences in ranks, called \( d_i \), are shown in the 6th column and the square of \( d_i \) in the last column of Table 3.

3. Now we have,

\[
\sum_{i=1}^{n} d_i^2 = 560 \quad n = 20
\]

Substituting these values in equation for the rank correlation,

\[
r_s = 1 - \frac{6 \times 560}{20 \times (20^2 - 1)} = 1 - \frac{3360}{7980} = 1 - 0.4210 = 0.579
\]

The rank correlation coefficient between retinal thickness and duration of diabetes also indicates a positive correlation. Like the Pearson’s correlation coefficient, Spearman’s rank correlation also ranges from –1 (complete discordance between the rankings) to +1 (complete concordance). A value close to zero indicates that the two variables are independent. Rank correlation can also be used to evaluate the agreement between the rankings given by two raters or judges to a group of observations. Because the calculation of Spearman’s rank correlation does not require any assumption of the distribution of the data, it is also referred to as a non-parametric method.

REGRESSION

While discussing the correlation between two variables we saw how to quantify the relationship between two variables. During this process, we did not take into account prior knowledge on whether one variable is dependent on the
other since our aim was only to quantify the relationship between the two variables. In practical applications in medical sciences, we often know that one variable is dependent on the other variable. For example, in the example of data thickness of retina and duration of diabetes it is logical to consider that the retinal thickness is dependent on duration of diabetes rather than duration of diabetes on retinal thickness. If the amount of correlation is comparatively high, we may be interested to predict the value of the dependent variable for a given value of the independent variable. Or, we may want to find out the regression of the dependent variable on the independent variable.

In this section, we will see how to predict the value of the dependent variable for a given value of the independent (predictor), based on a sample of measurements on both the dependent and independent variables. That is, we observe a set of values on both the dependent and independent variables and using a mathematical relationship between these measurements, we calculate the value of the dependent variable based on the values of the independent variable. Thus, this technique is called regression analysis.

**Linear Regression**

For easier understanding, we denote the independent variable as X and the dependent variable as Y. The first step in regression is to draw a scatter diagram for X and Y. If there is any association between X and Y, a trend can be seen in the scatter diagram of the values of the dependent variable Y for given values of X. The regression technique applied to situations where the trend happens to be like a line or linear is called a linear regression. It is one of the simplest types of regression analysis. The concept of regression lies in identifying a line called the regression line, that is nearest to the data points marked on the scatter diagram, so that for a given value of X, we can make a close prediction of the value of Y. Mathematically, the equation for any straight line is given by, \( Y = a + bX \) where Y is the value of the dependent variable (shown on the vertical axis), X is the value of the independent variable (shown on the horizontal axis), \( b \) is the slope (also called as the regression coefficient) of the line and \( a \) is the point where the line intercepts the vertical axis, i.e., the value of Y when X is zero. The aim in fitting a regression line to the data is then to obtain the values of \( a \) and \( b \) in the equation. The method of estimating the slope and the intercept of a linear regression is called the least squares method. Since this is a mathematical approach, the details of regression analysis are not given here. By applying the Least Square method of estimation we can estimate the values of \( a \) and \( b \) in the equation.

**Numerical Example of the Calculation of the regression coefficient (b) and the Y-intercept constant (a) in the Linear Regression equation:**

Let us work out the estimates of \( a \) and \( b \) for the example of data on thickness of retina (dependent variable) and duration of diabetes (independent variable). Interpretation

Let us work out the estimates of \( a \) and \( b \) for the example of data on thickness of retina (dependent variable) and duration of diabetes (independent variable).

\[
\begin{align*}
\sum_{i=1}^{n} X_i &= 232 \\
\sum_{i=1}^{n} Y_i &= 3133 \\
\sum_{i=1}^{n} X_i Y_i &= 30650 \\
\sum_{i=1}^{n} X_i^2 &= 3392 \\
\sum_{i=1}^{n} Y_i^2 &= 539295
\end{align*}
\]

\[
b = \frac{\sum_{i=1}^{n} X_i Y_i - \frac{1}{n} \sum_{i=1}^{n} X_i \sum_{i=1}^{n} Y_i}{\sum_{i=1}^{n} X_i^2 - \frac{1}{n} (\sum_{i=1}^{n} X_i)^2} = 4.7192
\]

\[
a = \frac{\sum_{i=1}^{n} Y_i - b \sum_{i=1}^{n} X_i}{n} = 101.9075
\]

Hence, the Linear Regression of Y (retinal thickness) on X (duration of diabetes) is given by the equation:

\[
Y = a + bX = 101.9075 + 4.7192X
\]

The equation, \( Y = a + bX \), implies that the retinal thickness (y) is the sum of two components—a constant component (a) irrespective of the duration of diabetes and a component that varies with the duration of diabetes (b). The slope or regression coefficient \( b \) can be viewed as the change in the value of the retinal thickness if there is a change in the duration of diabetes. In particular, \( b \) conveys the average change in the dependent variable for a unit change in the independent variable. In the example, the slope or \( b \) is 4.7192 implying that for an increase of one year in the duration of diabetes, retinal thickness increases by 4.7192 \( \mu \text{m} \). In our example, the regression line is:

\[
Y \text{ (Thickness of Retina)} = 101.9075 + 4.7192 \text{X (Duration of diabetes)}
\]

This regression equation can be used to predict retinal thickness for a diabetic patient if his/her duration of diabetes is known. For example, if the duration of diabetes of a diabetic patient is 8 years, his/her retinal thickness can be predicted from the linear regression equation.
Y = a + bX

Retinal thickness = a + b duration of diabetes

= 101.9075 + 4.7192 X 8

= 139.6611 = 139.66

If the duration of diabetes is 20 years, the predicted value of retinal thickness of that diabetic patient =

= 101.9075 + 4.7192 X 20 = 196.2915

Prediction will be more accurate if the value of the correlation coefficient between retinal thickness and the duration of diabetes is higher and higher. Linear regression analysis should be used for prediction only if the value of the correlation coefficient is comparatively higher and statistically significant. Also, prediction for a new case should be done only if the value of the independent variable is within the limits of the independent variable. In the example, prediction of retinal thickness may not be valid for any diabetic patient if his / her duration of diabetes is greater than 20 years or lesser than 3 years, as per the data.

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References:
4. Orchard CC, Kaye SM, Gigandet FC, et al. A randomised crossover, multiple-dose study to compare the performance of 0.1% w/v sodium hyaluronate with 1.4% w/v polyvinyl alcohol in the alleviation of symptoms associated with dry eye syndrome. Eye 2002;16(1): 80-107.

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ABSTRACT

Objective
To compare between the contrast sensitivity in photopic and mesopic conditions in patients who had undergone uncomplicated cataract extraction with different types of monofocal intraocular lens implantation using contrast sensitivity measurement.

Methods
This in a prospective, comparative, observational study from January 2012 to May 2012. From patients who had undergone uncomplicated Phacoemulsification and IOL implantation, those who had a postoperative BCVA of 6/6 N6 and no other ocular pathologies, 4 groups of patients were selected (25 eyes in each group). They are Group A—Hydrophilic spherical IOL group (Rayner & Acryfold), Group B—Hydrophobic spherical IOL group 1 (MA60AC), Group C—Hydrophobic spherical IOL group 2 (AR40e) & Group D—Hydrophobic aspherical IOL group (SN60WF & ZCB00). At 3 weeks after surgery, the monocular contrast sensitivity (CS) function was measured using Pelli–Robson Contrast Sensitivity measurement chart at one photopic luminance level and one mesopic luminance level.

RESULTS
In the hydrophilic spherical IOL group a photopic contrast sensitivity of >1.65 was noted in 60% and a mesopic contrast sensitivity of >1.05 in 84%. A spherical equivalent (SE) of <0.75 was present in 92%. In the hydrophobic spherical IOL group 1, a photopic contrast sensitivity of >1.65 was noted in 60% & a mesopic contrast sensitivity of >1.05 in 76%. A spherical equivalent of <0.75 was present in 72%. In the hydrophobic spherical IOL group 2, a photopic contrast sensitivity of >1.65 was noted in 60% & a mesopic contrast sensitivity of >1.05 in 80%. A spherical equivalent of <0.75 was present in 92%. In the hydrophobic aspherical IOL group, a photopic contrast sensitivity of >1.65 was noted in 68% & a mesopic contrast sensitivity of >1.05 in 84%. A spherical equivalent of <0.75 was present in 76%.

CONCLUSION:
All groups of IOLs had a comparable photopic contrast sensitivity. Mesopic contrast sensitivity was comparable in the 3 groups of IOLs except hydrophobic spherical group 1(MA60AC) which had residual refractive error. Hence we conclude that spherical error may also play an important role in postoperative mesopic contrast sensitivity.
top to less than 1% at the bottom of the chart in 0.15-log unit sensitivity steps for each triplet of letters. Test is done monocularly at 1m distance with +0.75DS added to the patient’s refractive correction. The patient’s task is to start at the top reading the letters aloud and moving through the chart until he or she cannot read any more. The original scoring system provides 0.15 credit per triplet if at least two of three letters are read correctly. Scores on the Pelli-Robson chart can range from 0 to 2.25 (corresponding to log contrast sensitivity). The postoperative clinical course was normal in all groups. After the surgery, the pupils of all patients were round, without iris trauma, and showed a good responsiveness to light. No case of posterior capsule opacification at the last visit was noted. Data was coded, entered and analyzed using Statistical Package for the Social Sciences (SPSS) software. Categorical variables were analysed using the analysis of variance (ANOVA) tables.

RESULTS:
In the hydrophilic spherical IOL group a photopic contrast sensitivity of > 1.65 was noted in 60% and a mesopic contrast sensitivity of > 1.05 in 84%. A spherical equivalent(SE) of < 0.75 was present in 92% (Table- 1). In the hydrophobic spherical IOL group 1, a photopic contrast sensitivity of > 1.65 was noted in 60% & a mesopic contrast sensitivity of > 1.05 in 76%. A spherical equivalent of < 0.75 was present in 72% (Table-2). In the hydrophobic spherical IOL group 2, a photopic contrast sensitivity of > 1.65 was noted in 60% & a mesopic contrast sensitivity of > 1.05 in 80%. A spherical equivalent of < 0.75 was present in 92% (Table -3). In the hydrophobic aspherical IOL group, a photopic contrast sensitivity of > 1.65 was noted in 68% & a mesopic contrast sensitivity of > 1.05 in 84%. A spherical equivalent of < 0.75 was present in 76% (Table-4).

Mean Photopic CS of in Group A -1.65, in Group B – 1.58, in Group C – 1.63 & in Group D – 1.66 was noted. Mean Mesopic CS of in Group A- 1.18, in Group B – 1.05, in Group C – 1.13 & in Group D – 1.13 was noted.
Pearson Correlation between postoperative spherical equivalent $\leq 0.75$ and a high mesopic contrast sensitivity was found to be statistically significant ($p<0.05$). Correlation between mesopic and photopic contrast sensitivity was found to be statistically significant ($p<0.01$).

**Discussion:**
Cataract surgery and IOL implantation is becoming more of a refractive procedure, where results are measured not only by means of visual acuity, but also by quality of vision. Contrast sensitivity and wavefront analysis effectively represent the optical quality of vision. Snellen acuity represents only a small portion of functional vision.

Contrast-sensitivity testing has the ability to detect differences in functional vision when Snellen visual acuity measurements cannot. For example, a patient with loss of low-frequency contrast sensitivity may be able to read 6/6 but be unable to see a truck in the fog.

Spatial contrast is defined as a physical dimension referring to the light–dark transition at a border or an edge of an image that delineates the existence of a pattern or object (Figure -3). The amount of contrast a person needs to see a target is called contrast threshold. In clinical research or patient care settings, contrast threshold is usually expressed as contrast sensitivity, where sensitivity is simply the reciprocal of threshold. Contrast threshold and contrast sensitivity are expressed on a logarithmic scale, as is the convention in visual sensory science. Thus, a contrast threshold of 0.01 (1%) is a log contrast threshold of $-2$, a contrast sensitivity of 100, and a log contrast sensitivity of 2(4).

Contrast sensitivity measurements uncover a hidden loss of vision—that is, it reveals the presence of visual dysfunction not apparent through other visual evaluations. Contrast sensitivity may help in detecting and monitoring ocular diseases such as glaucoma, cataract and optic neuritis. A second category of benefit that contrast-sensitivity testing engenders for the clinician and the researcher is that it provides another visual method to monitor the impact of treatment intervention. The third category of use for contrast-sensitivity testing is that it provides insights into the extent of patients’ visual disability and functional performance problems. Contrast-sensitivity impairment is independently associated with an assortment of visual performance problems, including difficulties in mobility, driving, reading, face recognition, and an assortment of everyday tasks such as using tools and finding objects.

Two types of contrast-sensitivity tests are used today—grating tests and letter tests. The most commonly used letter chart designed to assess contrast sensitivity is the Pelli-Robson chart (Haag-Streit). Scores on the Pelli-Robson chart can range from 0 to 2.25 (corresponding to log contrast sensitivity). The Pelli-Robson score provides an estimate of the peak of the contrast-sensitivity function. Test–retest reliability of the chart is high for the original scoring system, with an intra-class correlation of 0.86 for patients. Scores on the chart are relatively unaffected by background luminance in the photopic range, testing distance from 0.25 to 4 meters, and 2 diopters of defocus, which is facilitated by the chart’s use of large letters. The chart’s good test–retest reliability, relative immunity from varying test conditions, brevity and ease of administration (3–5 minutes), and availability of published normative data have led to its frequent choice for epidemiologic studies.

Contrast sensitivity declines with age even in the absence of ocular pathology, such as cataract, glaucoma, or macular degeneration. The pathogenesis of this decline in vision likely involves changes in the spherical aberration of the crystalline lens. A spherical lens does not refract all parallel rays of incoming light to a single focal point (Figure 4). As the aperture of the lens increases the average focal point moves toward the lens, so that a larger pupil produces greater spherical aberration. The young crystalline lens has negative SA that compensates for the positive SA of the normal cornea. The SA of the crystalline lens becomes positive with aging. The spherical aberration of a manufactured spherical IOL is in no better balance with the cornea than the spherical aberration of the aging crystalline lens. The intraocular implant has positive spherical aberration like the aging lens.
Development of Aspheric IOLs compensates for the positive SA of normal cornea. Currently, there are several aspheric IOLs in the market, the main difference between them being the asphericity of the IOL, and hence the amount of SA susceptible of correction when implanted. The Tecnis IOL was designed with a modified prolate anterior surface to compensate for the average corneal spherical aberration found in the adult eye. It introduces −0.27 μ of spherical aberration to the eye. The AcrySof IQ has the posterior aspheric surface designed to compensate for spherical aberration by addressing the effects of overrefraction at the periphery. It adds −0.20 μ of spherical aberration to the eye.

In our study the Hydrophobic Aspherical IOL group had the best contrast sensitivity in both the photopic and the mesopic categories (no statistically significant correlation). In a study by Shinichiro Ohtani, Kazunori Miyata et al. Ophthalmology Volume 116, Issue 5, Pages 896-901, May 2009.

CONCLUSION:
The Hydrophobic Aspherical IOL group had the best contrast sensitivity in both the photopic and the mesopic categories (no statistically significant correlation). All groups of IOLs had a comparable photopic contrast sensitivity. Mesopic contrast sensitivity was comparable in the 3 groups of IOLs except hydrophobic spherical group 1 (MA60AC) which had residual refractive error. Correlation between postoperative spherical equivalent <\=0.75 and a high mesopic contrast sensitivity was found to be statistically significant (p<0.05). Hence we conclude that spherical error may also play an important role in postoperative mesopic contrast sensitivity. Detailed analysis of the higher order aberrations by wavefront aberrometers are needed to evaluate why there is difference in mesopic contrast sensitivity in the different groups of Spherical IOLs.

REFERENCES:

Dr. Sara Jacob, after training at Kottayam Medical College, did Ratan Tata Fellowship at Sankara Netralaya. She is now consultant in Cataract & Glaucoma Services at Giridhar Eye Institute, Kochi.
**Lasik In Children**

**Abstract**

10 children who had unilateral high Myopia in the age group of 7 years to 13 years were selected in the study. This was a Prospective Study. A standard Lasik procedure was performed on all these eyes. Refraction was performed at the end of I Month, III, VI and VII month, in the first year and every 6 months there after for 2 years. Amblyopia treatment was given where ever needed. At the end of 2 years, 3 eyes had an uncorrected vision of 6/9. 3 eyes improved by 2 lines in the Snellens Chart with out correction compared to Pre Lasik vision.

