Ophthalmology PG Exam Notes

NOTES

2020

Lens

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I notes 2020

(Ophthalmology PG Exam Notes)

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by inotesforPG.blogspot.com

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This is a compilation effort from my Post-graduation preparation notes and multiple other sources. Whole of the Manual is now revised from advices received from students from all over the world. Any contributions or comments are welcomed in the effort to improve this Manual. **This manual is made to serve the Exam purpose and as a Handy Reference tool only.**

If you are reading this, just drop a comment or critic at:
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Dedication

To The **GOD**, the Almighty, for Giving me Imagination & Curiosity which keeps me always learning, for Giving me fine skills from which I can do my best for patients…

To My Grand-Mother; **Tejaben Patel**, for Training my childhood in such a disciplined way which has helped me to become what I am today…

To My Parents; **Bharat & Sudha Patel** and My Parents-In-Law; **Anil & Neela Patel**, for Trusting me, Motivating me and Helping me in my difficult times…

To My Wife; **Dr Dhara Patel**, for Believing in my strengths, Always supporting me in my all ventures, Bearing with me when I don't give her enough time while I am busy in my all ongoing projects and many more innumerable things which I always forget as usual…

To My Brother; **Dr Keyur Patel**, for helping me getting all the knowledge regarding Medical Science in the other continent…

To My Brother-In-Law; **Raj Patel**, for Bringing out Computer Science Kid within me and Teaching me in-numerous tips and tricks while dealing with computers…

To My Many **Friends and Relatives**; naming them all is not possible but they have helped me to Refine my life in one or the other way…

To All the **Ophthalmologists;** for pouring their knowledge and skills in this field which has now become one of the finest speciality in Medical field…

To **Patients;** for creating a demand which keeps all the ophthalmologists motivated to keep inventing and innovating methods, models and devices for their benefits…

I NOTES 2020

Ophthalmology PG Exam Notes

LENS

If I have seen further than others,

It is by standing upon the shoulders of giants.

-Isaac Newton

Thank you GOD !

When I compiled first edition of this **iNotes** Manual in 2014, It was simple collection of few notes (*very much incomplete!*) which I prepared for my Post-graduate Ophthalmology Exams at AIIMS, New Delhi. Since then I am regularly receiving emails and messages regarding usefulness of these notes as a study material for Post-graduate students all across the world.

For last few years, I am getting emails asking that if I am going to bring any updated version of my **iNotes** as ophthalmology has advanced a lot in last 10 years. Hence from last one year I have started reading newer edition of books, recent question papers, gathered notes and presenting to you as completely new version as **iNotes 2020**.

In this edition of iNotes, I have tried to include clinical, practical and surgical tips which is going to be used in your future practice also so that this manual can be a handy book for you as a future reference too.

Also Remember, this is a “**Manual**” and not a “Complete Book”, and Just like most of others, it is also far from Complete. One of the best way to utilise this for your exam preparation is to use this as a reference and make your personal manual by adding your own notes and topics asked in your university.

My Best wishes and Good luck to you All !!

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Cataracts

Anterior Polar Cataracts

- **Disease**: Opacity of the anterior subcapsular cortex and capsule, Frequently autosomal dominant
- **Symptoms**: usually asymptomatic, may have symptoms of glare
- **Clinical features:**
  - Often good vision
  - Central small opacity involving the anterior capsule
  - Frequently bilateral
  - Nonprogressive, usually
- **Differential Diagnosis**
  - Penetrating capsular trauma
  - Traumatic stellate cataract
  - Anterior lenticonus
- **Management**:
  - Eyeglasses or contact lenses
  - Phacoemulsification/ extracapsular cataract extraction (ECCE)
    - Capsulorrhexis may be challenging as the anterior capsule is often attached to the anterior polar cataract
    - Increased risk of radial capsular tear
      - Begin capsule tear away from polar cataract
      - Enlarge and encompass polar cataract if possible
      - Consider use of capsule staining

Posterior Polar Cataracts

- **Disease**:
  - Opacity of the posterior subcapsular cortex and capsule
  - Familial autosomal dominant when bilateral; sporadic cases are usually unilateral
  - Slowly progressive
  - Nodal point location; more symptomatic than anterior polar cataract
- **Clinical features**
  - Often relatively good vision
  - Central opacity involving the posterior capsule
  - Glare
  - Vision may be more impaired in bright light than in dim light

- **Differential Diagnosis**
  - Posterior subcapsular cataract
  - Penetrating capsule trauma
  - Mittendorf dot
- **Management**
  - Mydriatic eyedrops as a temporizing agent
  - Eyeglasses and contact lenses for any refractive error
  - Phacoemulsification/extracapsular cataract extraction
    - No hydrodissection but hydrodelineation may be useful
    - Consider low flow, low vacuum surgery
    - Increased risk of posterior capsular tear with vitreous prolapse since capsular opacity may weaken the posterior capsule or hide a pre-existing capsular defect
    - Increased risk of loss of lens material into vitreous

Hypermature / Morgagnian Cataracts

- **Disease**:
  - Opacification of the cortical lens fibers
  - Swelling of the lens material creates an intumescent cataract
  - Hallmark of Morgagnian cataract is liquified cortex allowing the nucleus to move freely in the capsular bag
  - Degenerated cortical material leaks through wrinkled capsule
- **Risk Factors**: Aging, Smoking, Trauma, Uveitis, Prolonged use of topical or systemic corticosteroids, Diabetes mellitus, Prior intraocular surgery, UV light exposure, Poor nutrition, Delay in treatment
- **Clinical Features:**
  - Poor fundus view
  - Loss of red reflex
  - May have phacolytic glaucoma or signs of anterior chamber inflammation
  - May have shallow anterior chamber due to lens swelling
  - Wrinkled anterior capsule
  - Calcium deposits in lens
  - Dense, white cortical material
  - Dense brown nucleus freely moving in capsular bag
- **Labs**: Ultrasonography for Posterior segment evaluation, HBA1c
- **Management**:
  - Topical steroids to decrease inflammation

- Phaco/ ECCE/ SICS

Cortical / Nuclear / Posterior Subcapsular Cataract

- **Disease**
  - Cortical cataract opacification of the cortical lens fibers
  - Nuclear cataract hardening and yellowing of the central lens fibers. Advanced nuclear sclerosis leads to dense brunescent nucleus
  - Posterior subcapsular cataract (PSC) central opacification of the posterior cortical material with granular and plaque-like opacities
- **Risk Factors:**
  - Cortical cataract Smoking, UV light exposure, Diabetes mellitus, Poor nutrition, Trauma
  - Nuclear cataract Advanced age, History of smoking, Female gender, Family history, Lower education levels, History of Intraocular Surgery, High myopia
  - Subcapsular cataract (PSC) Prior intraocular surgery, especially vitrectomy, Use of corticosteroids (topical, inhaled or systemic), History of intraocular inflammation, Diabetes, Trauma, History of periocular radiation, Alcoholism, Retinitis pigmentosa
- **Symptoms**:
  - Progressive loss of vision, more rapid with PSC and cortical cataracts
  - Glare
  - Monocular diplopia
  - Myopic shift and decreased color discrimination and contrast sensitivity with nuclear cataracts
  - Worsening of vision in bright lights and at near with PSC
- **Clinical Features:**
  - Cortical cataract
    - Opacification of cortical lens fibers
    - May have water vacuoles in lens cortex and wedge-shaped whitish opacities extending from periphery of lens toward the center
    - May progress to form white intumescent cortical cataract
  - Nuclear sclerotic cataract
    - Central yellow to brown discoloration of the lens
    - Myopic shift
    - Relative shallowing of the anterior chamber
  - Posterior subcapsular cataract
    - Granular or plaque-like opacities on anterior aspect of posterior lens capsule, often central
    - Frequently fast-progressing

- Decreased clarity of fundus details

- **Management**
    - Optimize eyeglasses/contact lens correction
    - Optimize lightening for reading
    - Phaco/ ECCE/ SICS

Steroid Induced Cataract

Mechanism: ***PCCLO***

- Inhibition of the **Na-K-ATPase Pump** mechanism, which increases the permeability of the lens to cation
- Conformational changes in specific amino groups of the lens **crystallins**, which lead to the development of disulfide bonds and protein aggregation.
- Decreased expression of **cadherin** (a family of cell–cell adhesion molecules that control the calcium-dependent cell adhesion of lens proteins that are necessary to prevent cataract formation)
- Binding of corticosteroids to lens proteins forming **lysine-ketosteroid** adducts that cause aggregation of lens crystallin proteins
- Corticosteroid-induced **oxidative stress** caused by accelerated gluconeogenesis, with reduced levels of glutathione sulphate attributed to the possible inhibition of glucose-6-phosphate dehydrogenase.

Intraocular Lens Power Calculation

- The three major components of IOL power calculation are (1) biometry, (2) formulas, and (3) clinical variables.

Biometry

- ***Biometry*** can be **divided** into its components needed to calculate IOL power:
  - the axial length
  - the corneal power
  - the IOL position: Post-operative ACD or ELP

Axial Length

- Contact A scan:
- Immersion A scan:
  - The Ossoinig Immersion is proven to consistently produce an axial length measurement that is 0.26 mm longer than that using the applanation technique, that may indent the cornea, creating an artificially shorter reading.
  - An 8 mHz non-focused transducer is recommended can be attached to most US machines.
  - An **Ossoinig shell (cup)** is placed between the lids and filled with Goniosol [cut 50% with Dacriose]. The probe is placed into the fluid and aimed in an axial direction.
  - **Prager shell** is another which can be used for the same purpose.
  - **Probe Alignment:**
    - An important indication of correct probe alignment is the presence of a strong Scleral Spike posterior to the Retinal Spike. Both spikes should be equal in height and strength.
    - If the scleral spike is not present, you are misaligned along the optic nerve
    - If the scleral spike is shorter than the retinal spike, perpendicularity to the macula has not been achieved.
    - If the orbital fat spikes are not present, you are misaligned and scanning the optic nerve rather than the macula.
    - Two Corneal Echoes of equal height should be present indicating the anterior corneal epithelium and the posterior corneal endothelium.
- Optical biometry methods are easier and matched to equal Immersion.
  - IOLMaster 1999
  - Lenstar 2009
  - Aladdin 2013
  - Nidek AL-Scan

- IOLMaster 700
- Movu Argos
- Tomey OA-2000
- Pentacam AXL
- To be Tested: Galilei G-6, Heidelberg Anterion, H-S Eyestar, Optopol

- **Ultrasound Speed**
  - Average US speed of a Phakic eye = 1555 m/sec and an Aphakic eye = 1534 m/sec. BUT AL affects this: e.g. 20 mm Phakic = 1560 m/sec & 30 mm Phakic = 1550 m/sec.
  - Aphakic NOT affected by AL because Short eyes are made up of smaller % of fluid axially (short AC, shorter vitreous, thicker lens) → Velocity faster.
  - How to correct for this: PHAKIC EYE: Measure all eyes at 1532 m/sec and add to it a CALF factor of + 0.37 mm.
    - APHAKIC EYE: Measure at 1532 m/sec and only add + 0.05 mm
    - PSEUDOPHAKIC Eye: Measure at 1532 m/sec and add CALF of: PMMA [+ 0.424*(TL) + 0.037] Silicone [0.563*(TL) +0.037] Acrylic [+ 0.243*(TL) + 0.037] TL = IOL Thickness
    - Use Average Velocities for 23.5 mm eye: PMMA 1556 m/sec Silicone 1487 m/sec Acrylic 1549 m/sec
    - Piggyback Lens Eye: AL = AL1532 + T1 *(1-1532/V1) + T2 *(1-1532/V2) + 0.037 Where T1 and V1 are the thickness and velocity of one IOL and T2 and V2 are the thickness and velocity of the other.
  - If AL not measured at 1532 m/sec, AL can be converted by formula: Vmeas= Velocity you used, Vcorrect = correct or new Velocity
    - AL corrected = AL measured = Vcorrect/Vmeas
    - Basically divide old AL by old V and multiply by new V
  - Scleral Buckle after RD: Use AL-1 mm for ACD prediction and AL for IOL power calculation, “Double-AL”
  - SILICONE OIL filled Eye
    - FIRST PROBLEM: Almost impossible to measure with US: BEST: USE OPTICAL BIOMETER.
    - SECOND PROBLEM: Refractive index of silicone acts like a minus lens was placed in the vitreous and will cause the eye to become hyperopic by 2-3 D (Plano-convex IOL) or 3-6 D (Biconvex IOL) [Concave IOL best]. Therefore the IOL power must be increased if silicone will be left in.
    - Due to 1 & 2 above, I recommend waiting and performing secondary IOL using Holladay Refraction Formula.
    - Advise all retinal surgeons to routinely perform AL measurement prior to placing Silicone.

Corneal Power [K-Keratometry]

- The manual keratometer should be standardized often. This is done with steel calibration balls from manufacturer.
- K reading errors = diopter for diopter error in IOL power. Hard CL's must be kept out > 2 weeks
- Average K reading is always used; Cylinder is ignored. It has NO effect on IOL power
- Ignore surgical change in corneal power unless a study of your cases reveals a consistent trend.
- PK: Do secondary IOL after corneal transplant heals when the true K reading is able to be obtained
- For every 1.00 D change in Rx must change IOL by 1.25 D. For every 1.00 D change in IOL, get 0.87 D change in RX.
- Refractive Surgery Eyes
  - Over 30 methods to calculate K or fudge the IOL power
  - ARAMBERRI DOUBLE-K METHOD: Use Preop K to predict the ACD and PO calculated K for the IOL power
  - IANCHULEV OR REFRACTION METHOD: Alcon WaveTec ORA microscope system proven accurate.

IOL Position/ ELP

- All formulas require an AC depth (ACD) = Corneal thick + Endo to IOL surf dist + 10% TL (Pl-cvx) or 50% TL (Bicvx)]
- ACD (ELP) is not the ultrasound pre-op anatomical AC depth reading; it is the axial position of the IOL (estimated).
- ACD is individual to each IOL style and can be predicted by the formula or is the average of a PO series.
- The A constant in SRK formulas and the Surgeon Factor (SF) in the Holladay formula are used to predict ELP.
- Hoffer Q formula uses pACD and the Q formula to develop the predicted ELP for an individual eye.
- Decrease IOL ~1.00 D when shifting from bag to sulcus placement (0.50 to 1.50 D depending on power of IOL).
- Expect ~ 1.25 D/mm shift in IOL Position.

Clinical Tips in Biometry

- Be wary of transcription errors, e.g. AL and K readings. Calculate an average K quickly and use it from then on.
- If you are accurate, aim for emmetropia but ask the patient what they want. If they want other, have them sign for it.
- IOL power for a monocular cataract in a bilateral high myope: carefully discuss the options of monocular emmetropia and the necessity of wearing a contact lens on the other eye versus lifelong myopia.
- DO IOL EXCHANGE QUICKLY whenever required. USE Piggyback IOLs: **Error Minus X1; Plus X1.5**
- In most studies, the **Barrett U2, Hill RBF, Olsen, and Holladay** Consultant are reported to provide best outcomes.
- In his classic 2008 paper, Norrby stated that the **major sources of error were ELP**, axial length, and refraction.
- ***Sources of Errors:*** Today, thanks to optical biometry, axial length is no longer among the top 3, with corneal measurements now on this list, in addition to ELP and refraction. That said, measuring the axial length in segments rather than as a whole could increase the accuracy in very short and very long eyes.