**Aim**

The Aim of the study was to give maximum visual acuity for these eyes with unilateral myopia hence attain binoculary and prevent development of Amblyopia

**Materials and Methods:**

10 eyes of 10 different children who had unilateral myopia were selected for the study. It was a prospective study conducted in 2010, 2011 and 2012. The Demography Profile of the children and the refraction are given in Table I.

<table>
<thead>
<tr>
<th>Sl NO</th>
<th>Age</th>
<th>Sex</th>
<th>Uncorrected Visual Acuity</th>
<th>Refractive Status</th>
<th>Best Corrected Visual acuity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7 yr</td>
<td>Male</td>
<td>1/60</td>
<td>-6.00Dsp,</td>
<td>6/24</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-1.00x180 Cly</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>7 yrs</td>
<td>Male</td>
<td>3/60</td>
<td>-5.00 Dsp</td>
<td>6/18</td>
</tr>
<tr>
<td>3</td>
<td>8 yrs</td>
<td>Female</td>
<td>5/60</td>
<td>-4.50Dsp</td>
<td>6/18</td>
</tr>
<tr>
<td>4</td>
<td>8 yrs 3months</td>
<td>Male</td>
<td>6/60</td>
<td>--5.50Dsp</td>
<td>6/24</td>
</tr>
<tr>
<td>5</td>
<td>9 yrs</td>
<td>Female</td>
<td>3/60</td>
<td>7.50Dsp</td>
<td>6/36</td>
</tr>
<tr>
<td>6</td>
<td>10 yrs</td>
<td>Female</td>
<td>4/60</td>
<td>-6.50Dsp</td>
<td>6/24</td>
</tr>
<tr>
<td>7</td>
<td>10 yrs 6 months</td>
<td>Male</td>
<td>3/60</td>
<td>-8.00Dsp</td>
<td>6/24</td>
</tr>
<tr>
<td>8</td>
<td>11 yrs</td>
<td>Male</td>
<td>6/60</td>
<td>-8.50Dsp</td>
<td>6/36</td>
</tr>
<tr>
<td>9</td>
<td>11 yrs 7 months</td>
<td>Female</td>
<td>2/60</td>
<td>-7.50Dsp</td>
<td>6/12</td>
</tr>
<tr>
<td>10</td>
<td>13 yrs</td>
<td>Male</td>
<td>6/60</td>
<td>-5.50Dsp</td>
<td>6/18</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-2.00 x180 Cly</td>
<td></td>
</tr>
</tbody>
</table>

Table I Demography and Refractive Status
The selection Criteria was children with only one eye having myopia , systemic diseases excluded and the child should be co-operative. The procedure was performed under topical Anesthesia hence all the children had be cooperative.

Dynamic and Cycloplegic Refraction
Corneal sensation,Slit lamp Biomicroscopy
Dry eye Status
Direct and Indirect Ophthalmoscopy
Topography and Pachymetry

Surgical Procedure: It is given in Table IV

Local Anesthesia-Propocaine 0.5%
Micro Keratome-Corneal Flap raised
Lasik Laser applied
Mytomycin 0.02% applied
Flap replaced

All eyes underwent a standard Lasik Laser procedure under topical anesthesia with 0.5 % Propacaine. 2 Children were very apprehensive but were cajoled to undergo the procedure for which they agreed and were cooperative. All procedure were conducted by a single surgeon. After raising the vacuum of the eyeball to 60mm of Hg a micro Keratome corneal flap was raised Lasik Laser was applied. Eyes with myopic below 5 Diopter the Mytomycin was applied for 1 minute , above it the mytomycin were applied for 2 minutes . After application of mytomycin the stroma bed was thoroughly washed and cleared of any derbies using ringer Lactate solution. A minimal residual stromal bed thickness of 300mm was left behind in all these eyes after the ablation was carried out. Then the flap was replaced. Antibiotics Moxifloxacin and lubricants, Carboxy methyl cellulose was applied. The patient were instructed not to apply water into the eyes nor to rub the eyes for 5 days duration. There were no Intra or post Lasik complications. Post Lasik treatment included Prednisolone Eye drops 4 times a day for 3 weeks, Antibiotic Moxifloxacin eye drops 4 times for 1 month, Lubricant Carboxy methyl Cellouse for 3 months. First Post Lasik follow up was on the 5th day. Subsequent follow up were carried out on the III,VI,XII,XVIII and XX month.

Table II Pre Lasik Work up

<table>
<thead>
<tr>
<th>SL NO:</th>
<th>Pachimetry in MM</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>538</td>
</tr>
<tr>
<td>2</td>
<td>540</td>
</tr>
<tr>
<td>3</td>
<td>525</td>
</tr>
<tr>
<td>4</td>
<td>551</td>
</tr>
<tr>
<td>5</td>
<td>556</td>
</tr>
<tr>
<td>6</td>
<td>565</td>
</tr>
<tr>
<td>7</td>
<td>585</td>
</tr>
<tr>
<td>8</td>
<td>589</td>
</tr>
<tr>
<td>9</td>
<td>532</td>
</tr>
<tr>
<td>10</td>
<td>572</td>
</tr>
</tbody>
</table>

V and gives the post Lasik visual acuity. In the Table we can see that 3 eyes improved to 6/9 uncorrected. This vision was maintained for the II Post Lasik month till 24th Post Lasik month. They are No:2,3, and 9 in the table. 3 eyes improved 2 lines on the Snellens Chart without correction. They are Sl No:1,4, and 8 in the table. One eye with Sl No:7 needed -0.50 to improve to 6/18. One eye with Sl No: 5 in the Table had dropped to one line in the snellens chart. This eye had improved to 6/18 post Lasik but dropped to 6/24 after 24 months, the vision being best corrected visual acuity. All children below the age of 9 years were given occlusion of 3 waking hours for 2 months. They were told to occlude the better eye. But no conclusive evidence of improved vision could be gained from the same.

Discussion
Unilateral myopia is a common cause for Amblyopia developing in children. It not only effects binocularity, it could also cause squint in these children. Few of the
Results: Table V gives the Post Lasik visual status

<table>
<thead>
<tr>
<th>Sl NO:</th>
<th>Pre Lasik best corrected</th>
<th>1 Month Un corre</th>
<th>corre</th>
<th>III Month Un corre</th>
<th>corre</th>
<th>VI Month Un corre</th>
<th>corre</th>
<th>12 Month Un corre</th>
<th>corre</th>
<th>18 Month Un corre</th>
<th>corre</th>
<th>24 Month Un corre</th>
<th>corre</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6/24</td>
<td>6/12</td>
<td>6/12</td>
<td>6/12</td>
<td>6/12</td>
<td>6/12</td>
<td>6/12</td>
<td>6/12</td>
<td>6/12</td>
<td>6/12</td>
<td>6/12</td>
<td>6/12</td>
<td>6/12</td>
</tr>
<tr>
<td>4</td>
<td>6/24</td>
<td>6/12</td>
<td>6/12</td>
<td>6/12</td>
<td>6/12</td>
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<td>6/12</td>
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<td>6/12</td>
<td>6/12</td>
<td>6/12</td>
<td>6/12</td>
</tr>
</tbody>
</table>

Methods to attain better vision is use of spectacles or use of contact lenses. But spectacles could cause diplopia and hence children could avoid use them. Contact lenses may be difficult to manage in children. In these children Lasik gives hope to regain vision. Not only regain vision but also get good binocularity, but also prevent amblyopia developing in these eyes and also prevent development of squint.

In this prospective study of 10 such unilateral myopic eyes all eyes attained and maintained good vision. Post Lasik till 2 years of the study 3 eyes gained 6/9 Post Lasik one line more without corrections, than Pre Lasik with correction vision. 3 eyes gained a vision of 2 lines uncorrected post Lasik. These eyes had best Corrected visual acuity, Pre lasik of 6/24, 6/24, 6/36, gained to 6/12, 6/12 and 6/18 respectively. Only one eye which had 6/36 best corrected Pre lasik vision gained 6/18 uncorrected post Lasik after 1 month. But after 24 months dropped to 6/24. Reason could be due to Amblyopia having already set in.

Conclusion
Lasik in Anisometropic children is a good option to regain good useful vision. This is especially true in children having unilateral high myopia. This would help children to get binocular vision and also prevent amblyopia and strabismus. It helps these children imbibing good education and to lead a near normal life and have a good future for themselves.

References
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Lasik- Its Effect On Long Term Visual Outcome In High Myopes & Assessment Of Residual Refractive Error

Abstract:
Aim
To assess the long term visual outcome of LASIK in high myopes & to assess the residual refractive error.

Materials and methods: A prospective study of 204 eyes of 119 patients with high myopia (MRSE of -6 to -14) who underwent LASIK during the time period of March 2010-March 2011 was done.53 males & 66 females in the mean age group of 29 years were included in 3 categories; those with a pre Lasik CDVA of 6/6 in Category 1; 6/9-6/12 in Category 2; and <6/12 in category 3. UCVA & CDVA of these patients were assessed pre & post operatively. They were followed up at 1 month, 3 months, 6 months & 1 year.

Results: At 1 year follow up; in Category 1, 100% of patients had a post-op UCVA of 6/12 or better of which 79.62% had 6/6. In Category 2 patients, 90% got a post op UCVA of ≥6/12 & 18.6% got 6/6 post op UCVA. In Category 3, 38.46% achieved their pre-op CDVA. Of 204 eyes, 83.82% achieved their pre-op CDVA. 20.5% had residual error and most of them were undercorrected.

Conclusion
Lasik is safe & effective in high myopes & majority of patients achieved corrected visual acuity of 6/12 or better.

INTRODUCTION:
Laser in situ keratomileusis (LASIK) is a refractive surgery procedure that involves the use of a microkeratome to create a corneal flap through a lamellar cut, and a laser-usually an excimer laser-to ablate exposed stromal tissue. The ablation changes the curvature of the central part of the cornea, thus producing a change in refraction. Although the technique was originated to treat high myopic refractive errors, it is currently employed to correct a wide range of refractive errors, low to high myopia, astigmatism and hyperopia. Though laser in situ keratomileusis (LASIK) surgery is now one of the most common procedures performed worldwide, few studies have been published on long term outcome and safety in the Indian context as we tend to use western nomograms for treatment. In this study we report the long term refractive stability for high myopic correction & assessment of residual refractive error.

AIM OF STUDY:
To assess the long term visual outcome of LASIK in high myopes & to categorize the residual refractive error.

MATERIALS AND METHODS:
This was a prospective analysis of visual and refractive outcome of patients who had LASIK procedure for high myopia in CEHRI, TVM performed during the period March 2010-March 2011.

All patients who underwent LASIK during the stipulated period and had a preoperative spherical equivalent >/-6.0 to -14.0D were included in the study. Patients who failed to complete a minimum follow up of 1 year were excluded from the analysis.

The main outcome parameters assessed were uncorrected visual acuity (UCVA) & Corrected distance visual acuity (CDVA) post LASIK. The patients were grouped into 3 categories; those with a pre Lasik CDVA of 6/6 in Category 1; 6/9-6/12 in Category 2; and <6/12 in category 3. The initial surgery was performed by one experienced surgeon & the same surgeon saw all patients at follow up. All patients had a preoperative examination including uncorrected visual acuity (UCVA), CDVA, cycloplegic refraction, slit lamp examination, keratometry, aberrometry, topography, pachymetry and fundus examination.

PROCEDURE: The flap was cut with a Moria microkeratome using 90µ disposable blade. Laser ablation was done with Allegretto 400 hz excimer Laser. (Fig 1).

After repositioning, the flap was allowed to dry for 2 minutes. Once the flap dried, adherence of the flap to the underlying stroma was checked using striae test. Antibiotic (Gatifloxacin-0.5%) eye drops were instilled at the end of the procedure.

Post operatively patients were advised Fluorometholone 0.1% eye drops 2 hourly for the first 2 days & then 4 times/day for 1 week, Gatifloxacin 0.5% eye drops 4 times/day for 1 week and HPMC/CMC eyedrops 4-6 times/day for 3 months. They
RESULTS
119 patients (204 eyes) took part in the study; 44.54% males & 55.46% females. [Fig2]

The mean age was 29 years
Of the 204 eyes, 109 (53.43%) eyes were in category 1; 69 (33.82%) were in category 2 & 26 (12.74%) were in category 3 [Fig3]

AFTER LASIK
In Category 1, 100% of patients had a post-op UCVA of 6/12 or better of which 78.89% had 6/6

In Category 2 patients, 90% got a post-op UCVA of >/=6/12 & we were surprised to find that 18.6% got 6/6 post op UCVA, though these patients had never read 6/6 preoperatively.

In Category 3, 23.08% had gained one or more lines of visual acuity and could see 6/12 or better whereas most of the rest only achieved their pre-op CDVA.

Spherical equivalent: The preoperative spherical equivalent ranged from -6.0 to -14.0D with a mean of -10.76D. The mean spherical equivalent post Lasik reduced to -0.96D.

BSCVA was unchanged/improved in 92.64%. 66.67% eyes were unchanged; 20.58% eyes gained 1 line; 3.43% eyes gained 2 lines & 0.49% eyes gained more than 2 lines. Also 7.84% eyes lost 1 line & 0.49% eyes lost more than 2 lines of BSCVA. Therefore overall 21.07% patients had residual refractive errors spread over all categories with almost equal distribution between undercorrection, overcorrection & astigmatism.
COMPLICATION RATE
6.37% patients reported striae, 4.90% - interface debris, 0.49% - stromal opacity and 0.49% - epithelial ingrowth.

DISCUSSION
LASIK surgery involves the formation of a corneal flap. This, theoretically, could disturb the organisation of collagen fibres that make up the corneal stroma at this level which could lead to compromise in corneal strength. Thus, there has been concern expressed over the long term refractive and biomechanical stability associated with LASIK surgery. The biomechanical and wound healing properties of the cornea undermine the predictability and stability of refractive surgery and contribute to discrepancies between attempted and achieved visual outcomes after LASIK, and other keratorefractive procedures.

While laser and incisional refractive surgery offer the promise to correct visual refractive errors permanently and predictably, variability and complications continue to hinder wide-spread acceptance. To explain variations, recent studies have focused on the role of corneal wound healing in modulating refractive outcomes. As our understanding of the corneal response to refractive surgery broadens, it has become apparent that the response of one cell, the corneal stromal keratocyte, plays a pivotal role in defining the results of refractive surgery. Studies reviewed herein demonstrate that injury induced activation and transformation of keratocytes to myofibroblasts control the deposition and organization of extracellular matrix in corneal wounds.

Myofibroblasts establish an interconnected meshwork of cells and extracellular matrix that deposits new matrix and contracts wounds using a novel and unexpected “shoe-string-like” mechanism. Hence Lasik may not be the perfect procedure in high myopes. Intra ocular Collamer Lenses (ICL) are considered the best option in high myopes though it has complications like CME, endophthalmitis, secondary glaucoma, cataract etc. But as it is very expensive in our set up many prefer Lasik over ICL.

The immediate postoperative refractive results of LASIK or surface ablation are dominated by the programmed ablation zone geometry, the laser-tissue interaction and perioperative biomechanical responses. Healing ensues immediately, however, and the cornea’s optical properties are further modified. Biological diversity in this response is the norm, even in genetically similar individuals or contralateral eyes of the same patient. As such, it is a major factor in refractive overcorrection, undercorrection and regression, induction of irregular astigmatism and haze formation.

A 5 yr followup study for LASIK for all levels of myopia by Doherty et al observed that, there was regression towards myopia with a mean change in refraction of -0.5D over the 5 years. In this study, severely myopic patients regressed more with a mean change of -1.06D.