- **Errors in measurement**
  - Keratometry inaccuracies
    - Contact lens wear: Out of CTL for a time, longer for RGPs
    - Prior keratorefractive surgery: Uncertainty about central corneal power
  - Axial length
    - Compression with A scan probe shorten axial length
    - >0.3 mm difference in axial length (equates to approximately 1 diopter error in IOL calculation)
      - Repeat measurements
      - Independent technician
      - Alternate biometry technique
  - Poor fixation or failure to find the visual axis accurately
      - Staphylomas Laser interferometry
      - iMature cataract, dense PSC Consider B-Scan

- **Postoperative modification of IOL power** is promising, with 2 technologies currently available or under investigation:
  - **RxSight**: curvature change via selective laserinduced molecular polymerization

    - **Refractive index shaping**: can theoretically be done in vivo to an IOL—and in the cornea

Formula

Generation Based Classification

- **Historical Theoretic:** Fyodorov (1967) Colenbrander (1972) Hoffer® (1974) R Binkhorst (1975)
- **Historical Regression:** SRK® [1980) SRK® II [1988)
    - "SRK and SRK II formulas are outdated and are no longer recommended; use the SRK/T for IOL power." John Retzlaff, M.D. (coauthor of SRK); 1990.
- **Modern Theoretic:**
    - **Holladay**® [1988]: Basic theoretic formula which calculates the corneal height (1st used by Olsen) added to the corneal thickness (0.56) and an IOL/surgeon specific constant (the SF), to calculate the ELP.
    - **SRK/T** ® [1990]: Basic theoretic formula (Holladay) using Olsen method for predicting ACD.
    - **Hoffer® Q** [1992]: Basic Hoffer formula [1974]. Uses Q formula to predict ELP which is dependent upon AL and K, using a personalized ACD. As accurate as the Holladay 1 formula and superior in short eyes.
    - **Holladay® 2** [1996]: Intended to improve short eye calculation. Requires: Rx, Age, CD, Pre ACD, LT. My study11 317 eyes: Less accurate in eyes 22.0-26.0 mm, equal to Hoffer Q (<22 mm). ? better in eyes <18 mm.
    - **Haigis**® [2000]: Uses a0, a1, a2 for ELP. Optimize only a0 = Hoffer Q. Better if optimize all 3 using 350 PO eyes.
    - **Hoffer® H11** [2004]: Holladay Log Factors of AL, K, CD, ACD, LT and Age: BEST in <22, 24.5-26, Highest % ±0.13D. 7. Olsen [2014] Ray-tracing using new C-factor. v II (2014): Not yet tested in large series.
    - **Hoffer® H-5** [2015]: Holladay 2/Hoffer H upgraded to 5th Generation by taking into account gender and race.
    - **Barrett Universal II** (2014): Online. RBF No large studies yet show it to be superior; other new systems,
    - **Kane**: uses new modulators and artificial intelligence; showing to be most accurate formula so far.
- **COMPUTER DATABASE PROGRAMS**
    - Holladay® IOL Consultant. Uses Double-K only for Holladay 2 formula, not Hoffer Q Holladay 1 or SRK/T.
    - Haigis Website
    - Olsen PhacoOptics Olsen C-constant Ray Tracing, 4.ASCRS Website Calculator.
- **BIFOCAL IOL POWER**

- AL has no effect on Add power, K has minimal but ACD has real effect on add power

Method Based Classification

- Vergence: describe by the number of variables used to calculate effective lens position (ELP)
  - Two-variable vergence: Holladay 1, SRK-T, HofferQ
  - Three-variable vergence: Haigis
  - Five-variable vergence: Barrett Universal II
  - Seven-variable vergence: Holladay Consultant
- Ray tracing
  - PhacoOptics (Thomas Olsen)
  - Okulix (Rolf Preussner)
- Artificial intelligence
  - Hill RBF
  - Gerald Clarke
- Combination
  - Ladas Super Formula
  - Full Monte IOL

Clinical Variables

Long Eyes

- The problem of unanticipated hyperopic outcomes
- largely been eliminated with the Wang-Koch axial length modification and the Barrett, Hill RBF, and ray tracing formulas.
- **Wang-Koch axial length modification**
  - Holladay 1: ALadj = (0.8289 * AL) + 4.2663
  - SRK/T: ALadj = (0.8544 * AL) + 3.7222
  - Haigis: ALadj = (0.9286 * AL) + 1.5620

Short Eyes

- For eyes less than 22 mm, accuracy remains below 80% within 0.5 D of target because of the impact that small shifts in the ELP of highpower IOLs have on the refractive outcome.
- Prone to myopic errors
- Comparison of Haigis vs. Hoffer-Q vs. SRK/T vs. Holladay 1

    - **Haigis** performed best
- **Olsen** Formula is also good in which ELP is based on preoperative ACD and lens thickness

Astigmatism

- Posterior cornea
    - Anterior corneal steep meridian transitions from vertical to horizontal with age (ie, patients transition from with-the-rule [WTR] to against-the-rule [ATR] astigmatism).
    - Posterior corneal steep meridian remains vertical with age for the vast majority of patients (equivalent to ATR astigmatism since the posterior cornea has negative power).
    - Astigmatism magnitudes based entirely on the anterior corneal surface may overestimate astigmatism in WTR eyes and underestimate in ATR eyes.
- Astigmatism assessment is best accomplished
    - by factoring in measurements obtained with a combination of automated keratometry, corneal topography, and corneal tomography.
- Recommendations
    - Account for posterior corneal ATR astigmatism – 0.5 D in WTR corneas, 0.3 D in ATR corneas
    - Account for ATR shift with age (approx. 0.37 D per decade): OK to flip axis to WTR a small amount
    - Factor in your surgically induced astigmatism (SIA)
    - Account for lens effectivity: greater IOL toric effect in short eyes (with higher IOL power) and less in long eyes (with lower IOL power).
    - Measure posterior corneal astigmatism and intraoperative aberrometry, when possible.
- Tools available to maximize toric IOL selection and alignment
    - Planners
        - Baylor Nomogram
        - Barrett Toric Calculator (ASCRS.org)
        - Holladay Toric Planner
        - Manufacturer toric calculators
    - Intraoperative measurement and alignment
        - Intraoperative aberrometry (ORA and Holos)
        - Verion
        - True Vision
        - Calisto

Keratoconus

- Hyperopic surprises are common, and the steeper the cornea, the greater the hyperopic outcome.
- Most likely etiologies
    - Poor assessment of posterior corneal contribution to total corneal power
    - Poor estimate of ELP

First eye surprise

- Apply half the prediction error of the first eye to the calculations and IOL selection for the second eye.

Post Refractive Surgery

- ***3 sets of error:***
    - K misses flat central cornea
    - Incorrect index of refraction overestimates corneal power
    - IOL location miscalculated.

- **Approaches that rely entirely on historical data**
    - Clinical History Method:
        - Most accurate method Proposed by **Holladay**
        - requires pre-LASIK/PRK keratometry, pre-LASIK/PRK refraction and post-LASIK/PRK stable refraction.
        - **Corneal Power= $K_{pre\text{-}LASIK\text{-}PRK}$ + Refractive Correction**
    - Feiz Mannis Method
        - Calculate IOL power using pre-operative values
        - Correct IOL power for 70% of changes in refraction achieved by ablative refractive surgery.
        - **IOL $Power_{post\text{-}LASIK\text{-}PRK}$= IOL Power $_{pre\text{-}LASIK\text{-}PRK}$ + (Refractive Correction/ 0.7)**
    - Corneal bypass method
        - Its like using pre-excimer parameters and **aiming for pre-excimer refractive error**.

- **Combination of prior data and current corneal measurements**
    - Arramberi double K method
        - preoperative K→ used to predict ELP (Effective Lens Position)
        - postoperative K → used in the vergence formula to calculate the IOL power.

- Latkany Method:
  - PreLASIK data not available, but PreLASIK refraction (spectacles) available.
  - Measure the current flat K and calculate IOL power.
  - Adjust IOL power by: **-(0.47 [pre-LASIK SEq] + 0.85)**
- Masket Metohod: derived from plotting different data-set
  - IOL power adjustment= LSE x -0.326 + 0.101
- Modified Masket Method:
- Speicher/ Seitz method:
  - this takes into account 11.4% change in refractive index of the cornea after surgery. (n= 1.375-1 / 1.337-1 which is 1.11 that accounts for 11% change in K)
  - K= 1.114 x TK (Post-Surgery) – 0.114 x TK (Pre-Surgery)
- Barret True-K:

- **Approaches that require no prior data**
  - Contact Lens Method
    - Power of CL
    - Base curve of CL
    - Refraction with CL
    - Refraction without CL
    - K= base curve + power + refraction with – refraction without
  - Gaussian Optics Formula
  - Haigis-L formula
  - Wang-Koch-Malony Method: When no data available, K= 1.114 x central power – 6.1
  - Optimal single formula—OCT
  - Optimal formula combination—Avg OCT/ Barrett True-K/Haigis

- **Other practical methods:**
  - **Holladay Equivalent K readings: EKR**
    - This is value given by PENTACAM and you can directly put it into your formula as K value. This is because pentacam does not assume about refractive index of cornea and it gives overall average K value.
  - **ASCRS Post-Refractive IOL Calculator updates (post-myopic LASIK/PRK)**
    - Removal of formulas based on pre-LASIK/ PRK Ks and ΔMR achieved with LASIK/PRK (poor performance)
    - Addition of OCT and Barrett True-K formulas

History of Cataract Surgery

Evolutions of anesthetic techniques for cataract surgery

- General anesthesia 1846
- Topical cocaine 1881 **Koller**
- Injectable cocaine 1884 **Knapp**
- Orbicularis akinesia 1914 **Van lint, O'Briens Atkinson**
- Hyaluronidase 1948 **Atkinson**
- Retrobulbar (4% cocaine) 1884 **Knapp**
- Posterior peribulbar 1985 **Davis and Mandel**
- Limbal 1990 **Furata** et al.
- Anterior peribulbar 1991 **Bloomberg**
- Pinpoint anesthesia 1992 **Fukasawa**
- Topical 1992 **Fichman**
- Topical plus intracameral 1995 **Gills**
- No anesthesia 1998 **Agarwal**
- Cryoanalgesia 1999 **Gutierrez-Carmona**
- Xylocaine jelly 1999 **Koch and Assia**
- Hypothesis, no anesthesia 2001 **Pandey and Agarwal**
- Viscoanesthesia 2001 **Werner, Pandey, Apple** et al

Evolution of techniques of cataract surgery

- Couching 800BC **Susutra**
- ECCE (Inferior incision) 1745 **J Daviel**
- ECCE (Superior incision) 1860 **Von Graefe**
- ICCE (tumbling) 1880 **H Smith**
- ECCE with PC-IOL 1949 **Sir H Ridley**
- ECCE with AC-IOL 1951 **B Strampelli**
- Phacoemulsification 1967 **CD Kelman**
- Foldable IOls 1984 **T Marrocco**
- CCC 1988 **HV Gimbel and T Neuhann**
- Hydrodissection 1992 **IH Fine**
- In-the-bag fixation 1992 **OJ Apple/El Assia**
- Accommodating IOls 1997 **S Cummings/Kamman**
- Phakonit (Bimanual phaco) 1998 **A Agarwal**

- Air pump to present surgery 1999 **S Agarwal (gas forced infusion)**
- FAVIT technique 1999 **A Agarwal**
- MICS terminology 2000 **J Alio**
- Microphaco terminology using 0.8mm tip 2000 **R Olson**
- Eye enhanced cataract surgery 2000 **SK Pandey/I Werner/ OJ Apple**
- Sealed Capsule irrigation 2001 **AI Maloof**
- Factors for PCO Prevention 2002-2004 **DJ Apple /I Werner/ SK Pandey**
- Microincisional coaxial phaco (MICP) 2005 **Takayuki Akahoshi**
- Microphakonit cataract 2005 **A Agarwal**

History of Phacoemulsification

- 1960: Charles D Kelman finished his residency at Wills Eye Hospital → GA was used for cataract surgery, no microscope was used.
- Kelman's previous discoveries:
  - Cryoretinopexy
  - Co-discovered cryoextraction of cataract
- Various drills, rotary devices and several types of microblenders → a dental ultrasonic unit
- the Christmas tree opening/ triangular capsulorhexis
- can opener technique
- Using an ENT microscope, the red reflex from the coaxial light gave him an incredible depth perception intraocularly. From then on, only ENT microscopes were used until Zeiss finally made one more suitable for ophthalmology.
- The original phaco handpiece was about the size of a large flashlight, and weighed almost a pound.
- Teflon → silicon sleeve is one of the latest improvement.

Non-Phaco Cataract Surgeries in Brief

ECCE: Extracapsular Cataract Extraction

Indications

- High risk of complications with phacoemulsification in surgeon's judgment, e.g., weak zonules, shallow anterior chamber, brunescent lens, corneal endothelial dystrophy
- Conversion to large incision extracapsular cataract extraction (ECCE) may be indicated if a significant portion of the nucleus is present following posterior capsular rupture or phacoemulsification unit malfunction

Contraindications

Relative (disadvantages compared to phacoemulsification)

- Combined trabeculectomy or presence of a prior bleb
- Increased potential of suprachoroidal hemorrhage or of poor patient cooperation
- Scleral thinning disorders such as scleritis and ectasia

Advantages compared to phacoemulsification

- Potential for decreased intraoperative costs
- Certain complications less likely (wound burn, endothelial trauma from excessive ultrasound time, tissue trauma from phacoemulsification tip)

Disadvantages compared to phacoemulsification

- Larger incision
  - More difficult to control anterior chamber depth
  - Not self-sealing in case of intraoperative emergency (choroidal effusion/hemorrhage)
  - Less forgiving of intraoperative external pressure (Valsalva, coughing, lid squeezing, speculum pressure, etc.)
  - Conjunctival trauma
    - Disadvantage if bleb present or combined procedure needed
    - Less virgin conjunctiva available for future trabeculectomy
  - Not appropriate for topical anesthesia
  - Increased iris trauma leading to increased likelihood of intraoperative miosis or postoperative iris deformity
  - Increased suture and incision-induced astigmatism both early and late postoperatively
  - Increased risk of incision complications (early and late)
  - Need for greater physical restrictions postoperatively
  - Potential prolonged postoperative refractive instability

    - Long term refractive instability (astigmatism drift)
    - Suture removal may be necessary
- Nucleus is not usually fragmented
    - Requires larger capsulorrhexis
        - Often too large to overlap the optic x 360 degrees
        - Small diameter CCC may impede nucleus delivery
    - More difficult with smaller pupils
- Globe protection may be required for a longer period of time: Protective shield advised during sleep
- Initial physical restrictions
    - Avoid Valsalva and dependent head position
    - Avoid eye rubbing
- Suture-induced astigmatism
    - Tight sutures may need to be cut
    - Refractive stability and final refraction delayed
    - More frequent postoperative visits may be needed
- Increased postoperative inflammation: Due to larger incision and perhaps greater iris trauma during surgery
- Long-term wound-induced refractive instability
    - Longer term against -the-incision drift in astigmatism with large, superior incision
    - More frequent changes in refraction for several years

Manual SICS

- Advantages over conventional ECCE surgery
    - Minimal surgical time as no suturing performed.
    - Incision size less than half
    - Least chance of anterior chamber collapse.
    - Least post-operative visit as no suture related problems are expected.
    - Better wound stability
    - Least induced astigmatism
    - Early patient mobilization
    - Early visual rehabilitation
- Advantages over phacoemulsification
    - It is cost effective as does not depend on sophisticated machine
    - No expensive infrastructure is required
    - Does not depend on expensive and failure prone equipments

    - Not dependent on highly trained maintenance personnel. Does not require an excellent capsulorhexis
    - Feasible for all types of nucleus
    - Requires least learning curve
    - No simultaneous foot coordination required
    - No expensive instruments are required
    - Least risk of complications
    - Quicker surgical time
    - Decreases learning curve of phaco
    - At the situation of "Phaco Failure", this procedure can be performed as an alternative procedure without additional surgical risk
- **Basic surgical steps**
    - Smooth and clean edged sclero-corneal pocket
    - Closed chamber side port entry.
    - Envelope type of anterior capsultomy / large capsulorhexis
    - Perfect hydrodissection to separate capsule from cortex.
    - Hydro delamination to separate the "hard core" nucleus from softer "epinucleus"
    - Rotation of the nucleus to anterior chamber and nucleus delivery
    - Cortical aspiration to minimize size of the nucleus

MICS: Micro Incision Cataract Surgery

- **Jorge Alio** from Spain coined the term "microincision cataract surgery"
- 1.8 mm incision or less (Medscape)
- One of the most important achievements of MICS is the reduction of the ultrasonic (US) power delivered into the eye.
- Among the major advantages of MICS is the reduction of surgical trauma resulting in a reduction of surgically-induced astigmatism (SIA).
- MICS IOLs
    - Acrismart IOL
    - **Thioptics Rollable IOLs** (Wayne Callahan) → ultrathin lens using Fresnel principles

PhakoNIT

- In phaKONIT, Its phaKO and not phaCO..remember

- (PHAKO) being done with a needle (N) opening via an incision (I) and with the phako tip (T).
- Amar Agarwal
- 15 August, 1998
- 1 mm cataract surgery
- **Principle**:
    - because of the infusion sleeves, minimum size 1.9 mm, titanium tip 0.9mm size
    - sleeve was removed and irrigating chopper used
- internationally, name of phakoNIT is now Bimanual Phaco. **Steve Arshinoff** gave term Biaxial Phaco.
- **Phakonit Thinoptx Rollabar IOL**
    - Ultrachoice 1.0 lenses
    - plus or minus 30 dioptres of correction on the thickness of 100 microns
    - evolutionary optic and unprecedented nano-scale manufacturing process
    - off-the-shelf hydrophilic material
    - more glare and halos
- **ThinLens**
- **Fresnel Lens**
- **MicrophakoNIT:** 700 micron

Phacoemulsification Basics

Principle

- Metal phacoemulsification (phaco) tip vibrates at high frequency
- Motion may be longitudinal, torsional, elliptical or a combination
- Vibration produces mechanical and cavitational effects at the tip which break apart lens tissue and create a repelling force
- Ultrasound energy can damage ocular tissue (e.g. corneal endothelium) as a result of turbulence and frictional heat
- Greater amounts of ultrasound power
  - Generate more tissue destruction and cutting ability
  - May be necessary for denser grade nuclei
  - Generate greater heat, increasing potential for wound burn
  - May cause endothelial cell trauma and corneal edema

The Phaco Machine

- Computer to generate ultrasonic impulses, and a transducer, piezoelectric crystals, to tum these electronic signals into mechanical energy

POWER

- Power is created by the interaction of frequency and stroke length.
- Frequency is defined as the speed of the needle movement. Generally its 35,000 cycles per second (Hz) to 45,000 cycles per second
- Stroke length is defined as the length of the needle movement. Most machines operate in the 2 to 4 mil range. (thousandth of an inch)

ENERGY

- Forces which emulsify the nucleus, are thought to be a blend of the "jackhammer" effect and cavitation.
- The 'jackhammer" effect is merely the physical striking of the needle against the nucleus.
- Cavitation
  - Transient Cavitation: Phaco needle while moving creates intense zones of high and low pressure. This produces compression of the microbubbles until they implode. At the moment of implosion, the bubbles create a temperature of 13,000 degrees and a shock wave of 75,000 PSI.
  - Sustained Cavitation: beyond 25 milliseconds, transient cavitation with generation of microbubbles and shock waves ends. No shock wave is generated. Therefore, there is no emulsification energy produced
- Transient cavitation is significantly more powerful than sustained cavitation.