Another study by Alio et al evaluated the longterm visual outcome of LASIK in high myopia (with a mean preoperative spherical equvalent of -13.95 +/- 2.79 D) had a longer followup period of 10 years. The study observed that in the 196 eyes studied, at 10 years, 42% were within +/-1.00 D and 61% were within +/-2.00 D. 27.5% eyes underwent retreatments attributable to under correction and/or regression. The myopic regression decreases with time in eyes that did not undergo retreatment with a mean rate of -0.25 +/- 0.18 D per year. They concluded that LASIK for myopia over -10 D is a safe procedure with myopic regression that slows down with time and a high rate of BSCVA increase in the long-term.

In our study we noted that in Category 1, while most of them got 6/6 vision post Lasik a small percentage lost one line because of their residual power. Similarly in Category 2 & 3, a majority achieved their preop CDVA after Lasik. We also found that in spite of amblyopia, few people gained an UCVA over and above their CDVA. This must be owing to the correction of optical distortions induced by high refractive errors.

CONCLUSION
Lasik is safe & effective in high myopia & majority of the patients achieved corrected visual acuity of 6/12 or better. The procedure can be judged to have a high level of patient satisfaction and a level of visual outcome within acceptable limits as none of the patients demanded or underwent retreatment during the 1 year followup. While laser and incisional refractive surgery offer the promise to correct visual refractive errors permanently and predictably, variability and complications continue to hinder wide-spread acceptance. However, a better identification and knowledge of preoperative predictors of biomechanical and wound healing responses in individual patients may improve the
accuracy of the predictability of LASIK.

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Dr. Tina Susan Varghese is doing her post graduation at Chaithanya Eye Hospital, Trivandrum.
Automated Lamellar Keratoplasty For Post Lasik Corneal Scarring

A 41 year old gentleman came to us with complaints of non progressive diminution of vision in left eye since 11 years, with associated complaints of glare, more during night driving. He had been wearing glasses since childhood. He had undergone radial keratotomy 14 years ago in both eyes. He had a complication during the procedure for which cataract surgery was done in 2001. As he was still spectacle-dependent he underwent LASIK in both the eyes in 2002 elsewhere. He never regained good vision in the left eye and was advised rigid contact lens but never wore them due to discomfort. He had no known systemic illnesses and was unaware of any allergies. On examination his best corrected visual acuity was 6/6 N6 in the right eye and 6/18p N8 in the left eye. Retinoscopy showed a scissoring reflex in right eye and irregular reflex in the left eye. Contrast sensitivity testing with Pelli Robson chart showed 1.65 in right eye, 1.2 in left eye and 1.65 in both eyes.

Slit lamp examination of the cornea showed eight linear radial scars extending to more than 80% depth seen in the mid peripheral cornea, each measuring 4 mm in length in both the eyes, suggestive of an 8 incision RK (radial keratotomy). One mark in the left eye at 60 o'clock position showed full thickness opacification. There was a superiorly hinged LASIK flap in both the eyes. Multiple greyish white bead like opacities were seen adjacent to 6 o'clock and 8 o'clock RK marks suggestive of epithelial ingrowth in the left eye. Similar lesions were seen along the 6 o'clock RK mark in the right eye but were much smaller in area and density. The left eye had in addition a maculo-leucomatous grade opacity irregular in shape and density in the central cornea, prominent on tangential illumination with one area showing a well demarcated edge probably a button hole.

Other ocular findings were unremarkable in both the eyes. Intraocular pressure assessment with tonopen showed 12mm Hg and 13mm Hg in right and left eye respectively.

Visante Omni imaging of the left eye showed an area of flattening in the supero-nasal cornea with steepening in the central and inferotemporal cornea. Central cornea showed a symmetric bow tie pattern, but steepest point measured only 46.5D. Mean central pachymetry was 543 microns and thinnest point measured 520 microns. Posterior elevation map showed a central flattening and mid peripheral steepening, the steepest point measured is 31.15 microns. LASIK flap measured 160 microns with a residual stromal bed of 390 microns. The central cornea showed an irregular thinning of flap area in the central part with hyper reflective shadows in interface. Right eye showed a well-centered ablation, a flap thickness of 160 microns and a residual bed of 342 microns. Based on the above findings a diagnosis of OU – Epithelial ingrowth, OS – Interface scarring ? Button hole S/P LASIK, S/P Radial Keratotomy, S/P cataract surgery was made.

The different options - contact lenses, automated lamellar keratoplasty and penetrating keratoplasty were offered to the patient. Deep anterior lamellar keratoplasty(big bubble technique)- was not considered a good option in view of full thickness perforation along one RK incision in the cornea. A full thickness procedure was not preferred in view of young age and risk of progressive endothelial loss.

He underwent deep automated anterior lamellar keratoplasty with Amadeus microkeratome (ALTK SYSTEM) with a 400 micron head under local anaesthesia and corneal button was sent for histopathological study. Both donor lamellar button and recipient bed measured 8.5mm and 16 interrupted sutures were employed. Post operatively his best corrected visual acuity was 6/6 and in left eye was 6/9. The left eye had a central clear graft and there was no significant interface haze. Anterior segment OCT revealed a well apposed lamellar button measuring 270 – 280 microns.

Histopathological examination of the corneal button showed corneal tissue lined by non keratinized stratified squamous epithelium, with focal duplication in the superficial part of lamina propria. The duplicated deeper epithelium show devitalized trapped cellular debris.

DISCUSSION:

The incidence of epithelial ingrowth after LASIK has been reported to be as low as 0.2 percent and as high as 15 percent. Epithelial ingrowth is the presence of corneal epithelium in an area where it does not belong. After LASIK epithelial ingrowth can occur in the interface between the flap and the stromal bed of the patient’s cornea. Corneal epithelial cells can be introduced into the interface in two ways: during the microkeratome pass or other parts of the procedure or due to a loss of contact inhibition. Patients with corneal epithelial basement membrane dystrophy and patients with recurrent corneal erosion are at a risk for epithelial ingrowth after LASIK. Other risk factors include diabetes mellitus, older age, having had previous corneal
Corneal haze is a late complication of excimer corneal surgery that usually takes the form of a fine reticular subepithelial pattern that can sometimes interfere with vision. Corneal clarity is graded on a scale of 0 to 4+. The haze corresponds to a corneal healing response after LASIK induced by activation and migration of keratocytes (fibroblasts) and newly synthesized collagen. After LASIK the corneal epithelial cells may lose their characteristic morphological features and eventually degrade in the metabolically 'unusual' environment of the flap interface. Concurrently, a capsule of connective tissue similar to scar tissue forms, separating them from healthy cornea. A cytokine-mediated interaction between the epithelium and stroma has been suggested as the cause of keratocyte cell migration and scar formation. Histologically all hazy corneas show increased numbers of anterior stromal wound healing keratocytes with increased reflectivity of both nuclei and cell bodies.

A buttonhole flap is a relatively rare but known complication of LASIK, caused when the microkeratome passes through the top of the cornea while creating a flap of corneal tissue. Buttonhole flaps occur due to (1) loss of suction during microkeratome pass, (2) buckling of tissue which occurs usually in steep corneas and (3) microkeratome blade cutting too thin. In LASIK surgery after RK, there is an inherent weakness of the cornea. A full thickness buttonhole should prompt the surgeon to abandon the surgery, replace the flap, protect the flap with a bandage contact lens for a few days,
then if all heals well about three months later do the surgery again. The vast majority of people who have buttonhole flaps have no long-term problems and are able to have LASIK, PRK, or LASEK after the flap has sufficiently healed.

In our patient, in all likelihood two complications occurred [1] button hole - during the procedure and [2] epithelial ingrowth – in the post operative period. Both the conditions quite likely led to interface scarring which badly affected his quality of vision. As corneal scarring was extending up to 200 microns [as demonstrated in Visante OCT], corneal replacement was considered the best option for symptomatic relief. Deep anterior lamellar keratoplasty (big bubble technique) was not a good option in view of full thickness perforation along one RK incision. A full thickness procedure was not preferred in view of young age, need for prolonged steroid therapy and risk of progressive endothelial loss. Hence automated lamellar keratoplasty at a deeper plane was considered appropriate.

Conclusion
Deep automated anterior lamellar keratoplasty can be considered a good treatment option for stromal scarring following complicated refractive surgery. Being an extra ocular procedure the risk of immunological endothelial rejection can be minimised.

References

Fig 6 - Left eye cornea after deep automated anterior lamellar keratoplasty

Fig 7 - Anterior segment OCT after automated anterior lamellar keratoplasty left eye.
8 yr old tribal boy presented to our OPD with painless down and out proptosis of right eye of 2 months duration, which rapidly progressed by 2 weeks which was accompanied by defective vision, restricted extraocular movements, superonasal conjunctival congestion & upper lid ecchymosis. BCVA which was 6/24 at presentation dropped to perception of light with accurate projection of rays in due course.

Nil significant past history suggestive of any chronic illness or malignancies. Other than both parents having neurofibromatosis, no history of any familial malignancies. Child who was active and playful at presentation, had worsening of general condition due to severe pain.

On examination, vitals were within normal limits, trunk showing 6 cafe au lait spots of size >5mm. No significant lymphadenopathy. Systemic examination within normal limits. Ocular examination - down and out eccentric proptosis, RE, EOM-restricted.

An initial firm nodular non tender swelling of size 4x3cm in the superonasal quadrant of Rt orbit, which progressed to 6x5cm with tenderness and local rise of temperature which caused inadequate lid closure, dilated episcleral vessels and conjunctival congestion in the superonasal quadrant. Cornea which was clear at presentation later developed inferior haziness and infiltration suggestive of exposure keratitis.
Fundus examination showed clear media with hyperemic astigmatic disc, C:D ratio 0.1, choroidal folds superonasally, dilated and tortuous vessels nasal to disc, posterior pole edema with dull foveal reflex provisionally diagnosed as orbital rhabdomyosarcoma.

On investigation blood parameters-peripheral smear, routine, sickling test- WNL, CXR- WNL.

CT-SCAN- Enhancing heterogenous lesion in the superomedial aspect of right orbit in extraconal compartment with scalloping of adjacent bones possibly rhabdomyosarcoma or hemangioma. No extension to adjacent sinuses or nasal cavity, no bone erosion

MRI- Well defined lobulated altered signal intensity lesion in the superonasal aspect of Rt orbit with displacement of globe & scalloping of orbital margins s/o rhabdomyosarcoma or hemangioma. Few areas of flow voids noted within the lesion. Optic nerve appeared WNL, lesion showed marked post contrast enhancement in early phase with early wash out. No e/o intracranial extension.

Total excision of tumour was done through a bicoronal incision & superior orbital approach with the help of neurosurgeons under GA. Along with that lumbar puncture for CSF study & Bonemarrow aspiration was done for staging purpose. Gross appearance of tumour was nodular, grey brown in color & rubbery in consistency which was obtained as multiple bits. Largest bit obtained was having a size of 3.5*2.5*2 cm. Specimen sent for frozen section.

HPR showed EMBRYONAL RHABDOMYOSARCOMA

Histopathological report
Cells were arranged in myxoid stroma, having varying morphology pleomorphic cells, strap cells, tadpole cells, wreath like giant cells.

Bonemarrow aspiration was WNL. CSF cytology was negative for blasts. CT chest scan & USG abdomen was done to rule out any metastasis & was found to be WNL.
Post-operative period—proptosis decreased, lid closure became adequate, corneal infiltrate decreased & vision improved to 5/6. But abduction & elevation was restricted, ptosis & midriasis was present S/o 3rd nerve injury probably during surgery.

**MOLECULAR BIOLOGY**

Mutations in certain tumor suppressor genes, including TP53, predispose individuals to RMS. It is important to note that patients with Li-Fraumeni syndrome & neurofibromatosis type 1 are more likely to develop RMS. Upto 10% of patients with RMS may have one of these syndromes. Our patient has family history of neurofibromatosis.

Embryonal RMS is characterised by loss of heterozygosity (LOH) with loss of maternal genetic information & duplication of paternal genetic information at 11p15 locus. This locus is the site of insulin-like growth factor -2 (IGF-2) gene. LOH results in over expression of IGF-2. Another potential etiologic molecular finding is loss of 9q22, corresponds to a tumor suppressor gene in embryonal RMS.

**CLINICAL PRESENTATION**

Bimodal age distribution but 75% within first decade of life. Average age of presentation 7 years. Predominance in males. (5:3). RMS involving head & neck region are mostly embryonal subtype & rarely involve regional lymph nodes. Classic picture is rapidly progressing U/L proptosis over days to weeks. Most common site is superonasal quadrant. Alveolar variant more common in inferior orbit. Proptosis & paraxial globe displacement, eye lid edema, increased vascularity due to subadjacent blood vessel supplying the tumour are common finding in clinical examination. Blepharoptosis, strabismus & a mass may be palpable within the orbit. Rarely it can be intraocular within iris & ciliary body. By clinical presentation itself our provisional diagnosis was rhabdomyosarcoma.

**HISTOPATHOLOGICALLY** RMS is classified as small, round, blue cell tumours of childhood including neuroblastoma, ewing’s sarcoma, small cell osteogenic sarcoma, NHL & leukemia. Tumor arise from malignant transformation of pluripotent mesenchymal cells. Majority of primary orbital rhabdomyosarcoma (65%) are embryonal type, which arise from ectopic rest of striated muscle rather than extraocular muscles & grow in circumscribed masses. Rhabdomyoblasts are elongated with...
small & banal nuclei. Stroma typically has loose myxomatous structure with little collagen. Cross striations may be evident in only a minority of cells. Mitoses are frequently seen. Cross striations, strap cells, & tadpole cells evidence of abortive muscle fibre formation & are seen in better differentiated tumours. His HPR also was typical of embryonal rhabdomyosarcoma. Alveolar form often seen in patients presenting later in life, consist of individual cells similar to embryonal variety, but cells are compartmentalised by septa. These have worst prognosis.

According to TNM staging

<table>
<thead>
<tr>
<th>Stage</th>
<th>Orbit, Head &amp; neck (excluding parameningeal)</th>
<th>Genitourinary – nonbladder, Non prostate</th>
<th>T1 or T2</th>
<th>a or b</th>
<th>N0/N1/Nx</th>
<th>M0</th>
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| T1 – Confined to anatomical site of origin/ T2 – Extension &/fixation to surrounding tissue | a = <5cm / b= > = 5 cm | According to Risk Classification any patient with embryonal rhabdomyosarcoma at favourable site like orbit are at low risk.

Surgical-Pathologic Grouping System of Inter group Rhabdomyosarcoma Stud

RMS shows a strong tendency for local invasion, local recurrence, & hematogenous & lymphatic spread. Upto 1970 standard care for RMS was to attempt complete resection of tumour, which meant enucleation & possible exenteration. Survival rate was 35%. Beginning of 1960s local radiotherapy was introduced followed by chemotherapy. Combining both were based on stage & tumor grade. Survival rate increased upto 93%. Candidates for radiotherapy primarily include group 2 (low dose radiation of 40 Gy is given associated with local control rate of atleast 90%) or group 3 (radiation doses of 50 Gy). Most comprehensive review of the late effects induced by radiotherapy is derived from Intergroup Rhabdomyosarcoma study IRS 1, in which children received orbital radiation doses of 50-60 Gy, complications included delayed healing, dry eye, infection, keratopathy, cataract formation(90%), retinopathy, & neuropathy, growth centres of facial bone may also be damaged, leading to hypoplasia of brow and enophthalmos. More recent improvement in radiation technique have reduced total amount of radiation to 45 Gy with standard doses of vincristine for patients with low risk RMS, including group 3 orbital disease. Several authors have suggested that upto 40% of patients with localised RMS of orbit can be treated successfully without use of radiotherapy with no effect on the survival rate.

Standard chemotherapeutic regimen consist a combination of vincristine, actinomycin-D, & cyclophosphamide (VAC). The combination of ifosfamide & etoposide was tested in a phase 2 therapy window in IRS 4. Irinotecan may be a useful adjunct to current VAC regimen for treatment of advanced RMS. Side effects of chemotherapy include infertility on exposure to alkylating agents and cardiotoxicity after anthracycline exposure. Also there is risk of second malignancy induced by chemotherapy. Recurrent orbital RMS is less common. If recurrence is still confined to orbit, patient should undergo orbital exenteration. Factors associated with better prognosis of recurrent disease include embryonal or botryoid histology and stage 1 /group 1 disease. 95% of all failures occur within 3 years of treatment initiation. Pattern of relapse is local 35%, regional 16%, distant 41%, unknown 8%. Median survival from first recurrence or progression was 0.8 year, and estimated 5- year survival after recurrence was 17%.

According to Indian Journal of cancer volume 44 issue 3 2007, Primary modality of treatment of RMS is combined radiotherapy & chemotherapy which appears to permit effective control & possible care of this disease. At the time of biopsy maximum debulking is essential. Exenteration eventhough mutilating procedure is indicated in case of incomplete tumour regression or in case of recurrence after treatment with radiotherapy & chemotherapy.

According to Int.J . Radiation oncology Biol Phys 2012 jun1;83(2);720-6, Local control of reduced dose radiotherapy for low risk RMS-a report from children’s oncology group D9602 study results were comparable with IRS group 3 & 4 results that reduced dose of radiation doesnot comprisme local control for patients with microscopic tumour after surgical resection or with orbital primary tumours when cyclophosphamide is added to the treatment program.

According to Nepal J opthal. 2011 july-dec 3, Limits & chances in an unfortunate course of recurrent orbital RMS describes a child suffering from Embryonal RMS which didnot enduringly respond to multimodal therapy including local excision and exenteration.

According to Journal of Clinical Oncology volume 29 number 10 april 1 2011, Results of Intergroup RMS study Group D9602 protocol , using vincristine & dactinomycin...
with or without cyclophosphamide & radiation treatment for newly diagnosed patients with low risk Embryonal RMS; a report from soft tissue sarcoma committee of children’s oncology group. five year FFS & OS rates were similar to those observed in comparable IRS-3 patients, including patients receiving reduced radiation doses but were lower than in comparable IRS -4 patients receiving vincristine dactinomycin and cyclophosphamide. 5 year FFS rate were similar when VA / VA + cyclophosphamide was given.

**Conclusion**
A case of orbital embryonal Rhabdomyosarcoma of stage 1 being a low risk tumor with low recurrence rate, eventhough recurrent diseases are reported, effectively treated by total excision of tumour. Along with which chemotherapy VAC regimen can be started. Radiotherapy is questionable since studies showing its complications are much more devastating in an 8 year old boy than its recurrence rate. He should be under regular follow up so that we can pick up recurrence at the earliest if any.

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9. Duanes clinical ophthalmology- acute onset of proptosis in children

Anima M et al - A Case Of Proptosis

Anima is a Postgraduate in Ophthalmology at Calicut Medical college
Changing Trends

Refractive Lenticule Extraction- A New Application for Femtosecond Laser

In the mid 90s lasers were developed that would generate pulses of such short duration that minimal pulse energy would be required. So the lasers moved on from photodisruption and photoablation to photo dissection. This ultra short pulse lasers were called femtosecond lasers. There was so little effect to the surrounding tissues that it could be used cut highly explosive devices without the danger of detonation. IBM uses femtosecond laser in manufacturing microchips.

Ron Kurtz, MD, and Tibor Juhasz, PhD, the founders of IntraLase Corp, who between 1995 and 1997 developed the IntraLase Femtosecond Laser at the University of Michigan. In 2000, a corneal flap created by femtosecond laser along with excimer laser myopic correction was conducted on a patient for the first time. The companies now involved in the femtosecond laser for LASIK are AMO Intralase [60 & 150 khz], Alcon Wavelight FS 200[200 khz], Bausch & LombTechnolas Perfect Vision F520 [80 khz]{Carl Zeiss Meditec Visumax [500 & 200 khz]} and Ziemer Femto LDV (> 5 Mhz).

Basics

A femtosecond laser is an infrared laser that works at a wavelength of 1053 nm. It emits ultrashort laser pulses with a diameter of 1micron mm at one-billionth of a second (10^-15 s). Sharply focused laser pulse of an ultra-short duration generates plasma. Plasma expands and displaces surrounding tissue. When many of these bubbles are applied in the corneal stroma they expand separating the corneal lamellae. The emerging mixture of CO2 and water gets absorbed, leaving the separated corneal tissue behind. With the femtosecond laser, tissue can be cut very precisely and with practically no heat development. The laser pulses deploy their energy at an exactly defined depth inside the cornea. Typically each laser pulse consists of a low energy one repeated at a high frequency. Less energy translates to less heat generation and less collateral damage. With improvement in technology very low energy pulses [0.8 to 1 microjoules] are delivered into the stroma at high speed(60 khz to 1 Mhz) resulting in smooth stromal bed in minimum possible time6 -13.

Laser Power (in milliwatts [mW]) = Energy (in millijoule) / Time (in seconds)

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Uses of femtosecond laser
Refractive surgery

1. The main use is making precise flaps in LASIK. The machine can be programmed to produce flaps at different depths, change the angle of the cut and customize the hinge position according to the surgeons’ requirement.

2. It can be used to create penetrating or non-penetrating arcuate incisions for astigmatism. The femtosecond laser provides reproducibility, reduced variability compared with manual incisions, and it’s almost impossible to perforate the eye.

3. It can be used for correction of refractive errors without using the excimer. A refractive lenticule is carved within the cornea, and removed- ReLex (Refractive Lenticule Extraction) or SMILE (Small Incision Lenticule Extraction) – detailed later.

Keratoplasty

It can be used to make accurate cut for penetrating and lamellar keratoplasties. The side cuts can be customized so that it seals better. Radial alignment marks can be made to align the host and donor accurately. This could decrease the astigmatism seen in keratoplasties.

Keratoconus

It is used to create channels for placement of intracorneal ring segments in keratoconus. This is an easier and safer procedure than using a mechanical device. Femtosecond is also being investigated to deliver the riboflavin intrastromally for corneal collagen crosslinking without removing the epithelium.

Cataract surgery

Cataract surgery is soon becoming the most exciting application of the femtosecond laser. It is used for creation of the incisions, creating well centred accurately sized capsulorhexis and for nucleus disassembly.

Femtosecond laser technology and application in ophthalmology has evolved dramatically in the last decade. Advantages of the femtosecond flap in LASIK include: a smoother bed surface- Though tissue bridges between laser spots was a problem with earlier models [Intralase 10khz], the newer models Visumax 500 khz, Allegretto FS 200 khz and Intralase 150khz render excellent surface characteristics comparable to or better than microkeratome. Consistent thin flaps, which again is much better with the newer models [3] probably more stable flap architecture - vertical orientation of the flap cut is likely to make it more stable than a meniscus configuration seen with mechanical microkeratome [4] spares peripheral cornea - as smaller flap size can be designed and [5] not dependent on corneal curvature - with microkeratome, flat corneas [< 38 D] have a much higher risk of free cap and steep corneas [> 48 D] have a risk of button hole as mechanical movement of microkeratome is involved.

Disadvantages include: [1] high cost, [2] more expenditure of time is required, after flap creation with femtosecond laser, patient has to be shifted towards excimer laser, [3] sub conjunctival haemorrhage, [4] transient light sensitivity syndrome (TLSS) – photophobia with no other signs or symptoms seen in people who undergo femtosecond LASIK believed to be due to subclinical inflammation caused by gas bubble escaping to the ciliary body region during flap creation [5] high incidence of diffuse lamellar keratitis (DLK) or interface inflammation. The incidence of both TLSS and DLK has vastly reduced with new generation lasers with high frequency, but low energy delivery in stroma.

Refractive Lenticule Extraction [ReLex]

ReLex is a new group of corneal refractive procedures in which a stromal lenticule is removed mechanically after cutting it using high-precision femtosecond laser, thus altering the corneal curvature thereby correcting the refractive error. Marcus Blum and Walter Sekundo, principal investigators of Visumax (Femtosecond laser division of Carl Zeiss) first did this procedure in 2007. There are 2 types of ReLex procedures [1] ReLex flex [Femtosecond lenticule extraction] and [2] ReLex smile [Small incision lenticule extraction]

ReLex flex involves creation of a hinged flap and a stromal lenticule in one step using femtosecond laser. After lifting the flap, lenticule is removed manually after dissecting it. The flap is then repositioned and allowed to dry as in LASIK.

Surgical steps of ReLex flex

Step 1 – A 3-dimensional lenticule and flap is sculpted in the corneal stroma.
Step 1 – A lenticule and 4 mm side cut is made in a single step

Step 2 – Flap is opened, lifted and folded back

Step 2 – The lenticule is separated and removed through small incision

Step 3 – Lenticule is separated from the stroma and mechanically removed

Step 3 – Removal of lenticule alters the corneal shape and refractive status

Step 4 – Flap is repositioned and allowed to dry

Surgical steps of ReLex smile

ReLex smile [small incision lenticule extraction] is a further advancement of ReLex in which there is no flap creation. The advantage of not creating a flap is minimal disruption of corneal biomechanics. Through one or two 4 mm sidecuts, the stromal lenticule is separated and removed to achieve the refractive result.

Advantages of ReLex over regular / femtosecond LASIK

1. There is only mild elevation of IOP during the procedure
2. No black out during suction
3. No smell of fumes during the procedure
4. Better work flow – as the whole procedure can be done
with one laser, which obviates the need to shift the patient for excimer laser ablation.

### Additional advantages of ReLEx smile

[5] No flap lifting, hence minimal disruption of subepithelial nerve plexus and so much less postoperative dry eye

[6] Less symptoms (foreign body sensation) immediately following procedure as the incision is very small.

**Disadvantages**

[1] Lenticule extraction can be difficult at least in some cases

[2] Learning curve

[3] Too thin a lenticule in low myopia

[4] Slightly delayed visual recovery compared to LASEK.

**OUTCOME**

Blum M et al in a prospective study of 108 myopic eyes of 56 patients who underwent ReLex Flex found that at 6 months follow-up period 98.1% of treated eyes were within +/-1.0 D, and 74.8% of eyes within +/-0.5 D of the intended correction. The patients' mean age in this study was 35 years. The preoperative mean spherical equivalent (SE) was -4.59 +/- 1.3 diopeters (D) and postoperative spherical equivalent was -0.19 +/- 0.47 D. Eight (7.4%) of 108 eyes lost one line of Snellen VA, one (0.9%) eye lost two Snellen lines, 46 eyes (43%) gained one line, ten eyes (9.3%) gained two Snellen lines, and the VA remained unchanged in 42 (39.3%) eyes. 97.1% of patients were satisfied with the obtained results and would undergo the procedure again.

Prof. Marcus Blum and Prof. Walter Sekundo, principal investigators for Visumax femtosecond laser from Germany have recently come out with the 5 year results of their initial ReLex flex cases treated in 2006 (unpublished data). 88% of the eyes achieved UCVA of 20/25 and 77% achieved 20/20 (slight undercorrection was planned).

Rupal Shah, from India reported better results with ReLex smile in 2011 in which 51 eyes of 41 patients were enrolled. The mean spherical equivalent was -4.87 diopeters (D) ± 2.16 (SD) preoperatively and +0.03 ± 0.30 D 6 months postoperatively. Refractive stability was achieved within 1 month (P<.01). Six months after surgery, 91% were within + 0.5 D and 100% were within + 1.0 D. 79% of all full-correction cases had a UCVA of 20/25 or better. The 6-month postoperative BCVA was the same as or better than the preoperative BCVA in 95% of eyes. Two eyes lost 1 line of BCVA.

### ReLex flex vs LASEK

Vestergaard A, Iversen A, Asp S, Hjortdal JOS from Denmark compared 40 patients who underwent ReLex flex with 41 patients who underwent Femtosecond (FS) LASEK in moderate to high myopia. Preoperative spherical equivalent (SE) averaged -7.50 ± 1.16 D for ReLEX and -7.32 ± 1.09 D for FS-LASIK. Postoperatively, mean SE was -0.06 ± 0.35 D 3 months after ReLex and -0.53 ± 0.60 D after FS-LASIK. For eyes with emmetropia as target refraction, 41% of ReLEX and 61% of FS-LASIK eyes had an uncorrected distance visual acuity of logMAR ≤ 0.10 at day 1 after surgery, increasing to, respectively, 88% and 69% at 3 months. The proportion of eyes within ±1.00 D after 3 months was 100% (ReLEX) and 85% (FS-LASIK). For a 6.0-mm pupil, corneal spherical aberrations increased significantly less in ReLEX than FS-LASIK eyes. They concluded that results of ReLEX were comparable to FS-LASIK. Refractive predictability and corneal aberrations at 3 months seemed better than or equal to FS-LASIK, whereas visual recovery after ReLEX was slower.

Similar results were reported by Gertnere J et al who compared the one year results of ReLEX flex technique (44 eyes with a preoperative SE of -5.13 D) to wavefront-optimized Femto-Lasik (50 eyes with a preoperative SE of -5.42 D) in myopia and astigmatism found similar refractive outcomes. Postoperative SE in the ReLEX group was -0.23 ± 0.35 D and in the Femto-LASIK group was -0.15 ± 0.27 D. However, the mesopic contrast sensitivity of ReLEX-treated eyes at 12 and 18 cpd improved from 1.49 and 0.99 to 1.54 and 1.1 respectively. In the Femto-LASIK group the numbers were pre-op 1.51 and 1.03, and after 1 year 1.54 and 1.06. The high-order aberrations (HOA) after ReLEX changed from 0.15 to 0.23 μm, and after Femto-LASIK from 0.175 to 0.320 μm (p = 0.0023). They used Carl Zeiss Meditec VisuMax (200kHz) femtosecond laser system and Carl Zeiss MEL 80 excimer laser with an aspheric treatment profile.

### Postoperative dry eye after ReLEX

Dry eye following LASIK is related to severing of superficial nerve plexus with resultant decrease in corneal sensitivity. Wei S et al found that postoperative corneal sensitivity was not remarkably changed after ReLEX smile surgery compared with FS-LASIK. This might be because ReLEX is a flapless procedure.

### CONCLUSION

Technological advances in the last decade have made femtosecond laser a much more powerful tool in ophthalmology. Refractive lenticule extraction appears a great step forward in the application of technology with advantages over LASEK.

### REFERENCES


2) Blum M, Kunert K, Schröder M, Sekundo W. Femtosecond...


Dr Anil Radhakrishnan, after his MS from RIO Bangalore got his corneal training from LV Prasad Institute Hyderabad. He is now Head of Corneal Services at Amrita Institute of Medical Sciences, Kochi.
The evolution of modern cataract surgery has been from large incision extra capsular extraction with a basic monofocal intraocular lens to micro incision surgeries with advanced lens technology. Since its introduction, phacoemulsification technology has rapidly developed through improvements in intraocular lens technology, energy delivery, system fluidics and instrumentation. With the advent of multifocal and accommodating intraocular lenses and patients pursuing surgery earlier because of less tolerance for visual impairment, cataract surgeons are facing increasingly high patient expectations for refractive outcome. With the recent application of femtosecond laser in cataract surgery, premium intraocular lenses will have better results because of involvement of fewer variable factors.

Femtosecond lasers have been used in ophthalmic surgery since 2001 when they were introduced for the purpose of flap creation in laser in-situ keratomileusis (LASIK) 1. The flaps created by femtosecond lasers were more reproducible, uniform, closer to their intended thickness and centration and had improved safety profiles compared with those made by manual keratome. The application of femtosecond lasers in corneal refractive surgery clearly demonstrated increased precision of corneal tissue photo disruption while avoiding significant collateral damage 2,3,4. Today, cataract surgery is the most commonly performed surgical procedure in the world, with an estimated 19 million operations performed annually 5. The early success and wide acceptance of femtosecond lasers for flap creation and astigmatic keratotomy have stimulated the development of this technology for laser-assisted or femtosecond cataract surgery 6,7. Femtosecond laser for cataract surgery was first used by Professor Zoltan Nagy in Budapest, Hungary in 2008 8.

Femtosecond laser-assisted cataract surgery represents a potential paradigm shift in cataract surgery, but has also generated considerable controversy. Advocates of the technology suggest that the use of femtosecond laser precision will deliver superior outcomes, an improved safety profile for patients and pave the way for further advances in the field. Conversely, detractors point to the large financial costs involved and claim that similar results are achievable with conventional small-incision phacoemulsification.