- Continuous power: Only the initial energy is transient. The remainder is stabilized energy.
- In a 50-millisecond pulse, only the initial25 milliseconds is transient.
- In micropulse phaco, the entire pulse is transient energy

Physical Components of Phaco

- Two physical components of Phaco
    1. Rheology
    2. Power Modulation

Rheology

- Function of OVD (Ophthalmic Viscoelastic Devices)
- The manoeuvres performed in phaco can be viewed from the perspective of what we are asking the OVD to do, resulting in 3 distinct rheologic functions.
    1. SPACE MAINTENANCE (PRESSURE) & STABILITY:
        - During Capsulorhexis and IOL Implant
        - Best achieved with viscous cohesive OVDs Healon5, Healon GV, Healon, ProVisc
    2. ENDOTHELIAL PROTECTION & PARTITIONING SPACES (from fragment contact trauma, fluid turbulence & free radicals)
        - During Phacoemulsification and I-A steps
        - Best achieved with lower viscosity dispersives Viscoat, Healon Endocoat, HPMCs
    3. REDUCE RESISTANCE AT SURGICAL PLANE
        - During capsulorhexis step
        - Best achieved with BSS, Xylo-Phe.

Power Modulations

- Alteration of Stroke length: foot pedal adjustment
- Alteration of Duration: burst, pulse, micropulse
- Alteration of emission:
    - Power intensity is modified by altering bevel tip angle.
    - Power intensity and flow are modified by utilizing a 0° tip
    - flow can be modified by utilizing one of the microseal tips

- **Continuous mode**
    - When foot pedal is activated, the tip is constantly vibrating

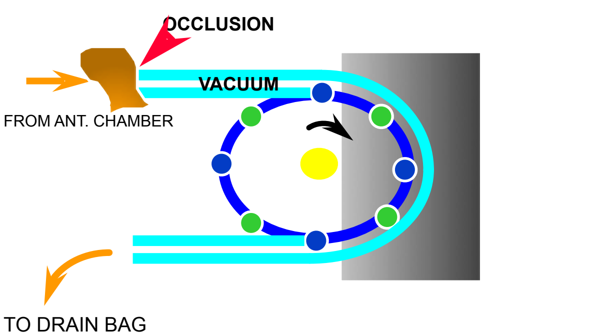
- Typically used for sculpting of the nucleus

- **Pulse mode**
    - When foot pedal is activated, ultrasound automatically cycles on and off
    - Often used for evacuating nuclear quadrants and fragments
- **Burst mode**
    - When the foot pedal is activated, a single burst of phaco energy is delivered
    - As pedal is further depressed, bursts occur more frequently
    - May be used to impale the nucleus during chopping
- **Micropulse** → Abbott Medical Optics (AMO)
    - A duty cycle is defined as the length of time of power on combined with power off.
    - Phaco OFF: 1. Nuclear material can be drawn towards tip 2. Cooling of phaco tip
    - Cold phaco: misnomer, its actually warm (<55 degree, temperature less than needed for wound burn)

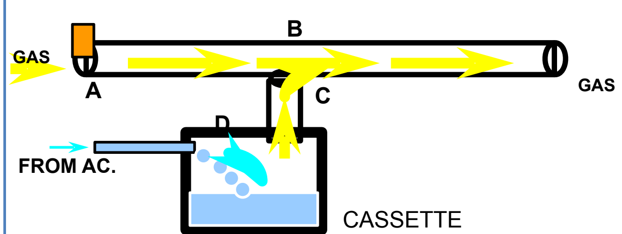
Phacodynamics

- Inflow: Irrigation Flow
- Outflow: Aspiration flow, Leak flow, Surge flow
- **Incisions**
  - Important for fluid dynamics
  - Too wide → Too much leak flow
  - Too tight → Irrigation flow compromised
- **Phaco Pump Differences**
  - Peristaltic pump: Aspiration flow and vacuum can be controlled separately
  - Venturi pump: Vacuum and aspiration flow are linked

Peristaltic pump



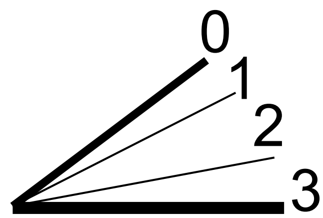
Venturi Pump



- **Irrigation Flow**
  - Bottle height determines infusion pressure
  - Resistance determined by narrowest point = Incision ~ Sleeve ~ Phacotip
  - When phacotip occluded, the entire infusion line pressure = Intraocular pressure
  - For e.g. 75 cm H2O: 13, 6 (density of Mercury) = 55 mm Hg (120 cm H2O = 88 mm Hg)
- **Aspiration Flow**
  - Speed of rotation of rollers (Peristaltic) determines flow and speed
  - Vacuum level determines force of suction and therefore Flow (Venturi)
  - There is only flow when the tip is free
  - On occlusion aspiration flow is zero
- **Vacuum**
  - Preset maximum level
  - Gradually increases after occlusion
  - Speed of vacuum build-up depends on aspiration flow
  - Vacuum is lost when occlusion breaks

- Vacuum → Holding force
- To keep nucleus to tip and suck lens material in and through aspiration tubing
- Higher vacuum → better suction

- **Footswitch**
  - 1 Irrigation
  - 2 Irrigation + aspiration → Vacuum build up
  - 3 Irrigation + aspiration + ultrasound → Occlusion break and loss of vacuum



- **Surge Flow**
  - Only on occlusion break
  - Necessary for all surgeons to understand mechanism
- **Mechanism of occlusion break**
  - Atmospheric pressure compresses aspiration line under vacuum
  - Fluid partially converts to gas at 300+ mm Hg vacuum
  - After occlusion breaks, aspiration line expands, gas bubble collapse
  - Expanding aspiration line and collapsing bubbles pull fluid from AC
  - **Beware of air bubbles!**
    - Aspirated air in aspiration line expands enormously under vacuum
    - On occlusion break this air space collapses instantaneously
    - Big surge flow and collapsing anterior chamber + posterior capsule rupture
- **Ultrasound**
  - A hollow metal sharp rimmed tip vibrating longitudinally (or sideways) at
  - 28000-40000 Hz, 0-100 microns under footswitch control
  - Ultrasound energy emulsifies the crystalline lens mainly by the jackhammer effect of the metal tip in direct contact with the lens
  - Torsional ultrasound emulsifies the lens by a shaving action
  - No contact = no emulsification
  - **Ultrasound & heat**
    - Friction between tip and silicon sleeve causes heat (rubbing hands)
    - More friction if tip presses harder against sleeve
    - Can cause wound burn = bad
  - **Ultrasound modulation**
    - Reduction of heat
    - Reduction of repulsion
  - **Ultrasound power setting (longitudinal ultrasound)**

  - Ultrasound stroke sufficient to break up lens material (harder nucleus requires higher stroke)
  - Not higher than necessary, otherwise too much repulsion
  - Pulse mode, Burst mode Micropulse
- **Torsional ultrasound**
  - Alcon Oil
  - Side to side movement of Phaco Tip
- **Transversal ultrasound**
  - AMO technology, Ellips FX
  - Combined, simultaneous action of longitudinal and sideways movement of phacotip end

Ophthalmic Viscosurgical Devices

History

- Advent of viscoelastic substances as a result of the research conducted by **Dr Endre A Balazs**, MD Budapest, Hungary).
- Work on the structure and biological activity of hyaluronan
- Healon, Swedish Pharmacia: 1st viscoelastic, Noninflammatory fraction (NIF) of hyaluronic acid
- **Miller and Stegman** were the first to use Healon in human cataract surgery
- Change in generic name suggested by → **Steve Arshinoff** → OVDs

Indications

- **In cataract surgery**: maintain the anterior chamber, mydriasis and media clarity, To prevent iris prolapse and trapping nuclear fragments, To protect the corneal endothelium To coat the interior of IOL injection cartridge
- Filtering procedures: intracameral and subconjunctival Healon,
- Vitreoretinal surgery: protect corneal epithelium

Categories

- According to cohesiveness parameters, viscoelastics can be classified depending on their point-of-rupture (of the cohesion) and **cohesive/dispersive index (CDI)** into two main groups: cohesive and dispersive (i.e. not cohesive) substances. *The CDI is defined as the percentage of viscoelastic agent aspirated 100mm Hg*; it classifies OVDs in terms of viscosity, cohesion and dispersion.

- **Higher viscosity cohesive OVDs: Jelly like**
  - Create and preserve spaces; displace and stabilize tissues
  - Low protection due to ease of aspiration
  - Clear
  - Easy to remove
  - Healon9 (Abbott Medical Optics), Healon GV9 (Abbott MO), Provisc9 (Alcon), Amvisc9 (Bausch & lomb)
- **Lower viscosity dispersive OVDs: Honey like**
  - Selectively moves and isolates tissues
  - Very protective of corneal endothelium
  - Less clear visualization
  - More difficult to remove

- Healon9 (Abbott Medical Optics), Healon GVS (Abbott MO), Provisc9 (Alcon), Amvisc9 (Bausch & lomb)

- **Viscoadaptative OVD:**
  - The rheological properties vary with the fluidics of phacoemulsification surgery.
  - A viscoadaptative OVD changes its behavior at different flow rates.
  - Healon5 (Na Ha 2.3%)(Abbott Medical Optics, Santa Clara, CA) was the **first and only** product marketed as viscoadaptative
  - it as a pseudodispersive, super-viscous cohesive that behaves as a highly cohesive viscoelastic to pressurize and create space, but can also provide the protection of a dispersive OVD.
  - At low flow rates, it is very viscous and cohesive. At high flow rates, it becomes pseudodispersive and effectively protects endothelial cells

Characteristics

- **CHEMICAL Characteristics: Three families of molecules**
  - Sodium hyaluronate (Na-HA) or Hyaluronic acid:
    - linear polysaccharide molecule of sodium glycuronate and N-acetylglucosamine
    - first isolated from the vitreous humor and possesses a high uronic acid content
  - Chondroitin sulfate (CS):
    - biopolymer found in the extracellular matrix, mainly in solid tissue parts
    - in the vitreous: Type IX collagen and versican.
    - shark fin cartilage and bovine or porcine cartilages.
  - Hydroxypropyl methylcellulose (HPMC):
    - Disaccharide
    - synthesized from methylcellulose, a component of plant fibers like cotton and wood pulp
    - significant inflammatory potential

- **The Rheologic characteristics:**
  - Viscoelasticity (Elasticity refers to the ability of a solution to return to its original shape after being stressed)
  - Viscosity, (reflects a solution's resistance to flow, which is in part a function of the molecular weight of the substance)
  - Pseudoplasticity = rheofluidity (refers to a solution's ability to transform when under pressure, from a gel-like substance to a more liquid substance)
  - Surface tension.

  - Coatability: It measures the adhesion capacity of OVDs. It is inversely propmtional to surface tension and the contact angle between the OVD and a solid material.
  - Cohesiveness: Cohesiveness is the degree to which material adheres to itself.
  - Dispersiveness: It is the tendency of a material to disperse when injected into the anterior chamber.

- **Desired properties of an ideal OVD**
  - Ease of infusion
  - Retention under positive pressure in the eye
  - Retention during phacoemulsification
  - Easy removal/no removal required
  - Does not interfere with instruments or IOL placement
  - Protects the endothelium
  - Nontoxic
  - Does not obstruct aqueous outflow
  - Clear

Combinations

- **Viscoat**: single syringe combination of 3% sodium hyaluronate & 4% chondroitin sulfate
- **Eyefil**: single syringe combination 1.37% biofermentative hyaluronic acid and 0.57% HPMC.
- **Duovisc**: two syringes with two different products, Viscoat and Provisc
- **Ixium Twin**: One syringe with two phases, phase one contains 2% Na-Ha and phase 2 contains 1.4% Na-Ha
- **Twinvisc**: The first product to be injected is dispersive 1% Na-Ha and the second product is cohesive 2.2% Na-Ha
- **Visthesia**: combination of a cohesive OVD and an anesthetic product, 1% lidocaine and 1% or 1.5% sodium hyaluronate
- **Healaflow**: For glaucoma surgery, slowly resorbable cross-linked sodium hyaluronate injectable implant, indicated for penetrating and nonpenetrating glaucoma surgery, acts as a chinage implant and limits the postoperative fibrosis thus clearly improving the surgical success rate and in most cases eliminating the need of antifibrotic agents like mitomycin-C

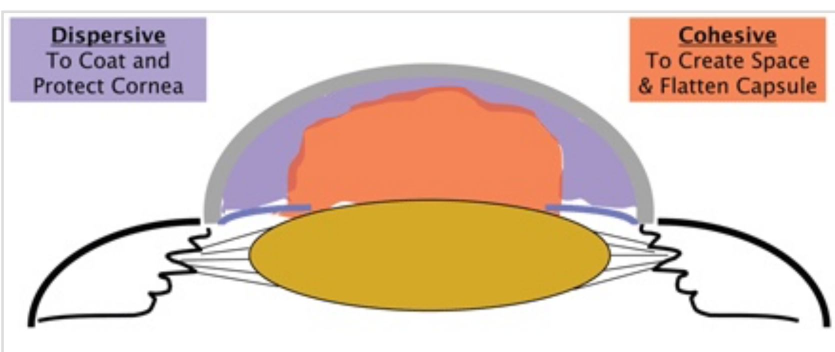
Complications of OVDs

- IOP increase
  - Due to incomplete removal of OVD
  - First noted with the use of Healon, the elevation is especially severe and prolonged if the material is not thoroughly removed at the conclusion of surgery, giving rise to what has been termed, **Healon-block glaucoma.**
  - Treatment of known or suspected retention of OVD at time of surgery

        - Installation of long-acting intraocular miotics
        - Topical application of glaucoma medication
        - Short term oral carbonic anhydrase inhibitors
    - Treatment of elevated IOP postoperatively
        - Topical application of glaucoma medication
        - Short term oral carbonic anhydrase inhibitors
        - "Burping" the paracentesis at the slit lamp
        - Anterior chamber washout
- Incision burn
    - Caused by occlusion of tubing
    - More likely with a dispersive OVD and brunescent cataract

Techniques of OVDs Use

- **ARSHINOFF'S SOFT-SHELL TECHNIQUE (SST)**
    - Arshinoff, 1999
    - A low viscosity dispersive (or dispersive/cohesive) agent is first injected into the anterior chamber (Healon®, a dispersive/cohesive agent is mainly used). Then a highcohesive OVD (e.g. Healon GV®) is injected into the posterior center of the dispersive agent, towards anterior capsule surface.
    - Once the cataract has been extracted, its better to proceed the other-way-round: the cohesive OVD is injected first, and then the low viscosity dispersive viscoelastic is injected in the center of the high viscosity OVD. The cohesive agent will stabilize the intraocular tissues during IOL insertion, and the dispersive agent will be easily aspirated at the end of surgery by placing irrigating/aspirating cannula on the I OL at the pupillaty plane. The cohesive OVD will be easily removed as a bolus after that.
    - The disadvantage of the soft shell technique is that it requires the use of two separate syringes of OVDs which must be used sequentially, with correct sequence and precise positioning, instead of a single OVD syringe, thus increasing cost and inconvenience

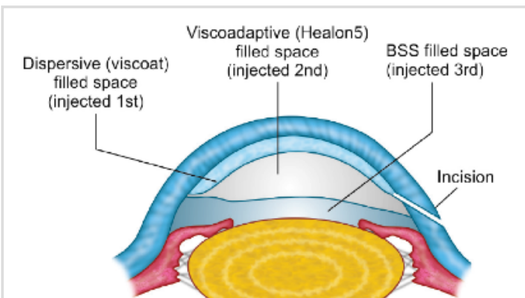


Arshinoff Soft-Shell Technique

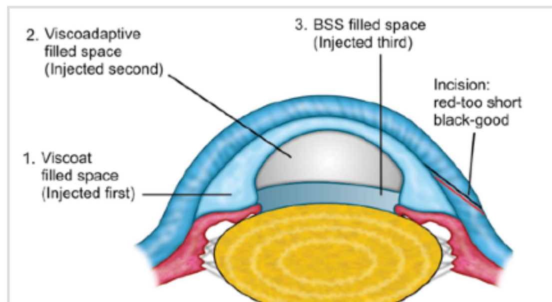
- **Ultimate soft-shell-technique (USST):**
  - Uses viscoadaptive and BSS (instead of dispersive) → good condition for controlled capsulorhexis without peripheral extension.
  - Healon 5: The essence of Healon5 is it's rheological idiosyncrasy that makes it unique in being both very highly viscous cohesive and retentive.

- **Tri-Soft Shell Techniques (TSST) → SST-USST combinations**
  - Uses layers of dispersive against the cornea, viscous cohesive centrally to establish stability, and BSS (or XYLO-PHE) on the lenticular surface (for a low-viscosity surgical space). Optimizes pupil dilation and makes cases easier.

- **IFIS Soft Shell Bridge (SSB) technique**
  - Just like TSST but iris is also coated by Viscodispersive OVDs.