**Mechanism of Action**

The femtosecond laser used in ophthalmic applications is in the near-infrared wavelength of light (1030 nm) similar to the neodymium:yttrium aluminum garnet (Nd:YAG) laser, with the exception that it has significantly shorter pulse duration. This enables a different way of laser-tissue interaction called ‘laser induced optical breakdown’, which means that the laser produces smaller shockwaves and cavitation bubbles affecting tissue volumes than what is seen with a picosecond laser such as the Nd:YAG. Ultra short laser pulses used in femtosecond lasers can ablate a very small fraction of tissue. No heat is generated during the ablation process. This attribute of femtosecond laser is especially important for cataract surgery wherein preservation of ocular structures is critical for good visual outcomes.

### Table 1: Comparison of parameters in corneal and cataract femtosecond laser technologies

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Corneal Lasers</th>
<th>Cataract Lasers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wavelength</td>
<td>1030–1060 nm</td>
<td>1030–1060 nm</td>
</tr>
<tr>
<td>Pulse duration</td>
<td>200–800 fs</td>
<td>600–800 fs</td>
</tr>
<tr>
<td>Pulse energy</td>
<td>≤1 µJ</td>
<td>8–15 µJ</td>
</tr>
<tr>
<td>Repetition rate</td>
<td>60–250 kHz</td>
<td>33–80 kHz</td>
</tr>
<tr>
<td>Scanning range</td>
<td>10 mm in diameter</td>
<td>12 mm in diameter</td>
</tr>
<tr>
<td></td>
<td>1 mm in depth</td>
<td>8 mm in depth</td>
</tr>
<tr>
<td>3D imaging</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Femtosecond laser can be focused with precise accuracy at different depths, using a guidance system to create the corneal incisions, astigmatic keratotomy, capsulotomy, and nuclear fragmentation. The focused laser energy increases to a level where plasma is generated. The plasma expands and causes a shockwave, cavitation, and bubble formation. The bubble then expands and collapses, leading to separation of the tissue. Because femtosecond lasers function at nearly an infrared wavelength, they are not absorbed by optically clear tissues. This allows the femtosecond laser to be used on the anterior segment of the eye as the anterior chamber provides an optically clear tissue pathway. This wavelength of light is not absorbed by the cornea. The shock waves generated by femtosecond photodisruption dissipate within approximately 30 μm of the targeted tissue thus protecting the posterior capsule and corneal endothelium. The surgical effect is achieved by delivering thousands of individual laser pulses per second to produce tissue separation or continuous incisions. Optical imaging is critical for the development of the femtosecond laser for cataract surgery. A higher laser energy level is required for fragmentation of the crystalline lens compared to cuts within the cornea.

Femtosecond lasers have been successfully used in the creation of the LASIK flap. The development of laser cataract surgery using 3-dimensional segmentation of the crystalline lens requires different laser parameters. Because of the large focal depth required, the beam diameter must be increased compared to that required in corneal surgery. This requires a higher threshold energy for fragmentation of the lens. The differences in 2 systems are summarized in Table 1.

Currently there are four femtosecond laser systems. These systems include LenSx® laser (Alcon, Fort Worth, Texas), Catalys (OptiMedica Corporation, Santa Clara, California), LENSAR™ laser (LENSAR Inc., Orlando, Florida), and VICTUS™ (Bausch + Lomb and Technolas Perfect Vision GmbH). The LenSx system was the first system to be marketed commercially and has received US Food and Drug Administration 501(k) clearance for laser anterior capsulotomy and laser lens fragmentation. Currently, the LensAR system has also received US FDA 501(k) clearance for laser anterior capsulotomy and lens fragmentation. All laser systems share a common platform which includes an anterior segment imaging system, patient interface and femtosecond laser to image, calculate and deliver the laser pulses. The specific technology to achieve these steps differs between the individual lasers with notable differences in imaging and docking systems and laser treatment algorithms. These features are summarized in Table 2.

### Femtosecond Laser Cataract Surgery: Surgical Technique

Detailed planning of each stage of the operation is required in the first phase. This involves assessing the anatomy of the patient’s eye, taking into account pupil diameter, anterior chamber depth, and thickness of the lens and cornea. Size, shape, and centration of the capsulotomy are then calculated, with the choice of IOL in mind. The type of lens fragmentation or liquefaction is chosen and customized by the surgeon, as this will have a bearing on the amount of phaco time and power, which is required subsequently. Parameters for the location, structure, and depth of the clear corneal incisions (CCIs) are fed into the system. If astigmatic relieving incisions are to be performed, their depth, length, and axis are currently determined by traditional nomograms.

Laser cataract surgery requires dilatation of the pupil and topical anesthesia, followed by applanation of the cornea with a docking system that distributes pressure evenly on the cornea. The docking system minimally distorts anterior segment anatomy and increases IOP.

<table>
<thead>
<tr>
<th>Docking mechanism</th>
<th>LensAR</th>
<th>LensX</th>
<th>Optimedica</th>
<th>Technolas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imaging system</td>
<td>Fluid filled interface</td>
<td>Curved applanating contact lens</td>
<td>Liquid optics interface</td>
<td>Curved interface with intelligent pressure control</td>
</tr>
<tr>
<td>Treatment algorithm</td>
<td>3D confocal (Scheimpflug)</td>
<td>Real-time OCT</td>
<td>High-resolution OCT</td>
<td>Real-time OCT</td>
</tr>
<tr>
<td>US FDA approvals</td>
<td>Anterior capsulotomy, lens fragmentation</td>
<td>Anterior capsulotomy, lens fragmentation</td>
<td>–</td>
<td>–</td>
</tr>
</tbody>
</table>

### Table 2: Main features of the different femtosecond cataract surgery laser systems
Docking of the eye into the LASIK interface is known to cause a significant rise in intraocular pressure, in the order of ≥80 mm Hg 10,11. This rise in intraocular pressure is likely to be more problematic in elderly cataract patients, with the risk of ischaemic retinal and optic nerve injury. In particular, patients with advanced glaucoma may be at risk of ‘snuff-out’. For this reason, the developers of FLACS platforms have been compelled to devise alternative methods of stabilizing the patient’s eye within the optical system, while reducing intraocular pressure rise and anatomical distortion. LenSx uses a curved contact lens, which applies the cornea and produces an IOP rise of up to 40 mm Hg 12. OptiMedica’s liquid optics interface has been found to generate an intraocular pressure rise of 15 mm Hg 13.

Friedman et al 13 reported, with the Catalys platform (which has a liquid optic interface) that the average rise in IOP is 10 mm Hg and avoids corneal folds. The other laser platforms did not report a degree of IOP rise in their study.

Once the docking has been completed, high-resolution, three-dimensional, wide-field imaging of the anterior segment is performed. Detailed visualization of the cornea, iris, iridocorneal angle, and lens (including anterior and posterior capsule) is the key to success and safety with FLACS. The accuracy of OCT imaging is critical to specify boundaries, including the iris and the posterior surface of the lens. Inaccuracy at this stage increases the risk of incomplete capsulotomy, imprecise corneal incisions, damage to the iris, and posterior capsular rupture. The surgeon can program the location of the corneal incisions for the wound, paracentesis and any limbal relaxing incisions. LenSx, Catalys (Optimedica), and VICTUS (Technolas Perfect Vision) systems utilise Fourier-domain optical coherence tomography while LensAR employs a confocal structured illumination-scanning transmitter system similar to the Scheimpflug imaging systems developed for corneal topography 7.

Each laser incision is constructed in the postero-anterior plane, a principle that elegantly employs the posterior microcavitation bubbles to scatter the laser beam and reduce the amount of energy reaching the retina. By keeping the bubbles posterior to the laser target, the focus of the laser beam is maintained and this avoids scatter before the target tissue 14.

Laser-assisted anterior capsulotomy is performed before lens fragmentation because gas bubbles form during lens fragmentation. This could potentially stretch and displace the lens capsule from its original position, causing the laser pattern to miss the capsule.

After the capsulotomy step, the lens fragmentation patterns are applied starting from the posterior part of the lens and moving anteriorly. Gas formation during lens fragmentation can help separate the horizontal lens lamella, which can further enhance the softening of the nucleus. Expansion of the lens as a result of gas formation occasionally can lead to lifting of the capsulotomy disk.

Corneal incisions are performed as the last step prior to moving the patient into the operating room. In the operating room, the corneal wound and paracentesis are opened. The anterior capsulotomy is removed with forceps using a circular movement similar to a capsulorhexis. This technique is safer than just pulling it out in case there are any remaining bridges connecting the central disk to the capsular bag. This is followed by removal of the cataract using significantly less ultrasound energy.

The three companies differ in the order of incision delivery. The OptiMedica system delivers the capsulotomy first, and then the lens fragmentation pattern. With accurate surface identification, the capsulotomy depth can be minimized to reduce bubble generation and eliminate interference with subsequent incisions. This sequence reduces the risk of tearing the capsule bag or creating zonular dehiscence because the lens is allowed to relax as it is fragmented. With the LenSx system, the lens is fragmented, the capsule is reimaged for expansion and then the capsulotomy is made 18.

**Femtosecond laser applications in cataract surgery**

Femtosecond lasers can assist or replace several aspects of traditional cataract surgery, including a clear cornea incision, correction or reduction of astigmatism, through arcuate corneal incisions, anterior capsulotomy and fragmentation of the lens.

1) Clear corneal incisions:

Even though clear corneal incision is the preferred method of access into the anterior chamber because of the many described advantages of clear corneal incisions like rapid recovery of vision, preservation of the subconjunctival space for future filtering procedures, improved visibility during phacoemulsification due to the shorter tunnel etc., there are reports of increased incidence of endophthalmitis related to the use of clear corneal incisions 15. Although the incidence of endophthalmitis is only 0.13 % 15 this remains the most feared complication of cataract surgery with a potential devastating impact.

Manually created incisions have potential for leakage because of difficulty in controlling the ideal length and architecture of the incision. A poorly constructed clear corneal incision may result in leakage, hypotony, iris prolapse or endophthalmitis. Incisions created with blade will typically have the simple
uniplanar configuration and fluid may leak in and out of the eye which increases the risk of endophthalmitis. Femtosecond laser has the potential to create a more square architecture using complex multiplanar incision (Fig 1), the interlocking zig-zag design which could provide a more stable wound configuration that is more resistant to leakage. Xia et al 16 in their study utilizing anterior segment OCT demonstrated that the majority of eyes had an internally gaping corneal wound and detachment of Descemet’s membrane. It is hypothesized that these clear corneal wound abnormalities may be a factor in increasing the risk of postoperative endophthalmitis. Laser made wounds show less features of damage and faster healing properties by virtue of the wound properties and reduction in intra operative mechanical damage.

Fig 1: Customized corneal wound architecture with a multiplanar configuration to reduce leakage and induced astigmatism

2) Astigmatism Correction : Relaxing Incisions
The ability of femtosecond laser to perform intra stromal relaxing incisions to reduce preexisting astigmatism is a potentially significant benefit. Laser system can correct up to 3.5 D of astigmatism, flattening the steepest corneal meridian 17. An axis misalignment of just 50 results in a 17 % reduction in effect 17.

Manual relaxing incisions often lack consistency as the cuts suffer from an imprecise depth, length, position and shape. Even when the blade depth is customized, by modifying the depth of corneal incision based on pachymetry, the ultimate outcome depend on surgical expertise, the quality of the cutting blade and resistance of the corneal tissue. Reproducible and precisely placed laser incisions have the potential to improve outcomes compared to manually performed incisions. Femtosecond laser systems can deliver reproducible cuts at a precise location, depth, angular orientation and length 18. Since these intrastromal incisions do not penetrate the corneal epithelium or posterior surface of the cornea, femtosecond laser can potentially minimize postoperative discomfort, epithelial wound healing, infection and tear film disruption.

3) Anterior Capsulotomy:
A continuous curvilinear capsulotomy is a critical step in cataract surgery. However in conditions like corneal scarring, a shallow anterior chamber, weak zonules, fibrotic anterior capsule, poor red reflex, deep set eyes and in intumescent white cataracts, the possibility to create an intact capsulorhexis with the desired diameter is remote. A properly sized, shaped and centred capsulorhexis enhances safe hydrodissection of the lens, nuclear disassembly and removal, cortex clean up, IOL positioning and centration and prevention of posterior capsule opacification.

The capsulotomy is also closely related to the effective lens position (ELP) and it has been found that imprecise estimation of the ELP is the single biggest cause of inaccurate IOL power calculation 19. A small capsulorhexis (<5.5mm) is more likely to develop anterior capsule fibrosis and hyperopic shift while a large capsulorhexis can lead to increased chance of developing IOL tilt and decentration since there is insufficient overlap of the IOL by the capsule. An irregular capsulorhexis may lead to a reduction in visual results, including higher order aberration that are difficult to tolerate due to optical decentration and lens tilt 20. Tilt, rotation, decentration, and changes in ELP may have even more profound effects with toric, accommodating and multifocal IOLs. All of these factors have implications for the final refractive outcome, while also increasing the risk of aberrations such as astigmatism, halo and coma. Ideally, the capsulotomy should be perfectly circular and overlapping the IOL optic by 0.5 mm for 360 degrees 13. These factors are of great significance when considering the newest IOL designs. One example is the dual-optic accommodating IOL, whose accommodative ability depends on movement of the anterior optic with ciliary contraction and relaxation. This relies on the IOL being fully overlapped by the anterior capsule, without which the anterior optic may prolapse out of the capsular bag 21. The remarkable potential of these more complex IOLs may not be fully realised with the current limitations imposed by the relative imprecision of the manual capsulorhexis. Indeed, a suboptimal capsulorhexis is a relative contraindication for an accommodating IOL.

Although there are variations between the LenSx, LensAR and Catalys systems in their capsulotomy results, they are united by increased precision and circularity relative to manual capsulorhexes 22. The LenSx and Catalys systems have also been reported to give improved results for IOL centration when compared with the manual technique. Using LenSx, Kranitz et al 22 found the improved IOL centration to remain statistically significant at 1 year postoperatively. In this study, horizontal and vertical IOL centration was found to worsen
more over the first year with manual capsulorhexis than with femtosecond capsulotomy (anteroposterior IOL position was not evaluated). This was presumed to be a result of asymmetric capsular contraction, although interestingly the study found no significant difference in circularity between femtosecond capsulotomy and manual capsulorhexis after 1 month. The authors concluded that the risk of IOL decentration was six times higher with manual capsulorhexis than with femtosecond capsulotomy (anteroposterior IOL position was not evaluated). This was presumed to be a result of asymmetric capsular contraction, although interestingly the study found no significant difference in circularity between femtosecond capsulotomy and manual capsulorhexis after 1 month. The authors concluded that the risk of IOL decentration was six times higher with manual capsulorhexis than with femtosecond capsulotomy. Gred Auffarth et al 24 demonstrated in their laboratory pig eye study that femtosecond laser assisted capsulotomy resulted in a significantly stronger anterior capsule opening than the manual technique; the mean deviations from circularity were 6 % and 20 %, respectively. Nagy et al 7 demonstrated in porcine eyes that femtosecond laser capsulotomies were more precise and rounder than those with manual technique. They also showed that the capsule strength was as good or greater with femtosecond laser than a manual capsulorhexis enabling a greater force of stretch before rupture. The average strength of the capsule after manual capsulorhexis was 66±22 mN; after laser capsulotomy, it was more than twice as high: 152±21 mN. The creation of a stronger capsule edge may help reduce the probability of rupture of the capsule during lens emulsification, as well as insertion of an IOL. Gred Auffarth et al 24 in their laboratory pig eye study demonstrated that femtosecond laser assisted capsulotomy resulted in a significantly stronger anterior capsule opening than the standard manually performed capsulorhexis. The mean rupture force (that is, maximum amount of force measured immediately before tissue rupture) was 113 mN +/- 12(SD) for the laser assisted procedure and 73 +/- 22 mN for the manual procedure. Thus femtosecond laser assisted capsulotomy improves the strength of the capsulotomy, by more than a factor of 2, compared to the manual technique which makes the capsule manipulation during phacoemulsification and IOL insertion safer.

FLACS in Infants:
Anterior and posterior capsulotomies in early pediatric cataract surgery are often challenging 25. The primary posterior capsulotomy is a particularly difficult but necessary step to prevent posterior capsule opacification (PCO). Up to 100 % of young children (0 to 7 years) will develop with obstruction of vision when the posterior capsule remains intact 26. Today, the manual posterior capsulorhexis is one possible technique. In pediatric cataract surgery, the prerequisite for satisfactory results is well-centered and sized anterior and posterior capsulotomies. However, elasticity of the capsular bag is higher than in adult cases, which is why the rhexis is more difficult in infants and frequently ends up too big or with capsule tears. The use of a femtosecond laser with a non-applanating interface has great potential for successful performance of precisely centered, circular, continuous anterior and posterior capsulotomies that can be aligned with each other 26.