TSST Arsinoff SA Article



SSB Arsinoff SA Article

Phacoemulsification Steps

Incisions

- Scleral tunnel: Girard and Hoffmann
- 1989, McFarland and Ernest: corneal lip, corneal entrance and a posterior lip
- **Paul Koch**: incision funnel
- **Howard Fine** : single-step “stab" corneal incision
- **Charles Williamson**: Two step grooved incision
- ***Healing of limbal and clear corneal incisions***: **7 days** for vascular origin (limbal) and **60 days** for avascular origin (corneal)

Scleral Incisions

- smile shape or concentric to the limbus
- frown shape or opposite of the limbal curvature: The frown configuration minimizes against-the rule astigmatism and is reportedly the most astigmatically neutral of these incision
- The scleral tunnel must extend into the clear cornea to avoid the prolapse of the iris, damage to the structures of the chamber angle, fluid loss and a flat anterior chamber and to create a valve effect which will seal the wound at the end of the surgery.

Clear Corneal Incisions

- a bloodless, self-sealing, sutureless and quick, relative astigmatic neutral
    - Single plane no groove
    - Shallow groove< 400 microns
    - Deep groove > 400 microns.
    - Single-plane incision 2.5 by 1.5 mm, rectangular tunnel
    - Two-plane incision 2.5 by 1.5 mm rectangular tunnel.
    - Three-plane incision 2.5 by 1.5 mm rectangular tunnel

Relaxing Incisions

- LRI: Limbal Relaxing Incisions
- CRI: Corneal Relaxing Incisions
- AK: Astigmatic Ketatotomy

Capsular Dye

- Indocyanine green (ICG) and trypan blue dyes are both safe and effective
- Endothelial decompensation From Methylene blue dye has been reported.

- **Advantages of Trypan Blue over ICG**
    - Significantly darker and more intense staining of the capsule
    - More persistent staining of the anterior capsule
    - Decreases elasticity of the anterior capsule
- **Staining Techniques**
    - Minas Coroneo pioneered the use of trypan blue and holds the patent for its use in eye surgery. He prefers to inject the dye solution directly into the anterior chamber before washing it out. This produces a reasonable degree of anterior capsule staining.
    - Takayuki Akahoshi has described mixing ICG with viscoelastic for use as a single injection.
    - Marques and Osher described first injecting Healon 5, and then layering a small amount of saline directly over the anterior lens capsule. This creates a thin potential fluid space overlying the anterior lens capsule into which trypan blue can be placed, without created an opaque mixture of OVD and dye.
    - Horiguchi and Melles described the technique of injecting capsular dye after first filling the anterior chamber with air to avoid excessive dilution of the dye. Several drops of dye from a tuberculin syringe are placed directly onto the anterior capsule surface through a 30-gauge cannula. The dye is then irrigated away, the anterior chamber is filled with OVD, and the capsulotomy is performed in the usual manner. One drawback of this technique is that the air bubble meniscus displaces the dye from contacting the center of the anterior capsule.
    - David Chang advocated use of an air bubble, but then stroke the cannula slowly back and forth across the central anterior capsular surface. Capillary action causes dye to pool alongside the cannula shaft assuring prolonged capsular contact. This method results in darker capsular staining compared to the classic air bubble or direct injection techniques, and allows one to exchange the air bubble with a fresh OVD injection to provide a maximally clear view of the capsule.
- Capsular dye should be considered whenever difficulty with anterior capsule visualization is anticipated. It can even be applied ***even after the capsulorrhexis has been initiated.*** This is because both dyes preferentially stain the capsule, but not the cortex. Finally, capsular dye is a useful teaching aid when first learning to perform a capsulorrhexis, or for transitioning to horizontal phaco chop.

Capsulorhexis

- **“Third hand” in phaco**
- Thomas F. Neuhann & Dr Howard Gimbel
- Calvin Fercho, who developed continuous tear capsulotomy
- continuous tear capsulotomy → continuous curvilinear capsulorhexis (CCC)

Various Techniques

- **NEEDLE TECHNIQUE**
  - First an initial puncture of the anterior capsule within the central area, to be removed
  - End will automatically join the beginning of the curve *outside in*
  - BSS or viscoelastics
  - Only the 23-gauge needle is recommended:
    - lumen of this type of needle is just sufficient to produce a pressure exchange between the anterior chamber and the BSS irrigating bottle
    - just enough rigidity to provide the necessary resistance for difficult manipulations.
- **FORCEPS TECHNIQUE**
  - Utrata forceps, mini forceps
  - Forceps technique is easier to leam
  - Viscoelastics is mandatory.
- **TWO-STEP NEEDLE TECHNIQUE**
  - Older technique
  - Needle without bend → flap creation
  - Bent needle → flap rotation and completion
- **CAPSULOSTRIPSIS**
  - Invented by **F Rentsch** and described by **JH Greite** at the 1995
  - Vitrector with infusion sleeve is used to create an irregular opening in the anterior capsule
  - Rounded, mousebitelike cuts of the vitrector tip, nevertheless produce a stable rim
  - Time-consuming
- **DIATHERMY CAPSULOTOMY**
  - Multiple irregularities and offers less stability and less elasticity.
  - Two-incision push-pull capsulorhexis
  - Nischal
  - CCC in infantile and juvenile capsules
  - Here, two stab incisions are made proximally and distally to the incision approximately 4.5-5.0 mm
- **POSTERIOR CAPSULORHEXIS**
- **ANTERIOR AND POSTERIOR CAPSULORHEXIS**
  - **MJ Tassignon**: bag-in-the lens technique
- **CAPSULORHEXIS SIZE**
  - Somewhat smaller than the optic diameter of the intraocular lens (IOL)

Advantages & Disadvantages

- **ADVANTAGES**
  - Increases the resistance of the capsular bag to tearing during phacoemulsification
  - Allows for optimal centration of the intraocular lens (IOL) in the capsular bag,
  - CCC that overlaps the edge of the optic x 360 degrees decreases incidence of posterior capsular opacification and may reduce edge dysphotopsias
  - After CCC, anterior capsule can support sulcus fixated IOL (with or without CCC-optic capture) if the posterior capsule is compromised
- **DISADVANTAGES OF THE CCC**
  - Capsular shrinkage syndrome or capsular phimosis

Contraindications

- Cannot visualize the anterior capsule
- CCC may need to be abandoned in the setting of a tear has approaching the periphery or zonular fibers
- Capsular fibrosis
- Small diameter CCC may not allow delivery of a brunescent nucleus during extracapsular cataract extraction.

Complications & Management

- During the capsulorrhexis, the tear can extend to the periphery or zonules. At this point, consider converting CCC to can-opener capsulotomy
- During phaco, the CCC edge is torn or cut with a second instrument or with the phaco tip
- Performing phaco with a single radial tear in the CCC increases risk of a tear that "wraps around" into the posterior capsule
- CCCs with very small diameter
  - may cause posterior capsular block with hydrodissection and difficulty with cortical clean-up and IOL insertion
  - can lead to postoperative anterior capsule fibrosis, and capsulophimosis which can reduce peripheral fundus visualization and visual acuity
- Too large a CCC will eliminate the advantage of overlap of the IOL edge and may affect centration
- **Prevention of complications**
  - If visualization is poor, consider use of capsular dye
  - Frequent refilling of OVD if the anterior chamber shallows
  - Avoid overly large diameter
  - Familiarity with capsule rescue technique

- **Management of complications**
  - If radial tear is too peripheral, abandon the tear and consider additional relaxing incisions, tearing from the opposite direction, or converting to a can-opener capsulotomy
  - If CCC diameter is too small
    - perform secondary enlargement after the IOL is implanted
    - consider doing relaxing incisions along the CCC edge

Capsular Radial Tear & Management

- There are five general conditions that increase the risk of a radial capsulorrhexis tear:
  - Poor visibility: Stain, Microscope adjustments, Dryness and ocular causes management
  - Unexpected eye movement: Proper patient selection, avoid excessive light, block if required
  - Anterior chamber shallowing: Cohesive OVD, avoid excessive instruments pressure, Refill OVD when required
  - Elevated intralenticular fluid pressure (intumescent white lens): Cohesive OVD, fluid drainage if required
  - Increased capsular elasticity & Pseudoelasticity:
    - Pediatric anterior capsules are very thin and elastic, the flap tends to spiral outward and is very difficult to control
    - adult posterior capsule has less tensile strength and is thinner and more elastic than the anterior capsule
    - Weak zonules fail to keep the anterior capsule taut, giving rise to a situation called capsular *pseudoelasticity*.
    - capsulorrhexis is "zonular stress test," because the first indication of how weak the zonules are becomes evident during this step. If the anterior capsule is not taut, the cystotome tip will tend to first dimple, wrinkle, and indent it, rather than immediately puncture it.
    - If pseudoelasticity is severe, the surgeon can use iris hooks or specially designed capsule retractors to help anchor the bag during the capsulorhexis step
- **Brian Little's capsule tear out rescue maneuver**
  - The capsulotomy is normally created by pulling the free capsule flap ahead of its insertion point. Control is maintained by continually re-grasping the flap with forceps or re-engaging it with a sharp cystotome. When the surgeon starts to lose control, the tear can be seen to head radially outward rather than following the inward vector of the moving forceps tip. Recognizing this, the surgeon must stop before the tear escapes too far peripherally and assess the cause. If the anterior chamber has shallowed, re-deepening it with OVD and re-grasping the flap closer to its base may help.

    - The first step is to **unfold the flap backwards** and to place it on traction by pulling it away from the intended direction of the tear. By maintaining backward traction on the flap, one should be able to then redirect the tear back toward the center. Analogous to pulling on a bed sheet where one end is tucked in, this traction prevents the tear from moving in any direction other than that which the surgeon intends. One the diverging tear has been successfully re-directed, the flap can be folded forward and the traditional capsulotomy technique can be resumed.
- The incidence of anterior capsule tears reported from four contemporary studies varies from 0.8% to 5%.

Hydrodissection and Hydrodelineation

Hydrodissection

- Described by Howard Fine
- Cortical cleaving hydrodissection
- Eliminates the need for cortical cleanup as a separate step in cataract surgery
- **Purpose**
    - Permits rotation of the nucleus by severing cortical attachments to capsule
    - Facilitates cortex removal
- **Instrumentation and technique**
    - Syringe with hydrodissection cannula
    - Can use balanced salt solution, non-preserved lidocaine, or ophthalmic viscosurgical device (OVD)
    - Steps
        - Cannula tip is positioned beneath continuous curvilinear capsulorrhexis (CCC) edge & a fluid wave is directed toward and along internal surface of the capsular bag
        - Wave passes posteriorly behind the nucleus, causing slight forward bowing of the lens
        - Depress the nucleus immediately to separate a part of the nucleus from the anterior capsule so as to break capsulorrhexis-lenticular block and to propagate the fluid wave completely around the lens
        - Depress the nucleus approx. 180° away to separate the opposite part of the nucleus from the anterior capsule
    - Lens may be rotated
- **Complications and Management**
    - Failure to loosen nucleus or epinucleus
        - Greater forces imparted to capsular bag and zonule during attempted rotation resulting in zonular dehiscence or loss

    - Increased risk of surgical complications if the nucleus does not rotate
- Intraoperative capsular block and "blowout" of posterior capsule
    - Elevation of nucleus under the CCC edge can create intraoperative capsular block
    - Continued irrigation results in trapped fluid between the lens and posterior capsule
    - May tear the posterior capsule particularly with high risk patients (i.e.: posterior polar cataract, post vitrectomy, or trauma) where there is already a weakened or defective posterior capsule
    - Gently push down on nucleus and lift anterior capsule edge with cannula to relieve block and release trapped fluid

Hydrodelineation

- Term first used by Anis
- Act of separating an outer epinuclear shell or multiple shells from the central compact mass of inner nuclear material, the endonucleus, by the forceful irrigation of fluid
- Circumferentially divides the nucleus & Reduces overall size of the portion of nucleus that must be chopped or sculpted
- Provides a protective cushion.
- Reduces posterior capsule rupture during phacoemulsification
- Optional step that may be safer than hydrodissection in the presence of a capsular defect or posterior polar cataract
- During removal of last nuclear fragments, epinuclear shell can stabilize posterior capsule and restrain it from trampolining toward the phaco tip

Nucleus Emulsification

Pre-requisites

- Optimal visibility
- Capsulorhexis
- Hydro procedure
- Sculpting
- Width: wide enough for free movement of ultra sound tip
- Length: must extend just below the capsulorhexis
- Depth: 80 to 90% of the nuclear thickness, two and half times the diameter of the phaco tip,

Divide and Conquer

- Howard V Gimbel
- Deep sculpting until a fracture is possible,
- Nucleofractis of the nuclear rim and posterior plate of the nucleus,
- Fracturing again and breaking away a wedge-shaped section of nuclear material for emulsification
- Rotation or repositioning of the nucleus for further fracturing and emulsification

Crater Divide and Conquer (CDC)

- In c/o hard cataract
- Large crater sculpted, leaving a dense peripheral rim to fracture into multiple sections
- Each wedge-shaped section is generally left in place for capsular bag distention.

Trench Divide and Conquer (TDC)

- In c/o grade 2-3
- Central narrow trench

Trench Divide and Conquer with "Down Slope" Sculpting

- In c/o small pupil
- Nudging the lens inferiorly with the second instrument
- Upper central portion of the nucleus can be sculpted very deeply

Chip and Flip Technique

- Howard Fine developed a technique called the "chip-and-flip" that depends on circumferentially dividing the nucleus, as opposed to sectorally dividing it.
- Divide the nucleus into a central endolenticular mass surrounded by an epinuclear shell.
- Sculpt and then sublux the residual central endonucleus (called the chip) by inserting a spatula underneath it, bringing it up into the plane of the pupil, and then phacoemulsifying it, after which trim and flip the epinucleus.

Horizontal Phaco Chop

- K. Nagahara, 1993
- Physics of splitting wood
- A chopping instrument (the hatchet) is used to split the nucleus (the log) resting against the phacoemulsification tip (the chopping block).

- Horizontal choppers usually feature an elongated, but blunt-ended tip. A tip length of 1.5 to 2.0 mm length is necessary in order to transect thicker nuclei, and the inner cutting surface of the tip may sometimes be sharpened for this purpose of incising denser lens material. The very end of the tip is always dull, to diminish the risk of posterior capsule perforation. Many horizontal choppers have a simple right-angle tip design.

Stop and Chop

- Koch and Katzen
- His technique begins with sculpting a traditional deep, central groove in order to crack the nucleus in half. One then stops the divide-and-conquer method, and chops the hemi-nuclei.
- The advantage of "Stop and Chop" is that it avoids the difficult first chop. As a result, one chops only across the radius, rather than the full diameter of the nucleus. Second, unlike with the initial "non-stop" chop, the phaco tip can be positioned within the trough up against the side of the hemi-nucleus that is to be cleaved.

Vertical Phaco Chop

- Whereas the horizontal chopper moves inward from the periphery toward the phaco tip, the vertical chopper is used like a spike or blade from above to incise downward into the nucleus just anterior to the centrally impaled phaco tip.
- When the chop is first initiated, the instruments move toward each other in the vertical plane.
- Variations
    - Hideharu Fukasaku introduced his technique of "Phaco Snap and Split" at the 1995 ASCRS meeting.
    - Vladimir Pfeifer's "Phaco Crack" method of chopping was introduced at the 1996 ASCRS meeting and is a similar technique. This variation was renamed "Phaco Quick Chop" by David Dillman.
    - Abhay Vasavada published his "Stop, chop, chop, and stuff". technique in 1996
    - Steve Arshinoff published his "Phaco slice and separate" method in 1999.
- The most important step in vertical chop is to bury the phaco tip as deeply into the center of the endonucleus as possible. Depressing the sharp vertical chopper tip downward, while simultaneously lifting the nucleus slightly upward imparts a shearing force that fractures the nucleus.

Vertical and Diagonal Chop for Brunescent Nuclei

- Vertical chop is more consistently able to fracture the leathery posterior plate
- With an ultra-brunescent lens, one can also slightly alter the angle of the vertical chop. Instead of incising straight down like a karate chop striking a board, the vertical chopper should approach the embedded phaco tip more diagonally. This provides more of a

horizontal vector that pushes the nucleus against the phaco tip, while the vertical vector initiates the downward fracture. This "diagonal" chop therefore combines the mechanical advantages of both strategies.

- Vertical choppers feature a shorter tip that has a sharpened point in order to penetrate denser nuclei. If the tip is too dull, it will tend to displace the nucleus off of the phaco tip rather than incising into it. In contrast to horizontal choppers, the length of the vertical chopper tip is shorter because it never encompasses one side of the nuclear segment.
- The three dimensional motions required of the chopper are much simpler with vertical chop. Compared to horizontal chop, the chopper tip is not placed as peripherally and simply incises downward into the nuclear mass.

Aspiration and Irrigation

- Automated and Manual Systems
- Automated advantages:
    - Vitreous is pushed back thus ensuring safety of posterior capsule.
    - Less chance of endothelial damage due to well maintained AC.
    - Easier I/A because of open and accessible capsular fornices.

IOL Implantation

Postoperative Air

- Not ideal, so not in all cases
- ?? issue of sterility

Intracameral Antibiotics

- 2014 ASCRS Endophthalmitis Prophylaxis Survey (Cataract Clinical Committee)
    - 50% using intracameral antibiotics:
        - 84% direct injection
        - 16% place in infusion bottle
    - Antibiotics
        - Moxifloxacin (0.5%/0.15% in 0.1 mL)
        - Cefuroxime (1 mg/0.3 mg in 0.1 mL) (ESCRS Study)
        - Vancomycin (now not used because of HORV: hemorrhagic occlusive retinal vasculitis)

Corneal Hydration of Incision

- Popularized by Fine.
- Helps in preventing ingress of fluid from outside the eye to within
- decreased incidence of postoperative endophthalmitis in clear corneal wounds that were hydrated

FLACS: Femtosecond Laser Assisted Cataract Surgery

- Femtolaser assisted cataract surgery or FLACS has emerged as the newest technological advance in cataract surgery but modifications in technique are needed for success.
- **History**
    - 2001: Femtosecond for refractive surgery
    - 2009: Prof. Zoltan Nagy at the Semmelweis University in Budapest, Hungary, performed the first laser refractive lens surgeries with a femtosecond laser in 2008. He used the LenSx femtosecond laser, built by LenSx, Inc. (Aliso Viejo, Calif., USA). HE first published the results comparing laser-created capsulotomies to manual capsulorrhexes in porcine and human eyes.
    - Alcon acquired this company in 2010, and the first commercial lasers were sold in 2010.
    - 2010: FDA cleared femtosecond laser system for cataract surgery.
- **Four Femtosecond Laser Systems Available**
    - LenSx (Alcon LenSx; Fort Worth, Texas, USA)
    - Catalys (Optimedica Catalysis; Santa Clara, Calif., USA)
    - Victus (Technolas Perfect Vision and Bausch + Lomb; Rochester, NY, USA)
    - LensAR (LensAR, Inc.; Orlando, Fla., USA)
- **The Femto Step : Docking, planning and lasering:**
    - Good exposure of eye is critical. Docking with minimal tilt of globe is ideal although all the platforms compensate for tilt in one way or another. The Lensx uses a single piece docking system whilst most others use a two piece platform. It is worth noting that the suction on time for the Lensx system is the shortest among the major platforms but that the Catalys does the all important capsulorhexis much quicker than the others. Planning for treatment is automated in the Catalys but is surgeon controlled for the Lensx and Victus platforms.
- **The Phaco Step**:
    - **Incisions** may be sticky and it is necessary to use a femtospatula designed to open these incisions, typically about 0.9mm side port and 2.3mm main port. If there is marked arcus senilis, femtoincisions may be imperforate.
    - **CCC**: Completely free **anterior capsular flaps** are now the norm but care needs to be taken when removing the anterior capsule especially if there are adhesions, tags or bridges.
    - It is good practice to **burp the gas** out from behind the nucleus to reduce risk of hydrorupture of the posterior capsule. Less **hydrodissection** is needed as some pneumodissection has already happened.
    - **Nucleus removal**: For the softer cataract, it is useful to use a prechopper to complete the separation of femtofragmented quadrants. For denser ones, it is straightforward to groove centrally and then push the heminuclei apart or do a direct chop technique.

    - **Irrigation/aspiration** of lens cortex is ideally done a little beyond the edge of the white CCC to avoid aspirating a capsular tag. A side to side motion is useful to free the sticky cortex.
- **Other tips:**
    - Use a drop of NSAID with dilating drops an hour before surgery to avoid post FLACS miosis.
- **FLACS in complex cataracts**
    - Increasingly FLACS is making surgery easier and safer in patients with partially subluxated cataracts or weak zonules, white cataracts, fibrous capsules and posterior polar cataracts.
- **Complications**
    - Suction loss is a rare occurrence.
    - Conjunctival redness or hemorrhage
    - Incomplete capsulotomy
    - Imprecise corneal incisions
    - Damage to the iris
    - Hydrorupture of the posterior capsule was reported in early days but understanding of the role of gas formation and its release has reduced the risk of this.
    - System/computer failure

LenSx Femtosecond Refractive Cataract Laser Platform

- Most widely used platform in United States and worldwide
- Capsulotomy: SoftFit interface provides nearly 100% free-floating, pristine capsulotomies
- Lens fragmentation
    - Enhanced with SoftFit PI
    - Zero phaco energy possible: Questionable benefit
    - Numerous fragmentation patterns available
- Corneal incisions
    - Precise arcuate incisions
    - Precise primary and secondary corneal incisions including bimanual phaco/irrigation/aspiration capability
- Patient Flow
    - Surgical stretchers of choice decreases need for moving patients on and off surgical beds
    - Docking
        - Easy and fast; no need to mess with liquids
        - Comfortable for patients
        - Software: Intuitive, fast, precise Time in laser room: 3 minutes

CataLys

- Catalys Precision Laser System (Sunnyvale, Calif., USA)
- Patient interface
    - Liquid Optics Interface minimizes IOP during dock over curved contact lens
    - Nonapplanating interface simplifies treatment of all patients and minimizes corneal folds.
    - Gentle docking allows treatment of infants and redocking with more flexibility for procedural flow (ie, capability of entering eye first and then performing laser procedure).
- Imaging modalities
    - Full-volume 3-D OCT high-resolution images inform surgical decision making.
    - OCT capable of imaging through posterior capsule even in thick, brunescent lenses.
    - OCT capable of detecting posterior capsule with lens removed.
- Image guidance
    - Automated image guidance minimizes time under dock.
    - Customization allows for surgeon input and creates flexibility to treat all patients.
    - Flexibility in surface fitting creates capability for new procedures, such as posterior capsulotomy with bag in the lens and posterior optic buttonhole.
- Laser technology
    - Extensive grid fragmentation pattern creates capability to eliminate ultrasound energy.

LensAR

- Small footprint and mobility
- Augmented RealityTM with intelligent imaging B. Image-guided cataract surgery
    - Lens anatomy
    - Lens grading
- Laser Anterior Capsulotomy
    - Tilt compensation and capsulotomy results
    - Effective lens positioning
- Lens Fragmentation
    - Range of treatable cataracts
    - Treatment algorithms
    - Cumulative dissipated energy reduction

- Corneal Incisions
    - Triplanar clear corneal incision
    - Arcuate incisions
- Accommodation Restoration

Technolas Perfect Vision

- Femtosecond laser with only combined platform
    - Flaps
    - Corneal transplants
    - Astigmatic keratotomy
    - intraCOR
    - Capsulorrhexis and lens liquefaction

Intra-Ocular Lenses

- Credit for the invention and first implantation of the IOL is given to **Sir Harold Ridley** of London. (two-step procedure: ECCE → IOL) 1949-1950, British fighter pilots' canopies's crush → made of polymethylmethacrylate (PMMA; Perspex). He worked with the Rayner, made Perspex CQ, a more purified "clinical-quality" PMMA. On May 25, 2001, at the age of 94 years he died in Salisbury, England, after a cerebral hemorrhage.
- **Warren Reese** was the first American surgeon to perform the first IOL surgery in the United States at the Wills Eye Hospital, Philadelphia, in 1952

Generations of Intraocular Lenses

1. 1949-1954, Original **Ridley posterior chamber PMMA IOL** manufactured by Rayner, Ltd., UK
2. 1952 -1962, **Early AC IOL**
3. 1953-1973, **Iris-supported**, including irido-capsular IOL implanted after ECCE
4. 1963-1992, Transition towards **modern AC IOLs**
5. 1977-1992, Transition to and maturation of **posterior chamber IOLs**
6. 1992-2000 Modern IOLs
   a) Monofocal IOLs designed specifically for in-the-bag implantation
      - Small, single piece modified C-loop designs
      - Foldable IOLs, designed for small incision surgery

   b) AC IOLs
      - Kelman (flexibility)
      - Choyce (footplates)
      - Clemente (fine-tuning, no-hole, three point fixation)
7. 2005--Present
   - Modern flexible, "Specialized" IOLs (often designated as "**premium"**)
   - Designed for special functions (refractive surgery, MICS, presbyopic correction, multifocal, accommodative IOL, telescopic IOL, light adjustable IOL, etc.)

Materials for Intraocular Lenses

Factors affecting Surface properties on cell adhesion:

1. **Free energy of the interface (FEI)**: most hydrophilic materials, with a low FEI (< 5 ergs/crn2) and the most water-repellent materials, which have a high FEI (> 40 ergs/cm2) resulted in much lower cell adhesion than does PMMA. The intermediate FEI values (5 to 40 ergslcm2) of a PMMA make it favorable to cell adhesion and cell proliferation
2. **Surface energy (SE):** hydrophilic → higher SE, hydrophobic → lower SE
3. **Angle of contact (AC):** hydrophilic → lower AC, hydrophobic → higher AC

PMMA

- Amorphous, transparent and colorless
- Refractive index of 1.49 to 1.50
- Transmits 92% of the incident light
- Specific density of 1.19 gm/cm3
- PMMA is fairly water-repellent
- Has an angle of contact of 70°
- Water absorption index of 0.25%.
- Has to be sterilized at a low temperature,
- Ethylene dioxide is therefore used to sterilize PMMA IOLs.
- Manufacturing Process: Turning or molding

- ***SURFACE PROPERTIES***
    - ***Treatment of the surface proper:*** alter some characteristics or the surface, such as roughness, hardness or slipperiness, without grafting molecules.
        - Chemical techniques (chemical oxidation-ozone)
        - Flaming
        - Electromagnetic radiation
    - ***Coating with a deposit:*** Another polymer (deposit) with the desired properties is deposited on the backing to form a layer, which may reach a thickness of about 10 microns. The method usually is that known as the "soaking method".
        - *Teflon-coated Lenses*
        - Grafting by the attachment of new molecules:
    - **Heparin surface-modified lenses:** better anti-adhesive effect, reduces complement activation by PMMA IOLs
        - Surface **passivated IOLs:** to lower the energy and reduce the irregularity of the surface
        - **IOLs treated with Cold Plasma CF4:** fluoridated by cold plasma treatment,

Silicon

- Can be folded and inserted through small incisions
    - Polydimethylsiloxane: low refractive index (1.412 at 25°C) → relatively thick lenses.
    - Copolymer of diphenyl and dimethylsiloxane: refractive index of 1.464

- Manufacturing: injection molding → surface irregularities at the junction of the two sides of the lens → known as **molding flash** → glaucoma
- ***Surface modification:*** oxygen plasma, which made their surfaces less water-repellant
- ***Discoloration and capsular opacification of silicone IOL:*** granular brownish appearance,
- It is recommended avoiding the use of this type of material if there is silicone in the posterior segment, or if there is a risk of a slipped retina, because the adsorption of silicone to the smface of these lenses is irreversible.

ACRYLIC IOL

- stiff hydrophobic polymethylmethacrylate (PMMA)
- soft hydrophilic hydrogels, such as PHEMA.
- vitreous transition temperature (VTT): VTT of PMMA is 110°C

SOFT ACRYLIC IOLs

- An ester of acrylic acid and an ester of methyacrylate acid (AcrySof®/ Acrylens®)
- two esters of methacrylate acid (Memorylens®
- higher refractive indices
  - ***HYDROPHILIC:*** Memorylens, Hydroview, EasAcryl, Akreos
  - ***HYDROPHOBIC:*** AcrySof (refractive index of 1.55, appropriate for multiple implantations)
    - Sensar
    - AcryLens

HYDROGEL IOLs

- 38% water, biconvex lens and flanged flat loops. Their rear surface has a continuous convex area of curvature, giving it a "taco-like" appearance
- Hydrophilic, gives them the advantage of having a lower cell adhesion capacity than PMMA.
- Two drawbacks: decentration, increased PCO (rarely backward displacement while doing YAG Cap)

ACIOLs

- First AC IOL implantation was done in France in **1952 by Baron**
- 2nd generation lenses were rigid anterior chamber lenses: Strampelli tripod ACIOL and Choyce Mark I AC IOL.
- 3rd generation IOLs were the iris supported lenses
- **4th generation IOLs**: Lusko lens, Cilco Optiflex;
- Modern AC IOLs:
- **Indications**
  - Rupture of the posterior capsule at the time of cataract surgery
  - Subluxated lens/IOL
  - Anterior/posterior dislocated lens/IOL
  - Aphakia with no capsular support
- **Contraindications**
  - The AC IOLS are best avoided in the following conditions:
  - Uveitis patients
  - Unhealthy corneal endothelium
  - Pediatric eyes
  - Eyes with shallow anterior chamber
- **Complications**
  - Corneal edema
  - Uveitis
  - Glaucoma
  - Hyphaema
  - Pupillary distortion
  - Cystoid macular edema
  - Synechiea
- ***Current status***
  - The flexible loops has decreased the need for exact determination of the IOL size
  - Tumbling technique used to polish the IOL provides a smooth optic haptic edges and a smooth surface this has decreased the incidence of iris chaffing and uveitis.
  - The haptic loops are so designed that there are three to four point contacts with the angle which has greatly decreased the risk of developing post operative glaucoma and synechiea formation.
  - The absence of holes in the IOL has resulted in easy explantation of IOL if and when required.

Iris Claw Lens

- In 1978 Worst developed the iris claw lens in Pakistan to be implanted after intracapsular cataract extraction.
- This anterior chamber lens is fixated on the iris, leaving the chamber angle free.
- The diametrically opposed haptics can be “pinched” on the midstromal iris tissue as “claws.” In this way the lens stays fixated on the immobile part of the iris.

Premium IOLs

- **Multifocal IOL**
  - ReStor (Alcon)
    - The FDA initially approved the AcrySof ReStor IOL (Alcon Laboratories, Inc., Fort Worth, TX) in March 2005. This singlepiece acrylic IOL was the first to offer apodized diffractive technology that allows for both distance and near vision. The term “apodization” refers to the gradual reduction or blending of the heights of the diffractive steps. Apodization, aspheric optics, and the change from a +4.00 to a +3.00 D add power are intended to improve the quality of patients’ vision at all distances.
    - The AcrySof IQ Restor IOL +3.0 D design has significantly improved patients’ intermediate vision to complement the IOL’s already excellent profiles for distance and near vision. The AcrySof ReSTOR lenses feature blue-blocking and ultraviolet light–filtering technology that may prevent the development and/or progression of macular degeneration, but this remains a subject of debate. Patients should bewarned of the possibility of postoperative glare and halos, but the incidence of these phenomena is dramatically lower with the most recent
  - Ceeon 811E (Pharmacia/Pfizer)
  - Tecnis Z9000
    - The Tecnis Multifocal is a clear hydrophobic acrylic lens. It offers a pupil-independent, fully diffractive posterior surface designed to optimize vision under all lighting conditions. The IOL’s wavefront-designed aspheric anterior surface was engineered essentially to eliminate spherical aberration and thereby enhance the quality of the patient’s vision at all distances. The +4.00 D add power attempts to optimize near visual acuity at a preferred reading distance of 33 cm.
    - This IOL was also designed to reduce chromatic aberration and provide protection from ultraviolet light. The 3-piece lens may be placed in the ciliary sulcus. Centration of the IOL is critical to obtaining optimal visual results. Glare and halos appear to be less problematic with this lens compared with previous multifocal designs.

- **Accommodative IOLs**
  - **Crystalens**

- Currently FDA-Approved Accommodative Lenses
  - Crystalens AT-45
  - Crystalens 5-0
  - Crystalens HD
  - Crystalens AO
  - Not approved: Tetraflex
- AT-45 CrystaLens (Eyeonics, Aliso Viejo, California)
  - The first Cystalens accommodating IOL (Bausch + Lomb, Rochester, NY) was implanted in England in 1991. The FDA approved the **AT-45** model in November 2003.
  - These IOLs feature a 5-mm silicone optic with hinges and square edges. Square silicone plate haptics with T-shaped polyamide loops help provide stabilization and centration of the IOL within the capsular bag. For eyes requiring corrective powers of 17.00 D and higher, the length of the IOL is 11.5 mm. A 12-mm IOL addresses corrections of less than 17.00 D.
- The **Crystalens 5-0** provides excellent distance and intermediate vision without the reduction of contrast sensitivity that is associated with multifocal IOLs.
- The blended bispheric optic of the **Crystalens HD** is supposed to enhance near vision while maintaining excellent contrast sensitivity. Released in January 2010, the Crystalens AO represents the first aberration-free accommodating IOL with aspheric optics.
- Potential challenges associated with the Crystalens technology include inaccurate refractive outcomes due to varying IOL position and movement, and inadequate near vision.

- **1 CU** (Humanoptics, Mannheim, Germany)
- The **Synchrony** (Abbott Medical Optics Inc., Santa Ana, CA) has a negatively powered posterior optic and a plus-powered anterior optic that are connected by spring haptics. Upon accommodative effort, the distance between the 2 optics increases.
- The Tetraflex accommodating lens (Lenstec, Inc., St. Petersburg, FL) is another monofocal IOL that moves with accommodative efforts.
- The only USFDA-approved accommodating IOLs are the Crystalens and the Trulign IOL (Bausch + Lomb).

- **Light adjustable lens (LAL)**
  - Calhoun Vision, Pasadena, California
  - The LAL is designed to allow for postoperative refinements of lens power in situ.
  - The current design of the LAL is a foldable three-piece IOL

    - Cross-linked silicone polymer matrix and a homogeneously embedded photosensitive macromer.
    - The application of near-ultraviolet light to a portion of the lens optic results in polymerization of the photosensitive macromers and precise changes in lens power through a mechanism of macromere migration into polymerized regions and subsequent changes in lens thickness.
    - Once the desired power change is achieved, irradiation of the entire lens to polymerize all remaining macromer “locks-in” the adjustment so that no further power changes can occur.