4) Lens fragmentation:
Nuclear disassembly is one of the most complicated steps of phacoemulsification and involves controlled, systematic breaking up and removal of the nucleus and requires a number of intraocular surgical maneuvers. Phacoemulsification can be considered successful not only by complete removal of lens material but removal should be performed in such a way that safeguards the surrounding ocular structures such as capsular bag and corneal endothelium from iatrogenic damage. Femtosecond lasers fragment the nucleus reducing the ultrasound energy required and also the effective phaco time. Nagy et al 7 demonstrated that in porcine eyes, application of femtosecond laser resulted in a 43 % reduction in phacoemulsification power and a 51 % decrease in phacoemulsification time. No complications were reported in the study. Femtosecond laser treatment thus diminishes the risk of capsule complications and corneal endothelial injury 27-29. It also allows surgeon to strip the sculpting and chopping steps thereby reducing the number of instruments used and intraocular manipulations. Excessive use of ultra sound energy during phacoemulsification can result in corneal endothelial damage as well as thermal injury to the corneal wound. In cases with weak zonules, techniques to fracture the nucleus result in further zonular dehiscence. This reduction in energy may be advantageous for patients who are at high risk for corneal decompensation, such as those with shallow anterior chamber, dense cataracts, Fuch’s dystrophy, prior corneal transplants or those with marginal corneal endothelial function.
Customized laser lens fragmentation profiles (algorithms) can be pre-programmed and incorporated into the femtosecond laser systems software. The choice of treatment algorithm depends on surgeon preference and nuclear density.

**Femtosecond laser and Macular Oedema**

Subclinical macular oedema is a common complication of conventional phacoemulsification. In a study 12 comparing the macular effects of FLACS versus conventional surgery with a ‘divide and conquer’ technique, significant less thickening of the inner macular ring was found to be in the FLACS group at 1 week postoperatively (mean difference of 21.68 μm, P<0.001) 12. This difference between the FLACS and control groups reduced after 1 month and no longer attained statistical significance, but the authors suggested that reduced subclinical oedema in the early postoperative phase could be beneficial for patients at risk of developing clinically significant cystoid macular oedema later on 12. No statistically significant differences between the two groups were found in terms of foveal thickness, total macular volume, or outer macular ring thickness. These findings may be relevant when considering patients deemed to be at high risk of developing postoperative inflammation, cystoid macular oedema, and diabetic maculopathy. However, long term studies are required to fully investigate this potential benefit. Little is known about the effects of FLACS on age-related macular degeneration (ARMD).

**Advantages of Femtosecond Laser-Assisted Cataract Surgery:**

- Reduced risk of intraoperative complications, especially in more complicated forms of cataract.
- The laser allows accurate positioning and centration of the artificial intraocular lens, reducing optical aberrations and refractive errors.
- More predictable surgery by using laser to perform some of the manual steps of surgery.
- The small curved patient interface of the laser prevents flattening of the cornea and the pressure sensors moderate excessive pressure on the eye to prevent vision “blackout” during laser procedure.
- Potential to reduce the risk of capsular tear and intraoperative complications during cataract surgery due to a stronger capsule.
- OCT imaging function of the laser platform which tracks progress of the procedure and gives real time feedback of eye images to the surgeon during the entire surgical process providing an added level of safety to patients.
- Lens fragmentation by laser reduces the amount of ultrasound energy used during phacoemulsification, reducing risk of capsule complications and corneal injury.
- Using the laser system reduces phacoemulsification power and results in reduction in effective phacoemulsification time.

**Limitations/Contraindications of Femtosecond Laser:**

Femtosecond cataract surgery is relatively contraindicated in patients in whom the initial docking can be difficult, including those with deep-set orbits, small fissures, or who suffer from significant tremors and inability to lie flat. Since patient co-operation is required, patients with dementia may not be satisfactory candidates.

The risk of IOP induced by the docking device, which has not been quantified with all systems, may preclude its use in patients with glaucoma or optic neuropathies.

Patients with poor dilatation, such as those on chronic miotic medications or with posterior synechiae, are also poor candidates.

Eyes with zonular dialysis or phacodonesis may not be ideal candidates because of instability of the lens during docking. It is unlikely that mild corneal opacification will preclude the use of the laser in cataract surgery. The femtosecond laser with a near-infrared wavelength of 1030 nm is scattered much less than visible light (400-700 nm). Corneal opacification may hamper absorption of the laser, and therefore affect the quality of corneal incisions. Significant central corneal scarring thus may be a limiting factor.

As with the introduction of any new technology there appears also to be a learning curve to the procedure. The femtosecond laser machine is placed outside the operating theatre in a specially designed room. Following the laser ablation, the patients are moved into the surgery preparation rooms.

This may cause an increase in the average time for each case. However, this can be dealt with efficient utilization of resources and better time management.

**Complications:**

Docking technique is essential for excellent surgery. Poor quality docking can lead to tilting of the capsule and lens. Good quality docking technique leads to a more certain capsulotomy and nuclear fragmentation. Complications can occur with a poor docking technique, which may result in an incomplete capsulotomy, capsular tags, and a secondary anterior capsule tear formation. It is important for the surgeon only to proceed only after proper docking. An anterior capsular tag requires careful surgical management to prevent these tags from extending and becoming an anterior capsular tear.

Small petechial subconjunctival hemorrhages in a ring pattern represent a common postoperative finding secondary to the
suction ring that is applied during the docking procedure. These subconjunctival hemorrhages are similar to LASIK during flap creation and typically resolve in 7–14 days.

Suction breaks can potentially occur at any stage of the laser procedure, which include the capsulotomy, fragmentation of the nucleus, corneal wound incisions, or limbal relaxing incisions. If this occurs, the procedure can be stopped and the rest of the procedure performed manually.

A capsular block syndrome is a rare complication specific to laser cataract surgery which can be prevented by proper technique 30. It is hypothesized that gas is trapped within the crystallized lens during fragmentation, which increases the intracapsular pressure. Subsequent hydrodissection can further increase the pressure within the capsular bag resulting in a posterior capsular rupture. It is believed that cataracts of increasing density are more likely to have gas trapped within the capsular bag, increasing the risk of this complication. Hydrodissection should only be performed after adequate decompression of the anterior chamber. The hydrodissection should be gentle in terms of volume of fluid delivered and force applied.

Financial Considerations:
Despite its perceived benefits, FLACS is not yet widespread, even in high-volume refractive centres. This is largely due to the significant financial costs involved in its implementation. Although costs are likely to reduce with competition and more entrants to the market, it could be difficult to justify the additional expense, except perhaps in a very high-volume refractive cataract practice.

Future directions:
The use of femtosecond lasers in cataract surgery continues to evolve and with that, its potential applications extend. Laser cataract surgery, with its improved precision and accuracy, may allow better preservation of the biomechanical properties of the lens capsule, enabling the creation of better accommodating IOLs since ultrasound biomicroscopy has demonstrated that the predominant action on the intact human lens is at the level of the anterior capsule 31.

Photodisruption with femtosecond laser has been shown not to cause cataractogenesis or loss of lens function. It has been suggested, through the creation of lenticular incisions across collagen fibrils, that an element of accommodation to presbyopic lenses could be restored. Femtosecond lasers have been studied on the effect to restore accommodation in an aging, stiffening lens by separating collagen fibrils, or increasing the flexibility of the lens with incisions that act as gliding planes 32.

Femtosecond laser has been used to reverse some of the accumulated damages contributing to cataracts and presbyopia. Kessel et al 33 showed that the yellowing in lens color can be reduced by femtosecond laser photolysis. The future of cataract surgery may be treatments that allow the lens to be extracted within a wholly intact capsule and replaced with an injectable polymer. It may be that the natural crystalline lens can have its optical properties restored with laser modifications.

A case series of eight patients has reported success using FLACS with 25-gauge phacovitrectomy 34, which paves the way for combining the technology with other ophthalmic procedures.

It is also possible that a combined machine may be built that includes a femtosecond laser and phacoemulsification. In patients with corneal opacity, it is conceivable that a femtosecond laser could be employed to create a corneal flap and improve visualization before proceeding with FLACS. If FLACS gains widespread acceptance, its improved precision and accuracy may pave the way for further advances in IOL design 35. The new femtosecond laser systems bring us one step closer to an ideal surgery that corrects cataract, astigmatism, and presbyopia.

Conclusion
We are at the beginning of a new era in cataract surgery that may be similar to the transition from ECCE to phacoemulsification in the 1980s and 1990s. It is probable that femtosecond lasers will revolutionize the technique of cataract surgery. Just as for LASIK, femtosecond laser technology can deliver remarkable gains in reproducibility, centration, and safety in cataract surgery, delivering the necessary accuracy and precision to improve beyond current clinical outcomes. The method has shown excellent results for accurate self-sealing corneal incisions, arcuate incisions to reduce astigmatism, highly circular, strong and well positioned capsulorhexis, and safer and less technically difficult removal of the cataract. An improvement in the predicted final resting position of the intraocular lens can significantly enhance the refractive outcome. A precise capsulotomy can reduce implant tilt or decentration and as a consequence reduce higher-order aberrations. The laser technology may allow ophthalmologists to meet the demands of cataract patients to the same level that has been accomplished with LASIK correction. There is a surgical learning curve with laser cataract surgery, and initially it will be more technically demanding and a longer procedure. The implementation of laser cataract surgery into clinical practice should be viewed as an effort to raise our surgery standards to a new higher level of safety and clinical results.
References:
Phacoemulsification is an elegant and safe procedure that provides prompt visual recovery and improved quality-of-life. Advances in phacoemulsification technology and innovations in intraocular lenses have made this technique extremely rewarding to both the surgeon and the patient. Though new generation phacoemulsification techniques have greatly reduced the incidence of complications of cataract surgery, even the most experienced surgeons do face complications during surgery. Surgical complications require careful and skilful management for optimal visual results. The interventions should be aimed at avoiding or minimizing the short term and long term sequelae of these complications.

Complications can happen at any time during the surgery.

**CORNEAL COMPLICATIONS**

**Tunnel related complications**

Tunnel related complications include a short corneal entry, wound leak, and wound burn. A short corneal tunnel predisposes to iris prolapse during and after the surgery and increases the risk of postoperative wound leakage which in turn leads to increased risk of endophthalmitis. Working through a poorly constructed wound damages the wound even further. It is better to close a poorly constructed wound and create a new tunnel at a fresh site. If there is wound burn or if wound leak is noticed at the end of the surgery, it is advisable to suture the wound. Suturing the wound in case of wound burn not only prevents wound gape, it also prevents epithelial irregularity, which may cause irritation.

**Descemets membrane detachment**

If detachment of the small Descemets membrane at the wound is not recognized early, ocular viscoelastic (OVD) or BSS can get injected between the Descemets membrane and corneal stroma causing extensive detachment. Small detachments can be repositioned by causing fluid egress from the anterior chamber by placing pressure on posterior lip of the tunnel. Larger detachments can be repositioned by air injection if noticed on table or postoperatively. Suturing techniques have also been described for management of these cases.

**CAPSULE RELATED COMPLICATIONS**

**Anterior Capsule**

Capsulorhexis (CCC) can run off to the periphery when the pressure inside the capsular bag is high relative to pressure in the anterior chamber. This can happen in intumescent cataracts and also when there is anterior chamber (AC) shallowing after ocular viscoelastic (OVD) leakage. The CCC may be reinitiated after completely refilling the anterior chamber with OVD to tamponade and flatten the anterior capsule. The capsular flap is then unfolded and made to lie flat on the surface of the lens (a viscoelastic like Healon5 would be of great help). The flap is then held firmly at the apex of the tear and pulled backwards circumferentially and towards the centre of the pupil in the direction of the CCC. Once it is safely back at the centre flap is refolded and CCC continued. One can also create a new tear at another site using Vannas scissors or a bent 26-gauge needle to start a new CCC and make sure that the new CCC goes through the periphery of the old CCC.

You tube link: [http://youtu.be/2YJJJNXw828](http://youtu.be/2YJJJNXw828)

**Posterior Capsule related complications**

To properly manage a case of posterior capsular rupture (PCR), its occurrence should be recognized early. When PCR occurs there will be a change in fluid dynamics with a sudden deepening of the anterior chamber with pupillary dilation as the hydrostatic pressures between the anterior and posterior chambers are abruptly equalized. Other signs of PCR include lens material blowing out of the bag, a bounce in the posterior capsule during phacoemulsification, and inability to attract the fragment to the phaco tip as the nuclear fragments do not flow as readily toward the phaco tip when the fluid currents no longer circulate through an enclosed bag and when vitreous clogs the aspiration port. There will also be a difficulty in rotating the nucleus. PCR may reveal itself as linear lines on the posterior capsule with a clear red reflex and star folds appearing during irrigation and aspiration (I/A). The PCR may not be visible because of nuclear or cortical material, but if the surgeon suspects that a tear has occurred, it probably has.
When PCR occurs, priority should be to prevent nuclear material and cortex from falling back into the vitreous. First natural reaction when a surgeon suspects PCR is akin to receiving an electric shock i.e. to withdraw hands away from surgical field. This impulse should be avoided at all costs. Stop phacoemulsification but keep the phaco tip in the eye with irrigation on and inject OVD into anterior chamber through the side port and only then take the phaco tip out. This helps prevent extension of tear and vitreous prolapse if it hasn’t already happened. Use of viscoat helps to support the lens fragments and prevent them from falling down into vitreous during further manipulations. Look out for vitreous above the pupillary plane and at the main wound by using a spatula from the side port to sweep over the iris at the wound and toward the pupil’s edge. Look out for pupil movement while performing the sweeping action. Automated vitrectomy is performed to clear of the vitreous. The vitreous strands can also be cut with the Vannas scissors if only a few strands are present. The nuclear fragments can be phacoemulsified after plugging the PCR with viscoat. Alternatively the fragments may be mobilised into the anterior chamber and taken out by either by extending the wound or by a separate scleral tunnel using a Vectis. If nuclear fragments have fallen into vitreous, leave them to be handled by a vitreoretinal surgeon by pars plana vitrectomy.

Vitreous should be handled carefully. Though a small amount of traction can be absorbed by the vitreous, a larger amount may be transferred through its collagen bundles to the posterior and peripheral retina, resulting in retinal tears and macular edema. For vitrectomy either a coaxial or bimanual vitrectomy system can be used. A bimanual vitrector has several advantages over coaxial vitrector. In a coaxial vitrector since the irrigation port is adjacent to the cutter, when it is used for cutting vitreous, it may cause the tear to enlarge and cause more vitreous to come forward due to local turbulent flow and vitreous volume expansion from hydration. This can be avoided in bimanual vitrectomy in which an additional side port is made to accommodate the vitrector. In a bimanual vitrectomy the irrigation flow can be directed toward the anterior chamber angle since the vitrector and irrigation cannula are separated. The anterior vitrectomy should be aimed at removing vitreous from the anterior chamber and from the entry incisions so that IOL can be safely implanted without vitreous traction. Before placing the infusion into the anterior chamber the bottle height should be lowered to a minimum height, to 15 to 20 centimeters above the eye. After infusion cannula is inserted, the vitrector is placed through the second side port incision. This creates a closed system in which vitrectomy can be done in a controlled fashion.

Removal of these lens fragments can be done with the vitrector by lowering the cut rate to 300 cuts per minute (cpm) and increasing the vacuum. The stiffer nuclear tissues are thus engaged at low vacuum and then molded into the port, to be cut as the vacuum is increased. Larger fragments may require elevation into the anterior chamber with viscoelastic and manual removal. Cortical remnants can be removed by turning off the cutter and using low vacuum to strip them from the bag with aspiration tip of the cutter.