Aspheric IOLs

- The human cornea has positive spherical aberration on average of +0.27 μm for a 6-mm pupil.
- Corneal spherical aberration varies widely among subjects, ranging in one study from 0.055 to 0.544 μm for a 6-mm pupil.
- Aspheric IOLs with various amounts of spherical aberration have been proposed to partially or fully compensate for the positive SA of the cornea.
- The SA of available aspheric designs ranges from 0 to −0.27 μm.
- Models
    - **Tecnis IOL(AMO):**TheTecnisIOLhasSAof−0.27μm for a 6-mm pupil and is designed to leave the “average” eye with no SA. The Tecnis multifocal is a diffractive multifocal IOL that also has SA of **−0.27 μm**.
    - **AcrySof IQ IOL (Alcon Laboratories):** The AcrySof IQ IOL has negative asphericity of **−0.20μm** for a 6-mm pupil, leaving a small amount of ocular positive SA for the average eye.
    - **Aspheric Restor (Alcon Laboratories)**: This diffractive multifocal IOL has **−0.10** μm of negative asphericity.
    - **SofPort AO/Akreos AO (Bausch & Lomb):** The SofPort AO/Akreos AO lens has **no** spherical aberration, leaving the average eye with the naturally occurring positive SA from the cornea.
    - **Afinity (STAAR):** This IOL has a very small amount of negative asphericity (essentially zero) and, like the SofPort, is designed to leave the eye with the SA induced by the cornea.
- Aspheric IOLs have less spherical aberration than spherical IOLs.
- Aspheric IOLs likely contribute to improved contrast sensitivity and functional vision.
- Clinical studies have shown slightly greater depth of focus with spherical IOLs and IOLs with no spherical aberration as compared to an IOL with asphericity of −0.27 μm.
- Subjectively, patients may prefer their vision through aspheric IOLs over spherical IOLs. Reducing spherical aberration alone does not equate to superior vision, as some patients preferred vision through their zero-SA IOL over the −0.27 μm aspheric IOL.

Bag-in-the-Lens IOL (BIL IOL)

- Implantation technique of Tassignon
- **Technique**
  - After cataract removal and cleaning the capsular bag, an incision of the posterior capsule is performed and viscoelastic is injected into the retrolenticular space in order to displace the anterior hyaloid and to separate it from the posterior capsule, respectively.
  - This is followed by a posterior capsulorrhexis of the same size as the anterior capsulorrhexis.
  - Finally, the foldable hydrophilic acrylic BIL is injected into the anterior chamber with an injector. Implantation is completed by placing the capsulorrhexis edges into the groove, which runs 360° along the rim of the optic of the lens.
- **Benefits**:
  - In combined phaco-vitrectomy it guarantees an excellent and stable centration of the lens, even during scleral indentation.
  - Postoperatively, there will be no IOL decentration, no matter what kind of an intraocular tamponade is used—air, gas, or silicone oil.
  - No posterior capsular opacification or contraction of the remaining anterior capsule can occur.
  - Another important benefit is that even in eyes with acute or chronic inflammation, no posterior synechiae can develop since the capsulorrhexis edges are hidden in the lens groove and no proliferating lens epithelial cells can get in contact with the iris. Even diabetic eyes with an already existing iris neovascularization do not develop posterior synechiae after phaco-vitrectomy.
  - Finally, an additional advantage of the lens is that even after many years it can be easily removed and exchanged if needed because of an altered binocular refractive situation.

Akreos MIL lens

It's a 4 leg type, aspheric, hydrophilic lens with a 360 degree square edge. The material has been found in trials to adhere to the capsular bag and this in conjunction with the square edge should successfully retard PCO formation for a while.

Electronic IOLs

- **ELENZA**: Sapphire AutoFocal IOL
- IOL with Artificial Intelligence
- **Rudy Mazzocchi**
- The IOL builds upon an existing technology from PixelOptics (Roanoke, Va.), which created the world's first electronically focusing prescription eyewear

- Relying on our individual pupillary response to automatically trigger accommodation between far and near.
- Battery itself will have a 50-year cycle-life, it requires recharging every 3-4 days
- The fail-safe system is the IOL falling back to having only optimal distance vision … defaulting to a monofocal IOL

Innovations in Postoperative IOL Adjustment

- Cataract surgery these days is always refractive surgery. Patients are more demanding than ever, and sometimes even 20/20 vision is not good enough if even minor additional correcting glasses are required to achieve that visual acuity.
- Refractive error is one of the major causes for IOL explantations. The numbers may likely further increase since the first generation of corneal refractive patients is now reaching cataract age and IOL power calculation tends to be more difficult in these eyes, with an increased likelihood of refractive error after cataract surgery.
- The **light-adjustable lens (LAL)** has been part of our clinical routine for more than 10 years now; the vast amount of experience underscores the value of this 3-piece silicone lens, whose refractive power can within in few weeks after cataract surgery be changed by specifically targeted UV irradiation. The LAL (RxSight, Inc.; Aliso Viejo, California, USA) gained FDA approval in November 2017. Spherical power can be adjusted by about 2 D (plus or minus), cylindrical power can be altered in a range from 0.25 to about 2 D. The enhancement which also correct individual asphericity, is easy to perform and has a good safety record, without any influence.
- A promising technology currently under development is refractive index shaping by femtosecond laser, also known as **LIRIC (laser-induced refractive index change).** This method uses low pulse energies below the ablation threshhold to modify the refractive index of the cornea or of an implanted IOL (and also of a contact lens). When performed on the cornea, there is no damage to the corneal nerves and thus there is much less dry eye than post-LASIK. Scott McRae, one of the pioneers of this technique, has called it "potentially the perfect method for finetuning the results of IOL implantation in case of residual refractive error." The technology may even go beyond correcting residual refractive errors, including astigmatism. The laser modification, done with an ultra-small spot size of about 0.5 µm (compared to ca. 500 µm in LASIK), is able to turn a monofocal IOL into a multifocal lens—and vice versa; for a patient who turns out not being able to cope with the pecularities of vision under multifocality, "reducing" the implanted multifocal IOL to a monofocal IOL might be a much less invasive option that another surgery for IOL replacement. Research is going on to develop IOL material particularly suitable for postoperative refractive index shaping.
- Infinite Vision Optics, a French manufacturer, has introduced a new concept of a lens system that consists of two elements that are preassembled prior to surgery. In cases of refractive error, the IOL's power can be altered by a small intervention: the upper optic, called the front lens, will be exchanged by minimally invasive surgery and replaced by an new component that better serves the patient's vision. Thus a total IOL explantation does not become necessary. The **multicomponent lens (PreciSight)** was implanted in Europe for the first time in July 2018.

Scleral Fixated IOLs (SFIOLs)

- Intrascleral fixation of IOL was described by Dr. Gabor Scharioth from Germany. (without glue)
- Maggi subsequently evolved the technique and its application has been extended to managing a decentered IOL or a Soemmerring ring and also as part of combined surgeries.
- Glued intrascleral fixation of intraocular lens (glued IOL) was described for the first time in 2007 by Dr. Amar Agarwal.
- The strength to the IOL fixation is provided by the tucking of haptics. Proper intrascleral tuck prevents the Horizontal and Vertical movement of the haptics and secures the fixation.
- Glue seals the scleral flaps and prevents hypotony in the immediate postoperative period.
- Dr. Shin Yamane introduced Double Needle technique that does not require application of glue/sutures. The haptic ends are cauterized to form a Flange.
- Techniques
    - Scleral sutured IOLs
    - Glued IOLs
    - Yamane technique
    - Hoffman technique

Glued IOL

- **Advantages**
    - Small self-sealing incision using a foldable IOL
        - Well-formed globe throughout surgical case
        - Less risk of iris prolapse
        - Less chance of suprachoroidal effusion or hemorrhage
        - Avoids complications of larger surgical wounds such as leakage, shallow anterior chamber, and astigmatism
    - No need for scleral sutures. Avoids suture-related complications: extrusion, cheese-wiring,breakage
    - Stable IOL
        - Compartmentalizes eye into 2 chambers nicely
        - No pseudophacodonesis
- **Disadvantages**
    - Requires surgical expertise to inject the lens through the main surgical incision and avoid dropping the lens into the vitreous cavity. The surgeon should be familiar with the handshake technique, which includes injecting the lens with one hand and grabbing the haptic to exteriorize it through sclerotomy using the other hand, then delivering the trailing haptic into the eye and exteriorizing it through the other sclerotomy.

- The surgeon should also be familiar with the use of fibrin sealant under scleral flaps and conjunctiva.

- **Procedure**:
  - Using a crescent blade, the first step is to create 2 scleral flaps 180° apart and then create 2 sclerotomies 1.5 mm posterior to the limbus and under the scleral flaps using an MVR blade. After placing a dispersive ophthalmic viscosurgical device (OVD) into the anterior chamber and an anterior chamber maintainer to prevent collapse of the globe, pars plana vitrectomy is performed to separate vitreous from the IOL, taking care to avoid exerting vitreous traction. It may be helpful to inject triamcinolone to help demarcate vitreous and simultaneously control postoperative inflammation.
  - The posterior chamber IOL is then inserted into the anterior chamber. The CT Lucia IOL is particularly effective in that the haptics are extremely flexible. Using 2 microforceps introduced into the eye through a limbal incision and one of the sclerotomies, the **handshake technique** is used to pass one of the haptics from the anterior chamber into the posterior chamber for externalization through the sclerotomy.
  - It is then helpful to have an **assistant** hold the first haptic while the second haptic is being externalized. Or one may attach a silicone retention slider from an iris hook onto the end of the externalized haptic to prevent its slippage while the handshake technique to grasp and deliver the second haptic through the sclerotomy on the opposite side is accomplished.
  - Once the ***haptics are externalized, they are placed into a scleral incision adjacent to the scleral flap.*** Then, the anterior chamber maintainer is removed and the scleral flaps and conjunctiva are fixed over the pockets with a small amount of fibrin glue.
  - **Modifications**
    - **No Assistant Technique** is an effort to decrease the dependence on the assistant and make it more surgeon dependent. This technique is an attempt to make the process of 'Externalization of haptics' that is considered to be the most technically demanding part of the surgery; more easy and feasible. When the trailing haptic crosses the mid-pupillary plane and is nearly at 6'o clock position, the vector forces act in a way that causes further extrusion of the leading haptic from the sclerotomy site with virtually no chance of slippage of leading haptic into the anterior chamber.
    - **OHTA'S TECHNIQUE**: Toshihiko Ohta from Japan started a simplified and safer method of sutureless intrascleral posterior chamber intraocular lens fixation. This is called the Y-Fixation technique.
    - **BEIKO-STEINERT-SAFRAN METHOD**: The silicon tire of Iris Hooks is slipped on to the externalized haptic which prevents haptic slippage.
- **Complications**
  - hyphema, decentration, optic capture (reverse pupillary block) and haptic disinsertion or extrusion.

Yamane Technique

- The Yamane technique has many similarities to the glued IOL technique.
- An ultrathin wall 30-gauge needle is employed. Using a toric marker, mark 0° and 180° for the main incisions. Then mark 2 mm from the limbus and 2 mm down from the main incision, and 2 mm from the limbus and 2 mm from the second incision. The 30-gauge needle is bent and placed at the initial marking and then tunneled 2 mm through the sclera prior to insertion into the anterior chamber. This is then repeated 180° degrees away.
- The IOL is placed in the anterior chamber, and using microforceps, the haptic is inserted into the 30-gauge needle tip on both sides. The needles are then withdrawn, pulling the haptics through the sclera, where they are externalized.
- A ***cautery is then employed to create heat to melt the tip of the haptic,*** creating a flange that is inserted back under the conjunctiva, fixating the IOL. Pulling on the haptics and shorting the haptic with cauterization can modify centration.
- Advantages
    - Transconjunctival procedure
    - Does not require the application of glue or sutures
    - Does not require dissection of the sclera or the creation of scleral flaps
    - No conjunctival scarring or inflammation
- Modifications of Yamane Technique
    - **Handshake Riveting method** The Handshake riveting flanged (HRF) technique facilitates maneuverability and threading of the trailing haptic in to the 26 G needle and the riveted flanges act as an anchor that prevents intraocular migration of the haptic through a comparatively wider intrascleral tract as compared to that of a 30 G needle. The HRF technique is applicable to all the variants of 3-piece intraocular lens and is independent of the availability of thin walled 30 G needle.
    - **Brian Kim's modification** – The leading haptic is externalized from the paracentesis incision created at opposite quadrant in reference to the surgeons seating position followed by trailing haptic exteriorization

Hoffman's Techniques

- This technique described by Hoffman et al is a modified technique for scleral fixation of Intraocular lenses within a scleral pocket. The scleral pocket is created from a clear corneal incision. This technique enables the suture to remain under the protective covering of the scleral roof thus avoiding problems of suture exposure. It also avoids the need for conjunctival dissection and scleral cauterization.

Gore-tex Sutured IOLs

- Gore-Tex suture (W L Gore & Associates) traditionally has been used for cardiac and vascular surgery. It is a nonabsorbable, expanded polytetrafluoroethylene (ePTFE) monofilament suture with greater tensile strength and theoretically lower risk of suture breakdown than alternative suture materials, including the commonly used polypropylene (Prolene, Ethicon).
- Gore-Tex was initially described for IOL suturing in **1996** by **Rosenthal** et al and to date there are no reported cases of suture erosion or breakdown.
- Two-point ab externo scleral fixation technique of Alcon lens
- 4-point fixation technique of Akreos AO60

IOLs for AMD

- **Intraocular magnifier telescope (IMT)**
    - The IMT is a fixed-focus quartz glass lens with wide-angle micro-optics which is implanted in the capsular bag through a 10–12 mm incision after the natural lens has been removed
    - The device weighs 60 mg in aqueous; 115 mg in air. The lens aperture is 3.2 mm
    - For end stage AMD
- **IOL-VIP system**
    - Consists of two IOLs that reproduce an intraocular Galilean telescope: a high minus-power biconcave IOL (about 66 diopters D) in the capsular bag acts as the eyepiece, and a high plus-power biconvex IOL (about 55 D) in the anterior chamber (AC) acts as the objective
- **Lipshitz macular implant (LMI)**
    - Dr Isaac Lipshitz
    - Telescopic IOLs → principle of using mirrors to magnify the central image while the peripheral field remains normal
    - The overall diameter of the IOL is 13.0 mm, and the optic is 6.5 mm. The anterior central mirror is 1.4 mm. The posterior mirror, which is doughnut shaped and 2.8 mm in diameter, has a central clear area of 1.4 mm in diameter
    - The entire IOL is coated with poly-para-xylylenes (Parylene C) to enhance biocompatibility. The LMI is placed through a 6.5 mm corneal tunnel into the capsular bag
- **LMI-SI**
    - younger and improved version of the LMI
    - LMI-SI is a non-foldable one-piece IOL positioned in the sulcus over a regular bag-implanted IOL.
    - LMI-SI is thicker, with a central thickness of 1.25 mm
- **Fresnel Prism Intraocular Lens**

    - Nonfoldable implant made of polymethyl methacrylate (PMMA)
    - Single optical power (+20.0 diopters) for aphakic correction, with a Fresnel prism IOL fashioned on the posterior surface of the optic producing a fixed 6° deviation, which gives a retinal image displacement of 1.8 mm (thus describing a circular area of 3.6 mm diameter) for a 23.1 mm average eye
- **iolAMD**
    - Most recent type of hydrophobic acrylic device
    - Based on a Galilean telescope using two lenses manufactured so that they can be injected with a standard soft tip cartridge and injector system for 3.0-mm incision size
    - The capsular bag positioned IOL (IOL 2) is a high-minus-power lens (−49 diopters [D]) with a 4.0-mm optic and an overall length of 11.0 mm. The plate haptic is symmetrical and vaulted posteriorly approximately 15°.
    - The sulcus-positioned IOL (IOL 1) is a high-pluspower lens (+63 D), and the 5.0-mm hyper-aspheric-optic is slightly de-centered on the plate haptic. The overall diameter is 11.75 to 12.0 mm and the haptic is bent anteriorly to enhance the recommended distance between the optics of 2 mm after implantation
    - Only noticeable disadvantage of this system is that there are no power ranges available
- **Scharioth Macula Lens**
    - One-piece foldable intraocular hydrophilic acrylic lens with a central magnifying portion implanted in the ciliary sulcus of pseudophakic eyes, which improves near vision in patients with AMD
    - Smallest incision required for implantation 2.2 mm.

Small-Aperture IOL

- XtraFocus Pinhole Implant
- The pinhole principle is based on the exclusion of peripheral ocular light rays of the image formation process, extending depth of focus. Since paraxial rays are less susceptible to optical aberrations, the result is a better image resolution. This principle is frequently applied in the field of ophthalmology for diagnostic reasons. When irregular corneal astigmatism is present, pinhole acuity testing usually yields a better vision than the best possible refraction because it limits image formation to paraxial light rays only.
- **XtraFocus Pinhole Implant:** This new device, which is made by Morcher GmbH, acts as an intraocular pinhole. It is intended for sulcus fixation in pseudophakic eyes, in a piggyback configuration. With no refractive power, it minimizes the impact of corneal aberrations, based on the pinhole principle.
- The main indications are as follows:
    - Post-RK
    - Post-PK
    - Keratoconus

    - Post-LASIK ectasia
    - uncorrected near vision improvement in monofocal pseudophakia, through extension of depth of focus.
    - Other (trauma, pterygium, etc.)
- It is made of a foldable black hydrophobic acrylic, with thin, rounded, and angulated haptics. It is implanted through a 2.2 mm corneal incision and has a larger overall diameter (14.0 mm) for adequate sulcus centration.
- The black material has a window of transmittance of infrared light, allowing retinal examination with infrared equipment (OCT, scanning laser ophthalmoscopes).
- The device received CE Mark in 2016.

Toric IOL Implants

- Astigmatism correction may be required in an estimated 15-29% of cataract cases.
- ***Management of Astigmatism***
    - Toric IOLs
    - Limbal relaxing incisions or astigmatic keratotomies
    - Keratorefractive surgery or by the use of conductive keratoplasty (CK-A)
- ***Models:***
    - Alcon Toric SN60T series 3-9 and the aspheric SN6AT series
        - recently approved by the FDA
        - built on the same platform as the standard AcrySof posterior chamber lens implant.
        - toric version has a 6.0-mm biconvex acrylic toric optic, available in the range of + 6.0 to +30.0 D.
        - SN60T/ SN60AT: 3 to 9 → T3 corrects 1.0D at corneal plane, 0.5D increase from 3 to 9
        - The axis of plus cylinder is marked on the lens optic.
    - STAAR Toric (silicone plate haptic)
        - FDA-approved, single-piece, plate-haptic, foldable silicone IOL designed to be placed in the capsular bag using an injector through a 3-mm incision. Once in the eye, it must be oriented with its long axis precisely in the steep meridian.
        - The 6-mm optic is biconvex with a spherocylindrical anterior surface and a spherical posterior surface.
        - The optic has a mark at either end to indicate the axis of plus cylinder. The IOL is available in a length of 10.8 mm or 11.2 mm. A 1.15-mm fenestration located at the end of each haptic is designed to maximize capsular fIxation.
        - The IOLs are available in the range of +9.5 to +28.5 D spherical powers, with a choice of cylindrical powers of 2.00 D and 3.50 D. The toric surface

corrects less astigmatism when measured at the corneal plane; STAAR states that the 2.00 D IOL corrects 1.50 D of corneal astigmatism and the 3.50 D IOL corrects 2.25 D.

- Zeiss AT TORBI
- Rayner T-Flex toric IOL
- Sulcoflex Toric (for sulcus placement) from Rayner

- ***Case Selection:***
  - The decision to implant a toric IOL is governed by the magnitude and axis of corneal astigmatism, patient expectations, type of IOL and the presence of other ocular comorbidities.
  - Toric IOLs are universally recommended in cases with significant pre-operative corneal astigmatism of 1.5 D or more.
  - Even in cases with low astigmatism with a magnitude of around 1 D, the superiority of toric IOLs over monofocal IOLs has been demonstrated in terms of better uncorrected distance visual acuity (UDVA).
  - Two major meridians of power are 90 degrees apart (regular astigmatism)
- ***Workup for Toric IOL***
  - Keratometry: Enhanced accuracy of keratometry estimation may be achieved by taking multiple measurements and employing atleast two separate devices based on different principles.
  - **Posterior Corneal Curvature:**
    - Newer investigative modalities that account for both the anterior and posterior corneal power are becoming the standard of care.
    - Can be measured by Oculus Pentacam, CSO Sirius, Zeimer Galilei, Tomey TMS-5
    - The posterior **steepest meridian is almost always vertically aligned in 85% of eyes.**
    - Such alignment generates an ATR astigmatism, which partially compensates anterior WTR astigmatism and increases anterior ATR astigmatism.
    - Total astigmatism less in WTR eyes but more in ATR eyes
      - Keratometric astigmatism overestimates WTR astigmatism by 0.22±0.32 D
      - Keratometric astigmatism underestimates ATR astigmatism by 0.21±0.26 D
    - In about 20% of eyes the opposite relationship occurs..!!
    - **Baylor nomogram (simplified)**
      - Take about 1D off all toric IOL cylinder powers for WTR eyes
      - Add about 0.45D to all toric IOL cylinder powers for ATR eyes
    - **Adelaide Nomogram**
      - Only adjust IOL cylinder where the IOL is calculated to be 2D or less

        - Reduce the K cylinder for correction by a factor of 0.75 for WTR eyes
        - Augment the K cylinder for correction by a factor of 1.41 for ATR eyes
        - No adjustment for oblique cylinders (300 to 1600 and 1200 to 1500)
- IOL Power: An ideal IOL power calculation formula should take into account the surgically induced astigmatism, the posterior corneal curvature as well as the effective lens position (ELP).
- Patient Counseling: Preoperative patient counseling is of paramount importance, and it is essential to address unrealistic patient expectations at the stage of planning itself. Patients who desire good uncorrected near vision may be counseled for toric multifocal IOLs.
- Barrett Toric Calculator (Online Tool)
    - Net astigmatism = total corneal astigmatism that has to be corrected by the toric IOL, including Ks, SIA and the posterior cornea.
    - Posterior cornea data are not derived from Scheimpflug devices or regression analysis, but from a theoretical model based on the elliptical method of the corneal diameter.
    - WTR astigmatism is automatically reduced.
    - ATR astigmatism is automatically increased.
- Baylor Toric IOL Nomogram
    - Based on Galilei total corneal astigmatism.
    - It accounts for the ATR shift with age. New target for postop astigmatism = 0.4 WTR
- Ratio of IOL Cylinder to Corneal Cylinder
    - Not all online toric IOL calculators take into account the influence of ACD on the conversion of the cylinder from the IOL plane to the corneal plane.
    - The current version of the Alcon calculator uses a fixed ratio (1.46) that is good for average eyes, but not for short and long eyes.
    - Actually this ratio can range from 1.29 (AL = 20mm, K = 38 D > shallow ACD) to 1.86 (AL = 30mm, K = 46 D= deep ACD)
    - Overcorrection of cylinder in hyperopic eyes
    - Undercorrection of cylinder in myopic eyes
    - Tools
        - ASSORT Calculator (N. Alpins, MD, FACS)
        - Holladay Consultant software
        - PhacoOptics (T. Olsen, MD)
        - Ray-tracing software

- **Online Toric IOL Calculators**
    - AcrySof: www.acrysoftoriccalculator.com/
    - Abbott Medical Optics: https://www.amoeasy.com/ toric

    - B+L/Trulign Toric Calculator: https://trulign .toriccalculator.com
    - ASCRS/Barrett Toric Calculator: http://www.ascrs .org/barrett-toric-calculator
    - Berdahl & Hardten Toric IOL Calculator-The Toric Results Analyzer: http://astigmatismfix.com/
- **Dr. Warren Hill's "Top 4" Sources for Error**
    - Preop measurement errors
    - Incorrect marking of reference points on the cornea
    - Incorrect placement of the IOL
    - Failure to take into account the impact of surgically induced astigmatism
- **Contraindications**
    - Cases with irregular astigmatism resulting from corneal scars or ectatic disorders are not ideal candidates for toric IOL implantation. They are unlikely to achieve complete refractive correction with toric IOLs.
    - Zonular instability and posterior capsular dehiscence are contraindications for implanting toric IOLs, as a stable capsular bag-IOL complex is essential for rotational stability of the IOL.
    - Poor pupillary dilatation is also a relative contraindication, as it may hamper the visualization of the alignment marks which are located in the periphery of the toric IOL.
    - Patients that have undergone prior vitreoretinal procedures, buckling and glaucoma drainage surgeries may not achieve the intended results with toric IOLs due to their primary pathology as well as the surgically-induced changes in the anatomical configuration.
- **Surgical Techniques and Alignment**
    - Preoperative reference and axis marks
        - Manual Methods of Marking: The three-step technique is commonly used for toric IOL alignment, which involves the preoperative marking of the reference axis, intraoperative alignment of the reference marks with the degree gauge of the fixation ring and intraoperative marking of the target axis. The manual marking methods have inherent sources of errors, such as smudging of the dye, irregular and broad marks. Moreover, they are associated with a significant learning curve and inter-surgeon variability may be observed in the accuracy of marking.
        - Image guided surgery:
            - The image guided systems involve the capture of a pre-operative reference image followed by intraoperative image registration wherein the limbal landmarks are used to match the two images with respect to each other. A graphic overlay is then superimposed on the surgical field along the target axis, which provides a guide for toric IOL alignment. The Verion image guided system utilises the scleral blood vessels, limbus and iris details as reference landmarks to determine the extent of cyclotorsion.

        - The image-guided systems such as VERION and CALLISTO Eye aid in pre-operative planning of the location and size of the surgical incisions and capsulorhexis, as well as IOL positioning. The CALLISTO Eye also assists in planning the position of limbal relaxing incisions. VERIONTM Reference Unit allows comprehensive astigmatism management, wherein the surgeons can optimize the incision locations and toric IOL power as per their SIA. Moreover, the position and length of arcuate incisions can be determined in cases planned for femtosecond laser assisted cataract surgery (FLACS).
        - Significantly more precise alignment has been observed with VERION guided image marking as compared to manual slit lamp-assisted preoperative marking using pendulum-attached marker. The accuracy of CALLISTO Eye and Z align is similar to VERION.
        - The eye tracker in these systems may disengage during surgery, and a repeat registration may be required. Conjunctival chemosis, ballooning and bleeding may interfere with intraoperative registration. Registration may also not be possible in extremely uncooperative patients or difficult orbital anatomy including extremely deep set eyes or narrow palpebral apertures. In addition to these limitations, the high financial cost involved may limit the widespread usage of this technology.
    - Intraoperative Aberrometry
        - Intraoperative aberrometry devices such as Optiwave Refractive Analysis (ORA; WaveTec Vision Systems Inc., CA, USA) and Holos IntraOp (Clarity Medical Systems, CA, USA) perform a real time assessment of the phakic, aphakic or pseudophakic refraction in order to provide feedback for toric IOL alignment.
        - Before obtaining the readings, the anterior chamber should be uniformly filled with a cohesive OVD in order to maintain the intraocular pressure and ensure a uniform fundal glow. The accuracy of aberrometry readings may be affected by intraoperative corneal edema, eyelid speculum, presence of air bubbles or clumps of dispersive OVD in the anterior chamber or inadequate intraocular pressure. Multiple radial keratotomy cuts encroaching the visual axis also preclude accurate measurements. The device is mounted directly onto the bottom of the surgical microscope and takes up a significant amount of space. In addition to these limitations, the high financial cost involved may act as a deterrent for surgeons.

- **Clinical Methods to Assess Postoperative Alignment**
    - The axis of implanted toric IOL may be assessed at the slit-lamp with a rotating slit and rotational gauge. This method requires adequate mydriasis to visualize the IOL optic marks. The 10-degree steps on the slit-lamp's measuring reticule limit the accuracy of this method.
    - A simple and inexpensive method to measure the toric IOL axis using a camera-enabled cellular phone and “ImageJ” computer software.

- An online toric results analyzer (www.astigmatismfix.com) has been developed, which determines the ideal position of the toric IOL in cases of postoperative malrotation. It uses patient's postoperative manifest refraction, power and current axis of the toric IOL to predict the ideal axis of toric IOL and postrotation refraction.
- Wavefront aberrometers such as the **iTRACE** system determine the orientation of the toric IOL based on the internal ocular aberrations. The toric IOL enhancement software of iTRACE also provides the magnitude and direction of the required rotation in order to achieve accurate alignment with minimal residual astigmatism.

- **Tackling Toric IOL Misalignment**
  - Prevalence of greater then 1 D of residual astigmatism after toric IOL implantation has been estimated to be 12%.
  - Postoperative toric IOL misalignment is the major factor responsible for suboptimal visual outcomes after toric IOL implantation. Misalignment of the toric IOL axis can cause reduction of the cylinder power along the desired meridian and induction of cylinder in a new meridian when misalignment exceeds 30 degrees. The new residual cylinder may be estimated by the formula R = |2C sin ø|, where C is the cylinder power of the toric lens and ø is the degree of misalignment.
  - One degree of misalignment causes a loss of approximately 3% of the effective cylinder power, and the entire toric effect is lost in cases with 30 degrees of misalignment.
  - **Factors Affecting Toric IOL Alignment**
    - It may be attributed to three factors, namely, inaccurate pre-operative prediction of the axis of IOL alignment, inaccurate intra-operative alignment and post-operative IOL rotation. Newer investigative modalities and advanced image-guided and aberrometry systems help to minimize the incidence of pre-operative and intra-operative alignment errors, and have been discussed in detail in the previous sections.
  - **Decision MakingWhen to intervene**
    - Re-alignment of the toric IOL is needed in cases with more than 10o of rotation from the target axis. A rotation of less than 10 o changes the manifest refraction by 0.5D, and usually does not warrant any additional intervention.
  - **Timing of re-rotation**
    - A significant negative correlation has been observed between the interval from cataract surgery to repositioning procedure and the degree of residual misalignment. A repositioning performed after 1 week of primary cataract surgery had superior outcomes in terms of precision of IOL alignment and minimal residual refractive cylinder
  - **Surgical techniques for re-rotation**
    - Intraoperative techniques to rotate toric IOLs depend upon the length of time from the initial surgery and the degree of adhesions between the IOL and the capsular bag. Optimal results have been observed in cases with early rotation using a long cannula mounted on a BSS-filled syringe to rotate the IOL via the paracentesis incision. The new target axis is determined relative

to the current axis; therefore, intraoperative marking is only necessary relative to the implanted IOL. This reduces repositioning variability and maximizes outcomes after IOL rotation.

- In cases with large residual cylinder not amenable to correction by rotation alone, an IOL exchange, piggyback IOLs or corneal ablative procedures may be considered. LASIK has been observed to be superior to lens exchange and piggyback IOLs, with a greater reduction in spherocylinder refractive error.

- ***ADVANTAGES OF TORIC IOL OVER LRI***
    - Predictability
    - Stability
    - Reduced likelihood of foreign body sensation
    - Reduced risk of dry eye syndrome
    - No corneal weakening-may be important in the event of severe blunt eye trauma
    - Correction nearer to the nodal point of the eye
    - Dangers of perforation for LRI.
- ***DISADVANTAGES***
    - Added cost of IOL
    - Not as straightforward to implant as standard IOL.

- the spherical equivalent of the toric lens is identical to that of a spherical IOL of the same dioptric power.
- the toric IOL flat axis (indicated by the three dots near each haptic insertion) is then aligned to coincide with the steep corneal axis.
- The IOL is then rotated so that last 15 degrees (clockwise) to be on axis.
- 10 degree misalignment → 33% astigmatic loss, 20 degree → 66%, 30 → 100%, >30 → adds

- ***SPECIAL SITUATIONS***
    - Very high comeal astigmatism
    - Combining LRI with Toric IOL.
- **Management:** combined "**bioptic**" approach, combination of LRI, LASIK, CK-A with toric IOL

Pseudophakic Supplementary IOL

- Aka “ADD-ON IOL”
- Aka Piggyback IOLs

- The piggyback technique, first described in **1993** by **Gayton and Sanders**, involves the implantation of 2 IOLs in the posterior chamber.
- One important drawback of this technique was the development of interlenticular opacification, which appeared when both IOLs were placed on the capsular bag.
- **Indications**
    - residual refractive errors in pseudophakic eyes
    - correction of higher astigmatism after any form of keratoplasty in pseudophakic eyes
    - Extreme IOL power
    - reversible presbyopia correction by implementing multifocal optics
    - reversible, bulbus growth adjusted treatment of ametropia in pediatric cataract surgery or AMD.
- **Calculation of Power**
    - Myopic refractive error: Spherical equivalent x 1.2
    - Hyperopic refractive error: Spherical equivalent x 1.5
    - The Refractive Vergence Formula or the Holladay R formula can also be used.
- **Available IOLs**
    - ***Add-On (Humanoptics)***
        - 7.0-mm optic
        - 14.0-mm diameter
        - Haptics angulation: 0°
        - Concave posterior surface preventing contact between both lenses
        - MicroCryl (optic: silicone with UV absorber, haptics: high molecular PMMA)
        - Well-proven undulation haptics
        - Convex-concave with round anterior edge for iris protection
    - ***Sulcoflex (Rayner)***
        - 6.5-mm optic
        - 13.3-mm diameter
        - Haptics angulation 10°
        - Convex/concave (≠ piggyback)
        - Material: hydrophilic acrylate
        - Waved haptics
        - Rounded edges
    - **AddOn 1stQ (Medicontur Ltd.)**
        - Material: Hydrophilic acrylic
        - 13.5 mm diameter
        - 6 mm Convex-concave

        - Romboidal
    - **Macular Add-On (Scharioth Macula Lens A45SML, Medicontur Ltd)**
        - Hydrophilic acrylic
        - 13 mm diameter
        - Central portion of 1.5 mm with +10.0 D
        - 4 symmetric haptics
- The Sulcoflex, Add-on, and Add-on 1stQ can be aspheric, toric, multifocal, or toric-multifocal.
- Although LASIK has shown a more accurate result for correcting refractive errors after cataract surgery, piggyback is a good option for those patients who have any contraindication for LASIK.