For vitreous removal cut rate should be set high, at 500 to 600 cpm, with low to moderate aspiration for removal of vitreous. This high cut speed causes vitreous to flow continuously into the cutter, so that there is less pulsatile stress on the retina. With the aspiration port facing up anteriorly toward the cornea, the cutter is placed through the capsular tear just below the capsule and maintained in a fairly central position. The vitrector should not be moved peripherally beyond the plane of the iris root to avoid undue stress on the vitreous base. Remove the vitreous to a level just posterior to the capsule.

After vitrectomy IOL implantation can be done depending on the capsule support remaining. In cases of small linear PCR not involving the lens equator, after filling the bag with the OVD, a single-piece IOL may be injected into bag. Alternatively, a small PCR may be fashioned into a stable posterior CCC, allowing safe in-the-bag IOL implantation. If the PCR is large and if the anterior rhexis rim is intact, a three-piece foldable IOL can be placed in the sulcus. Optic edge may then be captured behind the anterior capsular rim. Do not place a single-piece IOL in the sulcus. If the anterior rhexis rim is not intact a three-piece IOL can be placed in sulcus if there is enough anterior capsular support. If there is no capsular support the IOL to be used are anterior chamber, iris fixated or scleral fixated IOL.

After IOL implantation to ensure that no vitreous remains incarcerated at the wounds pupil should be constricted with pilocarpine and a manual Weck-Cel vitrectomy performed at all entry sites. Use of preservative free triamcinolone helps in visualising vitreous strands if present. Vitrectomy can then be done to cut the vitreous strands that are remaining.

Once all vitreous is cleared wound should be closed after washing off all the OVD from the anterior chamber. When closing the wound, if there is any doubt that it is not closing properly and that the wound is not watertight section has to be sutured.

You tube link: http://youtu.be/TeudwFb9vZ4

Other difficulties during IOL implantation IOL damage

If there is IOL damage during implantation it has to be
explanted. The IOL may be cut and removed without enlarging the corneal section or the section can be enlarged and IOL removed. 7

**Intraoperative positive pressure**

Posterior direction syndrome is thought to arise when irrigation fluid dissects posteriorly through the zonules. The fluid becomes trapped behind the posterior capsule and vitreous. An intact posterior capsule becomes convex, pushing the iris forward and shallowing the chamber. It is advisable to aspirate 0.3 to 0.5 mL of liquid vitreous through the pars plana 3 mm posterior to the limbus with a 24-gauge needle. Following this procedure IOL implantation can be performed without damaging the posterior capsule.

**You tube link:** [http://youtu.be/TX6e4LsWNF4](http://youtu.be/TX6e4LsWNF4)

The most serious cause of positive posterior pressure is choroidal effusion/haemorrhage. The incidence of acute intraoperative suprachoroidal haemorrhage is extremely low in small-incision surgery. One of the first signs of this complication is a loss of the complete red reflex. Rapid closure of the wound should be done. Surgery should be aborted if there is suprachoroidal haemorrhage.

**CONCLUSION**

Phacoemulsification helps a surgeon to safely and efficiently remove a cataract, with minimal damage to ocular structures and prompt restoration of vision with a good refractive outcome. Despite vast advances in technology and techniques, complications can occur during phacoemulsification surgery, even in the most experienced hands. Successful management depends on a well prepared and knowledgeable response which to a great extent depends on the sound judgement, experience and skill of the surgeon.

**REFERENCES**

1. Which is a better machine for Formalin fumigation, OT care or Fogger?
If you are so addicted to fogging both can be used. See that the particle size can be adjusted to minimum. That can be done only in a fogger. Ensure that the amount of water in the fogger is minimal and the machine is run not more than 5 minutes so that the humidity induced by the procedure is less.

2. Do you need separate cloth for cleaning different surfaces in the OT (eg: wall, floor, trolley, roof, etc.)?
Separate cloth is needed only if you expect more contamination in any area. Cleaning cloth should be kept in disinfectant solution at the end of the day for 30 min and preferably sun-dried.

3. After fumigation, can the OT floor be wet?
After fumigation OT floor can be wet but not excessively soaked. If OT is washed it has to be mopped dry to reduce humidity.

4. Can we use broom in the OT?
Brooms are not advised, especially dry sweeping as it will spread the dust. Brooms if used during washing of floor will splash water on to the walls and other materials.

5. Which is better for cleaning OT, with stick or using hand?
Cleaning stick can be used for the floor and ceiling. Walls are best cleaned by hand by unidirectional mopping. Floor should be mopped backwards.

6. How do we dilute the solution for fumigation and cleaning?
Diluting the disinfectants should be done as prescribed by the manufactures, but always use a measuring cup.

7. Can we spray Aerodesin daily in the A/c filters?
Aerodesin is alcohol and will not give much antimicrobial coverage. AC filter is better treated with aldehyde compounds, which is effective against fungus that is rampant in our hot and humid climate.

8. What should be the exposure period for fogging?
If glyoxal-glutaral combination like Bacillocid special or Aldasan are used, one hour will be sufficient. But no-entry should be ensured during the contact period.

9. Do we need to clean OT just before any surgical procedure?
If the OT was disinfected the previous day no further procedure need be done on the day of Surgery.

10. Can we use disinfectant inside the Autoclave machine?
Autoclave sterilizes the articles. Then why use a disinfectant. It needs periodic servicing only. If at all you are cleaning it, use clean water.

11. Which is the best solution for instrument cleaning and what should be the concentration?
Instruments need only be cleaned with distilled water and mild soap. They should be cleaned immediately after surgery to prevent formation of biofilms. Enzymatic cleaning is not needed in Ophthalmic OTs, as we don’t have Blood and other organic dirt in our instruments. There are very good instrument cleaning liquids in the market, but they are available in big containers (1gallon) which will last a life time for us.

12. Can we use soap solution for cleaning OT floor along with brush?
OT floor doesn’t need scrubbing unless it is mosaic or other rough surface. If it is visibly contaminated soap solution can be used. If there is blood spillage, it has to contained, disinfected with sodium hypochlorite and then cleaned.

13. Is it necessary to disinfect Lasik head, if so what should be the concentration?
Lasik head has been reported to get damaged even with alcohol. So people are trying UV light and just cleaning with distilled water.

14. How to dry the A/c filter?
AC filter is best dried under the sun.

15. After surgery, is it good to wipe OT floor with plain water?
After every eye surgery OT floor need not be cleaned unless there is spillage of blood or other organic material. In case of spillage of irrigating fluid wet mopping with a clean and disinfected cloth is sufficient.

16. How to clean the OT chappals? Is fumigation needed for chappals?
Disinfection of every article is dependent on whether it is a critical item (that enters the body like needles), semi-critical (that which comes in contact with mucosa like endoscopes) or non critical (that which comes in contact with intact skin). Chappalis a non-critical item and it need be washed after every OT day with soap and water.

17. Is autoclaving compulsory for OT staff uniform?
OT dresses are better autoclaved. Autoclaving can be avoided if they are cleaned and sun dried or ironed in a clean environment.

18. Should we take culture swab from the washbasin?
Surfaces are not uniformly contaminated while air is. The chance of contamination from surfaces far from the surgical site is very low. Hence routine sampling of surfaces like corners, washbasin etc. is not of much value. It only shows how meticulous your cleaning is.

19. Is Daily fumigation needed?
Daily fumigation is not needed in Ophthalmic OTs. But the walls (upto arm’s length) and floors should be wiped with disinfectants after every OT day.

20. How oftendowe have to take the OT cultures?
Once you have established an effective protocol of disinfection of your OT, cultures need be taken once in 2-3 months or if there is a suspicion.

21. Can ultra sound cleaner be used daily?
US cleaners should be used every day for cannulas, hinged and serrated instruments.

22. Is fumigation needed for all area in the OT complex or only for main OT?
Once a week fumigation can be used in the entire OT complex.

23. Can Lignocaine bottle be autoclaved?
Why should you autoclave the lignocaine bottles? In that case we have to autoclave the eye drops also. Further we do not know how autoclaving will affect the pH and potency of these drugs.

24. Can formalin chamber be used in OT?
Formalin chamber is best avoided. But in unavoidable circumstances it may be used but the tablets should be replaced periodically and it should not be used to disinfect instruments with lumen like vitrectomy probes.

25. Can the A/c be switched on during the OT cleaning time?
AC will circulate the OT air. While disinfecting the room we don’t need any turbulence in the room and the chemical should remain in the room. It is therefore better to switch off the AC while disinfecting the room.

26. Is A/c mandatory in OTs?
AC is a must for OT. The purpose of the AC is to provide clean air at controlled temperature and humidity and re-circulate it periodically. (20-22 degree, 50-55 RH and 20 air circulation per hour)

27. Which surface has to be wiped first, trolley, roof or wall?
Trolleys are movable and can be done any time. But ceiling and walls should be mopped before the floor and as mentioned before floor should always be mopped backwards.

28. Can the eye drops used in minor OT which has been already used in the main OT (if we keep it in the fridge)?
Any eye drop once opened can be used within one month and need not be kept in the fridge. Septidine should be used on the same day itself.

29. Can we use the cardboard boxes in the OT store room for keeping the consumables?
Cardboard boxes should be kept in the outer zone of the OT (reception and recovery room). There are high chances of dust accumulation in these boxes and fungus growth in the rainy days.

30. Do we need separate solution (BSS, Appavisc, Auroblueetc) for each case?
In an ideal set up separate consumables are preferred for every case. It is not done usually. In case of Auroblue try to take required quantity from the vial each time under sterile precautions. In case of Visco: change the cannula after every case.

31. How often should the Phaco items (tip, sleeve, handpiece, tubing) be autoclaved when there are continuous cases in a day?
Ideally the hand piece, the tips, sleeve, chamber and IA cannulas are autoclaved after every case. (Anything that goes inside the eye should be autoclaved). In many hospitals hand piece is usually not changed every case but only wiped with alcohol, which is a compromise.

32. What should be the minimum size of an Ophthalmic OT?
Operating room - 150sq ft. Can have a good OT complex with 800-1000 Sq ft area.

33. What material should be used for the wall, floor and ceiling of OT?
For walls and floor- non porous, glazed surface is better. (Large joint free Ceramic/ vitrified tiles with joints filled with epoxy. Epoxy paint, joint free metallic sheets are typically used in modular OT) Large vitrified tiles with minimum joints can be used. Epoxy is a good alternative. False ceiling may be needed if one opts for Vertical laminar flow. Otherwise conventional ceiling is enough with a good antifungal paint.

34. Which type of door is advised for OT, swing or sliding and why?
Sliding doors are preferred as Swing doors cause more turbulence.

35. How many Operating tables can be used in one OT?
One table per OT. More than one will compromise aseptic principles

36. Can false ceiling be used in OT?
False ceiling is not mandatory. If opted, better to go for metallic one (like steel or similar) with air tight joints

37. Which is the best type of ventilation for OT?
Vertical laminar flow system.

38. Is Air Conditioning a must for OT? If yes, which type?
AC is mandatory. Centralised AC with VLF is the best as it controls temperature, humidity, air exchange, positive pressure and provides filtered air.

39. Which is the safest method sterilisation?
Autoclave

40. What is the shelf life of autoclaved items?
Items packed in pouches remain sterile for 6 months. Linen packs can be kept for 1 week if packed and stored properly.

41. Can flash sterilizer be used routinely?
Not to replace Horizontal autoclave

42. Is Cidex safe for sterilizing instruments?
Can give high level disinfection if kept in freshly prepared Cidex solution for 10 hours.

43. Which is the best hand disinfectant?
70% Iso propyl alcohol

44. Which is the best Autoclave Indicator?
Biological indicator. Class 6 emulators are equally good

45. How frequently theatre culture should be taken and from where?
Open plate Blood agar culture kept open for 30 minutes at the head end of the OT table once a month. Moist swabs from the head end of the table and under surface of the operating microscope are taken and preferably streaked on to blood agar immediately.

46. How many persons can be there in the theatre during a procedure, safely?
According to AIOS Guidelines 5 people can remain in an area of 180sqft

47. Is fumigation still a method of disinfection?
Not advisable

48. Is double autoclaving advisable for extra safety?
No

49. Can cloth mask can be used in OR?
2 or 3 ply masks are preferred over cloth masks

50. What is HEPA filter?
High Efficiency Particulate Air filter which can filter particles of up to 0.3 microns which is used in air conditioning system.

51. How long should we do the surgical hand wash and why?
5 minutes if done properly.

52. Is it necessary to trim the lashes before eye surgeries?
No. But eye lashes should be kept away from the field by proper lid tapes and adhesive drapes

53. Which is the best antibacterial prophylaxis for ocular surgery?
5% Povidone Iodine drops retained for 2 minutes in the conjunctival sac

54. Is it necessary to Autoclave OVD?
No.
Toward Zero Effective Phacoemulsification Time Using Femtosecond Laser Pretreatment

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This study aimed at comparing the effective phacoemulsification time (EPT) using femtosecond laser pretreatment with conventional phacoemulsification. The study also sought to compare the differences using improved lens fragmentation algorithms and an alteration in surgical technique and equipment. Reduced ultrasound energy was hypothesized to lead to a reduction in endothelial cell loss, and improved capsulotomy regularity was hypothesized to lead to improved refractive outcomes through more consistent effective lens position. This was a prospective, interventional, consecutive case control study of 201 eyes that underwent cataract surgery by a single surgeon. Controls (n=51) underwent conventional phacoemulsification followed by insertion of IOL. Cases (n=150) included patients who elected to undergo femtosecond laser pretreatment.

High-resolution video and spectral-domain optical coherence tomography imaging were used for the surgeon to confirm the accuracy and size of anterior capsulotomy and lens fragmentation architecture before laser treatment. Lens fragmentation patterns were altered during later cases to permit analysis of improvements in ease of cataract extraction. Optical coherence tomography imaging also allowed the detection of posterior capsule and iris margin safety zones. Corneal incisions were not performed using the femtosecond laser. Subsequently the patient underwent cataract extraction followed by insertion of IOL. Controls underwent conventional phacoemulsification cataract surgery followed by insertion of an IOL. A subgroup analysis of femtosecond laser pretreatment cases was conducted to compare the mean effective phacoemulsification times when using a larger bore phacoemulsification tip (20 gauge).

The last 27 eyes of the series (24 cases, 3 controls) underwent phacoemulsification using a 20-gauge tip. The study groups had no difference between baseline cataract grades. One hundred percent of cases pretreated with the femtosecond laser had complete capsulotomy. Mean EPT was reduced by 83.6% in the femtosecond pretreatment group when compared with controls, with 30% having 0 EPT. Effective phacoemulsification time was reduced 28.6% within the femtosecond group using improved lens fragmentation algorithms, and a further 72.8% reduction was achieved with a 20-gauge Phacoemulsification tip. Overall, there was a significant reduction in EPT between controls and the optimized femtosecond pretreatment group. The study also found a significant reduction in endothelial cell loss in the femtosecond group. Visual and refractive outcomes were similar to those of conventional cataract surgery.

Topical Anesthesia versus Regional Anesthesia for Cataract Surgery: A Meta-Analysis of Randomized Controlled Trials

Li-Quan Zhao, MD, Huang Zhu, MD, Pei-Quan Zhao, MD, Qi-Rong Wu, MD, Yi-Qian Hu, MD

Purpose of the study was to examine possible differences in the clinical outcomes of topical anesthesia (TA) and regional anesthesia including retrobulbar anesthesia (RBA) and peribulbar anesthesia (PBA) in phacoemulsification. This is a systematic review and meta-analysis done in patients above the age of 18 years, from previously published randomized controlled trials (RCTs) of phacoemulsification under Topical Anesthesia and Retrobulbar / PeriBulbar anesthesia. A comprehensive literature search was performed to identify RCTs that compare TA and RBA/PBA in phacoemulsification.

Main outcome measures were pain score during and after surgery, intraoperative difficulties and inadvertent ocular movement, intraoperative necessity to administer additional anesthesia, and patient preference. Secondary outcome parameters investigated were postoperative visual acuity, anesthesia-related complications, intraoperative complications, and severe local or systemic complications. Fifteen studies were identified and analyzed to compare TA (1084 eyes) with RBA/PBA (1121 eyes) in phacoemulsification.

Data synthesis showed that intraoperative and postoperative pain perception was significantly higher in the TA group. The TA group showed more frequent inadvertent ocular movement and a greater intraoperative need for supplementary anesthesia. There was no statistically significant difference between the 2 groups in intraoperative difficulties as assessed by the surgeons. Patients significantly
preferred TA. The RBA/PBA group had more frequent anaesthesia-related complications, such as chemosis, periorbital hematoma, and subconjunctival hemorrhage. There was no statistically significant difference in surgery-related complications. The authors concluded that compared with RBA/PBA, TA does not provide the same excellent pain relief in cataract surgery; however, it achieves similar surgical outcomes. Topical anesthesia reduces injection-related complications and alleviates patients’ fear of injection. The choice of TA is not suitable for patients with a higher initial blood pressure or greater pain perception.

Anatomic and Visual Outcomes of Descemetopexy in Post-Cataract Surgery Descemet’s Membrane Detachment

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Objective of the study was to determine the anatomic and visual outcomes of descemetopexy in Descemet’s membrane detachment (DMD) after cataract surgery. This retrospective case series comprised of clinical notes of 60 patients who underwent DMD after cataract surgery between 2007 and 2011 at L.V Prasad Eye Institute. Descemetopexy was performed with air or 14% isoexpansile perfluoropropane (C3F8). This study included patients who underwent anterior chamber gas injection (descemetopexy) for the treatment of DMD aftercataract surgery between January 1, 2007, and December 31, 2011. Patients who had DMD that was recognized during surgery and were treated with descemetopexy in the same setting, and patients without a minimum follow-up of 1 month were excluded from the study. 44 patients who underwent descemetopexy intraoperatively fulfilled the inclusion criteria were included in the study. 16 patients referred with the diagnosis of post-cataract surgery DMD and were also included in the study, thus making it a total of 60 patients.

Outcome measures included anatomical (reattachment rates) and functional results (best-corrected visual acuity). Secondary outcome measures were assessment of surgical complications and association of various factors with final visual outcome. At 1 month, the mean logarithm of the minimum angle of resolution (logMAR) interval visual acuity (IVA) showed significant improvement. Five patients (8.3%) obtained 20/20 vision, and 37 of 60 patients (61.6%) achieved IVA of 20/40. Ninety-five percent (57/60) of patients had successful reattachment of the Descemet’s membrane (DM) after the intervention. Multiple linear regression analysis showed that patients with a cataract score of 5, with a cataract score of 4 with compromised visibility due to a corneal opacity and prolonged duration between cataract surgery and descemetopexy were associated with a significantly poorer final visual outcome. No association of final visual outcome was observed with age; sex; eye treated; cataract scores 2, 3, and 4; preoperative visual acuity; and involvement of the visual axis (P ≤ 0.5). The eyes in which air was used for descemetopexy had statistically significantly better final visual outcomes. Three patients (5%) had treatment failures and required subsequent endothelial transplantation. Pupillary block was observed in the early postoperative period in 7 patients (11.66%) in whom C3F8 had been used and was not seen with air. This study suggests that DMD after cataract surgery can be treated effectively and good visual outcomes can be expected if the patient is treated in time with anterior chamber injection of gas. Air has advantages of better efficacy than C3F8 without the risk of pupillary block and thus should be preferred.

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Postgraduate Ophthalmology

The two volume book “Postgraduate Ophthalmology” by Drs Zia Chaudhuri and M Vanathi is a revelation. It is one of the more comprehensive books on Ophthalmology covering all aspects of Ophthalmology needed by the residents and practicing ophthalmologists. The book has contributions from some of the best experts in the field from the country. In spite of being a multi author book, there is a very good uniformity of pattern and an excellent quality of text.

The strength of the book lies in its beautiful illustrations including clinical photographs which are extremely appropriate and line diagrams which are easy to reproduce. There are a number of tables which summarize the contents. The book has chapters on ocular pathology, pharmacology and radiology, which are very well illustrated. Blindness, low vision, genetics, ocular anatomy, lasers in Ophthalmology, ethical and medico legal aspects, operation theatres as well as ophthalmic emergencies have been dealt with well.

The authors being active post graduate teachers have a pulse on the requirements of the postgraduates and this is the reason the book has already acquired popularity with the residents. The book could however do well to have separate chapters on ophthalmic clinical examination, optical dispensing, instrumentation and embryology.

All in all, an excellent book, which is up to date and comprehensive and would be an ideal material for those learning and practicing ophthalmology.
### IOL Power Calculation Formula

<table>
<thead>
<tr>
<th>1) SRK T formula</th>
<th>Combines the benefits of both theoretical and regression formulae. The formulae uses theoretical elements like predicted postoperative AC depth, retinal thickness adjusted axial length and refractive indices of the cornea. This formula is significantly more accurate for extremely long eyes (&gt;28mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2) HAIGIS formula</td>
<td>The versatility of this formula lies in the three individualised A constants a0, a1 and a2. The a0 is linked to the manufacturers lens constant. The a1 is linked to the preoperative ultrasonically measures anterior chamber depth and a2 is linked to the axial length measurements and which has a default value of 0.1 When fully optimized this formula will work across the entire range of axial length values and will not require different formulas for different axial lengths.</td>
</tr>
<tr>
<td>D= DC+ ref/1-ref dBC</td>
<td></td>
</tr>
<tr>
<td>DC = nC-1/RC</td>
<td></td>
</tr>
<tr>
<td>d= a0 + a1 VKpr + a2 ALpr</td>
<td></td>
</tr>
<tr>
<td>a0= ACD-Konst-a1MW(VKpr)-a2MW(ALpr)</td>
<td></td>
</tr>
<tr>
<td>D-refractive power of IOI</td>
<td></td>
</tr>
<tr>
<td>DC-refractive corneal power</td>
<td></td>
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<tr>
<td>RC-corneal radius</td>
<td></td>
</tr>
<tr>
<td>nC-refractive index of cornea</td>
<td></td>
</tr>
<tr>
<td>ref-desired refraction</td>
<td></td>
</tr>
<tr>
<td>dBC- vertex distance between cornea and glasses</td>
<td></td>
</tr>
<tr>
<td>d-optical ACD</td>
<td></td>
</tr>
<tr>
<td>L-axial length</td>
<td></td>
</tr>
<tr>
<td>n-refractive index of aqueous and vitreous (1.336)</td>
<td></td>
</tr>
<tr>
<td>VKpr- preoperative AC depth</td>
<td></td>
</tr>
<tr>
<td>ALpr-preoperative axial length</td>
<td></td>
</tr>
<tr>
<td>ACD Konst-ACD constant of manufacturer</td>
<td></td>
</tr>
<tr>
<td>3) Holladay 2 formula</td>
<td>The unprecedented success of the formula is due to its accuracy and predictability by incorporating seven different parameters into the framework of the formulae. These parameters are axial length, central corneal power(K), anterior chamber depth, lens thickness measurement, limbal white to white measurement, age of the patient and previous refraction of the patient. This formula is best for eyes of axial length 22-25mm.</td>
</tr>
<tr>
<td>It is the most sophisticated formula. It is the improvement of Holladay 1 formula.</td>
<td></td>
</tr>
<tr>
<td>4) Hoffer Q formula</td>
<td>This formula performs best for short eyes (&lt;22mm) Uses pseudophakic anterior chamber depth</td>
</tr>
<tr>
<td>D2=[(1336/(Am-d-0.05))]</td>
<td></td>
</tr>
<tr>
<td>-(1.336/(1.336 / (Km+Rs))]</td>
<td></td>
</tr>
<tr>
<td>-[d+0.05/1000)]</td>
<td></td>
</tr>
<tr>
<td>D2 primary implant power predicted by the Hoffer equation</td>
<td></td>
</tr>
<tr>
<td>d chamber depth in millimeters</td>
<td></td>
</tr>
</tbody>
</table>
IOL Power Calculation in Special Situations

<table>
<thead>
<tr>
<th>In silicone oil filled eyes</th>
<th>IOL calculation for a convex-plano IOL (with the plano side facing towards the vitreous cavity) is determined by the following relationship</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• ( N_s = ) refractive index of silicone oil (1.4034).</td>
</tr>
<tr>
<td></td>
<td>• ( N_v = ) refractive index of vitreous (1.336).</td>
</tr>
<tr>
<td></td>
<td>• ( AL = ) axial length in mm.</td>
</tr>
<tr>
<td></td>
<td>• ( ACD = ) anterior chamber depth in mm.</td>
</tr>
<tr>
<td></td>
<td>Additional IOL power (diopters) = [\frac{(N_s - N_v)}{(AL - ACD)}] x 1,000</td>
</tr>
<tr>
<td></td>
<td>For an eye of average dimensions, and with the vitreous cavity filled with silicone oil, the additional power needed for a convex-plano PMMA intraocular lens is typically between +3.0 D to +3.5 D.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>In paediatric age group</th>
<th>It is suggested that the final aim of refraction should be 20% undercorrection in infants and 10% in toddlers.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Depending on the axial length the following IOL power must be used:</td>
</tr>
</tbody>
</table>
|                            | \[\begin{array}{c|c}
| AL & IOL power \\
| 17mm & 28D \\
| 18mm & 27D \\
| 19mm & 26D \\
| 20mm & 24D \\
| 21mm & 22D \\
| \end{array}\]                                                                                           |

<table>
<thead>
<tr>
<th>In keratorefractive surgery</th>
<th>Calculation method –</th>
</tr>
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<tr>
<td></td>
<td>Mean post operative ( K = ) (mean preoperative ( K )) – (Change in refraction at corneal plane)</td>
</tr>
<tr>
<td></td>
<td>Or</td>
</tr>
<tr>
<td></td>
<td>Contact lens method</td>
</tr>
<tr>
<td></td>
<td>( K = ) Base curve + (difference in refractive error without contact lens and with contact lens)</td>
</tr>
<tr>
<td></td>
<td>- <strong>If keratometric diopters but not refraction before refractive surgery is known</strong>, use the change in anterior surface keratometry readings after PRK or LASIK.</td>
</tr>
<tr>
<td></td>
<td>- <strong>If preoperative keratometric diopters and refraction are not known</strong> and the visual acuity is 6/24 or better, try the hard contact lens method after RK.</td>
</tr>
<tr>
<td></td>
<td>- <strong>If preoperative keratometric diopters and refraction are not known</strong> and visual acuity is less than 6/24 or plano hard contact lenses are not available, use average central power or the average keratometric diopters at multiple paracentral cursor points of videokeratography after RK, but use refined calculation of keratometric diopters from radius of anterior and posterior corneal surface after PRK or LASIK.</td>
</tr>
<tr>
<td></td>
<td>- <strong>Use more than one modern third-generation formula (Hoffer Q, Holladay 2, SRK/T, Haigis)</strong>. Do not use a regression formula (SRK I or SRK II) to calculate the IOL power and choose the highest value for your implant.</td>
</tr>
</tbody>
</table>

Deepa Elsa George(MS) is doing postgraduation at Amrita institute of Medical Sciences
c/o drop in vision – 2 weeks after uneventful LASIK
What is your diagnosis?

Send your answers to gopalspillai@gmail.com
The First Correct answer gets the prize

Answer for last time: Retinal angioma- Von Hippel Lindau
Associations: pheochromocytoma, cerebellar or spinal cord haemangioblastoma, renal cell carcinoma & visceral cysts
Winner is Dr. Vinodkumar N V from Calicut
General Instructions To Authors

The Kerala Journal of Ophthalmology (KJO) is a quarterly, peer reviewed one, devoted to dissemination of the latest in ophthalmology to the General Ophthalmologists as well as to specialists in the various subspecialties of this discipline. It invites submission of original work dealing with clinical and laboratory materials.

Authors submitting materials to this journal are requested to adhere STRICTLY to the norms laid down below. The matter must be typed on one side of the paper. A margin of 1” must be left all around and the material must be double spaced. A page should contain not more than 25 lines. Two copies of the text in paper and one copy in a CD must be submitted to the Editor and the corresponding author is advised to keep another copy with him. The corresponding author must give it in writing in his covering letter that the same matter will not be submitted elsewhere if accepted. He must also enclose the copyright transfer of his work to this journal. The papers sent will be subjected to peer review. The accepted manuscripts become the permanent property of this journal. The author is informed that, if his work is returned to him for correction / clarification after peer review, he should effect the same and send the manuscript back to the Editor within one month. Each manuscript component mentioned here under must begin with a new page and the pages are to be numbered at the right tip corner starting from the Title page.

1. TITLE: The title of the work must be brief and precise. It should not exceed two lines and 40 characters (including comma, period) Author(s) full name (s) must be given along with his (their) degree and the affiliations. Corresponding author’s name, correct address (including e-mail and Fax, if available) and phone number must be mentioned at the bottom left hand corner of the first page.

2. ABSTRACT: The abstract is to be given in the beginning itself. It should not exceed 200 words. It must contain the aim, methodology, results and conclusion. For case report, summary / conclusion alone is to be given.

KEY WORDS: (maximum five) in capitals are to be included at the end of Abstract.

3. INTRODUCTION: Describe the aim of the study, along with the hypotheses that were tested. Only necessary references are to be given.

4. METHOD: Give in detail the materials used and the methods employed. Describe the type of study. Pharmacological names only must be mentioned for the drugs used and, if proprietary name is used, then the manufacturers name must be given in parentheses. Except for standard, well-accepted abbreviations (including SI Units), all others must be introduced in parentheses when the full term is used for the first time in the article.

5. RESULTS: Give only the results obtained by the study under discussion. State the statistics in the correct scientific form (P value, mean etc). Results based on assumptions must not be given. Indicate in the text the place where the tables have to be inserted.

6. DISCUSSION: The discussion should be to the point and relevant to the subject under discussion. This section can be combined with the previous one if the author desires. Avoid speculations. Use only standard abbreviations or the abbreviations already introduced.

7. ACKNOWLEDGEMENT: This is to be made only to those who were directly and scientifically involved with the preparation of the paper. Permitting authorities, technicians, photographers who assisted in the work need not be mentioned.

8. REFERENCES: The references should be given in numerical order in which they first appear in text and not in alphabetical order (Citation Order System). It should be numbered consecutively in the text. The references will not be checked by the Editor or by the Peer reviewer and hence the author is solely responsible for its completeness and the accuracy. Period should not be employed anywhere in the references. Personal communications, unpublished data and poster references, if mentioned, should be in the text itself and the source mentioned in parentheses. References should be in the following form:

Journal reference: Author(s) full title, Journal name (as abbreviated in Index Medicus), volume number, pages and year. If there are more than three authors, then mention the first three authors and then ‘et al’.

Book reference: Author(s) (& Editor, if any), title of book (and chapter), publisher, place of publication, page number (s) of the cited portion and year.

9. THE LEGEND: The legend for the illustrations (and tables, if necessary) must be given in a separate sheet of paper and should be typed double-spaced.
Illustrations: The photos and figures should be prepared in glossy prints with good contrast and of the size 6” x 4”. Only salient details should be included. On the back of the illustration, the figure number in text, title of the paper, the first author’s name and the top side (marked with an arrow) must be specified. Except for arrows, no text is to be on the photos. It is the duty of the author(s) to get the patient’s written permission when the subject is identifiable in the photo. Submit two sets of illustrations. Illustrations from other Journals and books are usually not accepted. If used, it rests with the author(s) to get the copy right permission from the original author / publisher and this permission letter must be sent to the Editor at the time of submitting the manuscript. For Histological figures the stain and magnification used should be noted e.g.: H & E Stain x 70.

10. TABLE: It should be in double space. Each table must have an Arabic numeral (except for single table) and a title both in a single line. Each column in the table must have a short heading. If a table is large, then it must be continued in a second page, which also must have the table number and the title. Avoid vertical lines in the tables. Two sets must be submitted.

11. All manuscripts are subjected to editorial board review.

12. Other Categories of Manuscript

a) Original Articles should generally not exceed 3,000 words or 12 double – spaced pages.
b) Review Articles: can be on topics of relevance to clinical practice, research methodology, community ophthalmology or investigative work, of relevance to visual science. These articles should include up to date review of existing literature, and summarize the current status / preferred practice for that particular topic.

Brief reports are short communication of new instruments, new laboratory techniques or surgical techniques as well as interesting case reports with unique findings. These should not exceed 1000 words with a maximum of 2 illustrations. They should follow the format – introduction, case, and discussion. No more than 8 references should be cited. Each brief report must begin with a 75-100 word summary that highlights the significance of the articles.