Phakic IOLs (P-IOLs)

History

- As first ACIOL was discovered, **Benedetto Strampelli** in 1953 reported use of minus power ACIOL for Phakic eye in treatment of high myopia → **Strampelli Lens**: radius of curvature of 13 mm but was thick and rigid
- **Dannheim lens**: still hard to match the lens length
- 1959, **Barraquer** lens: support was curved and the haptics were more elastic, providing a better fit into the AC.
- **Peter Choyce** in 1964 started to use implants with thinner haptics and reported a significant decrease in corneal
- Surgeons believed that ACIOL is not a good option.
- Baïkoff of France, who modified the four-point, angle fixation, multiflex AC
- Worst-Fechner biconcave myopia lens in 1986
- 1991, Ophtec changed the IOL design to a convex-concave

Types

- three main types of phakic IOLs
    - **AC angle-fixated IOLs**: Bailkoff NuVita (B&L), Phakic 6 (OII), ZSAL
    - **PC IOL**: ICL (Staar), CIBA/ Medennium PRL, IPCL (Care)
    - **Iris-supported IOLs**: Worst iris-claw lens = ARTISAN lens in USA (Ophtec)

Available Designs

- Anterior Chamber P-IOL: **Artiflex**
- Iris-fixated lens
    - **Artisan**, Ophtec; Groningen, Netherlands

- Posterior chamber P-IOL
    - **ICL**, Staar Surgical; Nidau, Switzerland
    - **IPCL**, Care group, India
    - **EYECRYL** PHAKIC, Biotech Phakic IOL

Power of P-IOL

- **Van der Heijde's nomogram** for iris claw lens power calculation which uses the mean corneal curvature (K), adjusted anterior chamber depth (ACD−0.8 mm), and spherical equivalent (SE) of the patient's spectacle correction at a 12.0-mm vertex.
- **Feingold's formula** (proprietary) for a precrystalline lens implant
- **Matrix formula** for phakic anterior chamber intraocular lens (AC IOL) power calculation
- **Binkhorst 2 formula** for posterior chamber intraocular lens (PC IOL) power calculation

Ideal PIOL

- Predictability: Predictability for a wide range of correction, including astigmatism. Although all types of PIOLs have excellent efficacy and predictability in correcting spherical errors, only those PIOLs that have a toric option can correct eyes with astigmatic error.
- Large functional optic zone: This is important for providing a good quality of vision.
- Stability: Stability of the PIOL inside the eye is essential for long-term safety; a PIOL that rotates or sags down carries the risk damaging intraocular structures, especially the corneal endothelium and the anterior chamber angle, and can also have a negative impact on the refractive correction, especially if the lens is toric.
- Biocompatibility: Biocompatibility is a major criterion for the long-term safety of any PIOL. PIOLs that have less than optimal biocompatibility may induce chronic inflammation and may be detrimental in the long term.
- The ease of removal and/or exchange: The ease of removal and exchange of a PIOL is another key factor for an ideal PIOL. Many patients who receive PIOLs to correct their high myopia in their twenties or thirties will need to have these lenses removed if they develop cataract later in their lives, and a lens that cannot be safely removed through a small incision is obsolete in the era of small-incision and femtosecond cataract surgery.
- Accurate size calculation: Accurate size calculation is mandatory in PIOL surgery. An over or undersized PIOL carries the risk of rotation, inflammation, and intraocular tissue damage.

Patient Selection

- Myopia: -3 to -20
- Hyperoia: +3 to +12
- Pupil Size: optical one of the implant limits the maximum scotopic pupil size allowed.
- ECD
- ACD > 2.8 mm

Contraindications

- Visually significant cataract
- Chronic uveitis
- Low endothelial cell count
- Abnormality of the iris
- Diabetic retinopathy
- Abnormality of the anterior angle
- Glaucoma
- Any form of progressive vision loss

Complications

- **Potential Complications of Iris-Fixated P-IOLs**
  - Endothelial damage may occur in cases of shallow anterior chamber. It is agreed that 2.8 mm of central anterior chamber depth calculated from the endothelium is safe.
  - Iris damage is an uncommon complication of iris-fixated IOLs and may be seen many years after the surgery. It may lead to piercing of the iris and sagging of the implant.
  - Late dislocation due to trauma and/or poor enclavation
  - Decentration: Centration of iris-fixated P-IOLs is the responsibility of the surgeon, and in some cases a small decentration can lead to incapacitating edge glare, especially with large pupil diameter.
  - Low-grade chronic uveitis
  - Postoperative astigmatism after nonfoldable implants
  - Pigment dispersion
  - IOP elevation
- **Potential Complications of Posterior Chamber P-IOLs**
  - Sizing complications. Sizing remains the main unsolved issue in ICL surgery. White-to-white is the most commonly used method for sizing; it can be measured with calipers or with imaging devices including Orbscan (Bausch + Lomb; Rochester, NY), Pentacam (Oculus; Wetzlar, Germany), and IOLMaster (Carl Zeiss; Oberkochen, Germany). Many studies showed no correlation between white-to-white measurements and sulcus diameter; however, clinical outcomes showed that the rate of over or undersizing using the white-to-white measurement is less than 5%. More recent studies evaluated the use of high-frequency ultrasound and reported more reliable results compared to white-to-white measurement.
  - Lens induced anterior sub capsular cataract: Although a rare complication, induced cataract remains an important complication of posterior chamber P-IOLs. The most important cause of cataract development is surgical trauma during a faulty surgical procedure. The second cause is poor sizing leading to peripheral touch between

the implant and the crystalline lens, leading to poor aqueous circulation and accumulation of metabolites. The recently introduced model with a central hole is believed to improve the aqueous circulation and minimize the possibility of metabolic cataract.

- Postoperative IOP spikes. This may occur due to retained viscoelastic or, rarely, due to blockage of the central hole by inflammatory exudates in cases of severe postoperative inflammation. This must be treated immediately by decreasing the IOP through evacuation of viscoelastic through a paracentesis or anterior chamber wash if needed. In cases that are not promptly treated, this complication may end in a fixed and dilated pupil.
- Rotation of undersized posterior phakic IOL. This usually has a negative impact on the postoperative refractive outcome and commonly requires a lens exchange.
- Under/over correction
- Secondary glaucoma
- Corneal edema
- Pupillary block glaucoma
- Hyphema
- Retinal detachment
- Intraocular infection
- Additional surgery to remove or replace the implant
- Glare/halo
- Macular edema
- Increased astigmatism
- Endophthalmitis: The reported incidence after ICL is 0.0167%. Although this rate is very low, it is very important to pay attention to early signs in order to treat promptly to avoid any vision loss.
    - Use povidone iodine 15 min and 3 min before surgery, eyelid 15% and ocular surface 5%.
    - Short surgical intervention time
    - Small incisions

ICL (Implantable Collamer Lens)

- STAAR® Visian ICL is currently the only posterior chamber P-IOL approved by the FDA for correction of myopia
- It is made-up of 60% poly-HEMA, Water (36%), Benzophenone (3.8%) and Collagen (0.2%), it attracts the deposition of fibronectin on the lens surface, inhibits aqueous protein binding and makes the lens invisible to the immune system.
- Lasik for correcting high refractive errors has the drawbacks of lack of predictability, regression, corneal ectasia, and induction of high order aberrations.

- ICL was first developed in the late 1980's in Russia by Dr. S. **Fyodorov** and the first implant was placed in Europe in 1993
- **ICL Power Range**: moderate to high myopia ranging –3.0 D to –20.0
- **Models**
    - **V1** model had the same dimension for the optic diameter and variable dimensions for the foot-plate
    - **V2** model, the footplate dimensions remained constant and the optic diameter was variable. The optic diameter was inversely proportional to the diopter strength.
    - The optical diameter was optimized in the **V3** model. V3 is for Hyperopia.
    - By changing the concave base radius to 11.0 mm, increased anterior vaulting of the ICL was introduced in the **V4** model in 1998. V4, V4b, and V4c are for myopia and astigmatism.
    - **V4c Model**
        - The V4c is a newer ICL model with an artificial port (**CentraFlow**) integrated in the center of the lens optic.
        - This development eliminates the need to perform a preoperative peripheral laser iridotomy, simplifying the surgical procedure and reducing complications associated with ablating the iris.
        - The central hole improves the aqueous circulation between the crystalline lens and the implant and also from the posterior to the anterior chamber through the pupil. This new design carries the promise of a better efficacy.
        - Additionally, older ICLs were hampered with reports of raised IOP postoperatively, usually due to residual viscoelastic blocking the iridotomy site, and late-onset cataract, resulting from physical contact between the ICL and the crystalline lens.
        - The V4c may reduce the threat of both of these complications.
    - **Toric ICL**:
        - -3 to -23 D of sphere and + 1.0 to + 6.0 D of cyl (The toricity is manufactured in the plus cylinder axis, within 22 degrees)
        - The toric version of the ICL has expanded the pool of potential candidates for P-IOL implantation, including those with keratoconus.
        - The axis of the Visian V4 ICL is aligned with the 180-degree meridian, with only a minor adjustment of no more than 22 degrees rotation, clockwise or counterclockwise, required to correct the astigmatism.
        - Other applications of the Visian ICL include reduction of myopia and astigmatism in patients with keratoconus in combination with collagen corneal crosslinking.

- **Indications and pre-requisites**
    - When residual bed after LASIK is likely to be less than 250μ
    - When the initial corneal thickness is less than 480μ

- Refractive error between the ages of 21-45
- ACD greater than **2.8 mm**
- Stable refraction (<0.5D change in previous 12 months)
- No ocular pathology (NSC, glaucoma, lid pathology, etc)
- Mesopic pupil <6.0mm

- **Measurement of white to white diameter**
  - Pentacam, OrbScan, UBM or using calipers
  - In myopic eyes, to determine the overall length (in mm) of the ICL, add 0.5 mm to the horizontal WW measurement.
  - If the ICL is too short for the sulcus, the lens vault may be insufficient to clear the crystalline lens, exposing it to the risk of an anterior capsular cataract.
  - If it is too long, the lens will vault excessively, crowding the angle and possibly causing closed angle glaucoma.

- **Vault**:
  - Ideal ICL vault is approximately 500 μm, which is roughly one corneal thickness. There are concerns about high vault (1000 μm) leading to angle crowding and resulting in angle closure or synechiae formation. High vault may also increase iris chaffing and pigment dispersion, resulting in pigmentary glaucoma. Furthermore, low vault (125 μm) may also cause ICL contact with the crystalline lens and increase the risk of cataract formation over time.
  - Vault Classification
    - Vault type 0 (T0): no space between the ICL and the lens
    - Vault type 1 (T1): small central space, with peripheral touch of the lens
    - Vault type 2 (T2): small space across the ICL
    - Vault type 3 (T3): significant space across the entire ICL

- **Advantages of ICL over other PIOLs**
  - The ICL has passed the test of time and fulfills most of the abovementioned criteria.
  - Predictability: The ICL and toric ICL proved to be highly predictable in the range between -18 and +12 D and also for correction of astigmatism up to 6.0 D.
  - Quality of vision: Posterior chamber lenses, being closer to the nodal point of the eye optical system, provide a large functional optical zone and a magnification of the retinal image without significant effect on the quality of vision.
  - Stability: A properly sized ICL does not rotate inside the eye, as shown by internal optical path difference measurement using the OPD- Scan III (Nidek; Gamagori, Japan) at different postoperative intervals (see Figure 1). An undersized ICL can rotate inside the eye, and in this case the lens must be exchanged for a larger better fitting lens.

- Biocompatibility: Long-term studies showed that the ICL collamer material is highly biocompatible and safe to the corneal endothelium and other intraocular structures.
- Removal and exchange: The ICL can be removed and replaced through a small incision if needed.

- **Disadvantages of ICL**
  - Sizing remains the main unsolved issue in ICL surgery.
  - White to white is the most commonly used method for sizing; it can be measured with calipers or with imaging devices including Orbscan (Bausch + Lomb; Rochester, New York, USA), Pentacam (Oculus; Wetzlar, Germany), and IOLMaster (Carl Zeiss; Oberkochen, Germany).

Verisyse (Artisan/Artiflex)

- **Artisan**
  - The Artisan (Verisyse) lens is an anterior chamber iris claw-fixated P-IOL. Its myopic correction parameters are slightly wider than the ICL, ranging from -5 D to -20 D with 2.5 D of astigmatism at the spectacle plane. A toric Artisan model is available in Europe.
  - Patients who had myopic/toric Artisan in one eye and LASIK in the other reported no significant difference in satisfaction, but patients had a significantly higher preference for the Artisan due to better reported quality of vision.
  - Complications
    - higher incidence of glare and halos (18.2%) and cataract (5.2%) than the Visian ICL
    - but less endothelial cell loss and no influence on IOP.
- **Artiflex**
  - consists of a flexible convex-concave 6.0-mm silicone optic.
  - It is inserted via a small self-sealing incision, facilitating rapid return of visual acuity.
  - As a paradox, the tiny incision requires a more demanding surgical technique, and moving the instruments around the eye can cause damage to local structures.
  - The flexible lens is more susceptible to mechanical factors and therefore a flat iris, in addition to a sufficient anterior chamber depth, is an essential selection criterion.

AcrySof Cachet

- The AcrySof Cachet is an acrylic angle-supported P-IOL. It requires a small incision and does not require a peripheral iridectomy. There are good 3-year outcomes. However, there is no toric model available, and it is not yet FDA approved.
- Avoiding the need of iridectomy / iridotomy is also an advantage of Cachet just like ICL (V4c model with central hole).

Presbyopic P-IOLs

- A novel posterior chamber P-IOL has recently been marketed (**IPCL**, Care Group India) that may provide correction for presbyopia in addition to myopia and astigmatism.
- The IPCL is made from reinforced hybrid acrylic and has 6 points of contact with the ciliary sulcus, instead of the usual 4, to increase stability. It has 2 positioning holes in the haptics to facilitate implantation and 4 holes in the optical zone margin to regulate aqueous flow. A diffractive optical zone of 3.5 mm allows gliding of the iris over the lens and aims to reduce halos.
- The main target group for this lens is patients aged 40-55 who have not yet developed cataract, in whom this technology provides a reversible presbyopia solution.
- The lens comes with intermediate/near additions between +1.50 and +3.50 in 0.50-D increments. The interaction between this diffractive optic and the patient's natural lens is described by the manufacturers as "panfocality."

Presbyopia Management

- **Principle**
    - Either producing simultaneous focus as in multifocal IOLs
    - Alternating focus i.e.focusing one distance at a time as in accommodating IOLs.

Intraocular (Lenticular) Approaches

Monovision

- When one eye is made emmetropic and the second eye purposely made myopic by 2.5 to 3.0 D for near vision has also been accepted to restore multifocality but has the inherent limitation of loss of stereopsis, which is not well accepted in most patients.
- **Problems**:
    - Loss of stereopsis
    - Reduction in distance acuity
    - Difficulty with night driving
    - Reduction of contrast sensitivity.
    - Nocturnal halos
    - Photic phenomenon
- Presbyopic lens exchange (**PRELEX**) aim to correct the loss of accommodation by removing the crystalline lens by phacoemulsification and implantation of a multifocal intraocular lens (IOL) in the capsular bag
- C. Claou'e -1997?? first described monovision
- Monovision in pseudophakic patients was first described in 1984?? by Boener and Trasher
- Types
    - When dominant eye is optimized for distance vision, it's called as **conventional** monovision
    - when nondominant eye optimized for distance, it's called **cross** monovision.
- Factors affecting monovision
    - Ocular dominance
    - Degree of anisometropia
    - Stereopsis
    - Patient's motivation
- The mechanism that enables monovision to succeed is interocular blur suppression (i.e. the ability to suppress the blur image from one eye and it is assumed that it is easier to suppress blur in nondominant eye.

Multifocal IOL

- **History**
  - **Hoffer** in 1982 was the first to hit upon the idea of a multifocal IOL
  - Refractive Lens
    - **Dr. John Pierce** in 1986 who was to implant the **bull's eye style** of the multifocal IOL.
    - First presbyopia-correcting IOL to be FDA approved in 1997
      - Array (Advance Medical Optics; Santa Ana, Calif., USA)
      - ReZoom (approved 2005; Advance Medical Optics, acquired by Abbot)
  - Diffractive Lens
    - Pharmacia 811E (Advance Medical Optics)
    - 3M 815LE (3M Corp)
    - ReSTOR (Alcon)
      - First diffractive IOL to be FDA approved, in 2005
      - FDA approved aspheric version of the ReSTOR (AcrySof IQ, ReSTOR) in 2007.
- Many IOLs available but, Three multifocal lenses are **currently FDA approved** for use after cataract extraction:
  - the ReZoom lens (AMO),
  - the AcrySof ReSTOR (Alcon, Fort Worth, TX), and
  - the Tecnis (AMO) multifocal 101
- **Type of Multifocals**
  - **Refractive**
    - ***Bull's eye lens***, Precision Cosmet
      - central near add surrounded by distance optical power
      - two foci – one for near and one for distance.
      - sudden loss of vision in bright sunlight since constricted pupil blocks the distance segment of lens
      - pupil dependent
    - **ReZoom**
      - The *Rezoom lens* (non-aspheric) is a foldable acrylic MIOL from AMO. It has zones similar to Array, zone 1, 3 and 5 are distant dominant and zones 2 and 4 are near dominant
      - 60% of incoming light is for distance and 40% for near and intermediate distances
      - provided a comparable reading performance that was significantly better than the one obtained with refractive multifocal or monofocals

        - Dependent on spectacles for near tasks; intermediate vision is spectacle independent
        - Distant visual performance was excellent under photopic conditions, but was reduced under mesonic conditions
        - More frequent Photic phenomenon

- **Diffractive**
    - introduced by the 3M corp called as the **3M diffractive MIOL -PMMA**
        - basic refractive power is provided by the anterior aspheric surface and the diffractive power comes from the multiple grooves on its posterior surface.
        - 41% of light is focused for distance vision and another 41% is focused for near vision.
    - Pharmacia CEEON 808,811E -PMMA
        - pupil INDEPENDENT
        - first FDA approved foldable MIOL which was the silicone AMO Array lens. It is divided into 5 concentric zones on its anterior surface with 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
    - Tecnis ZMB00
        - Vision: At 60 days, 94.3% of eyes could read N6 without correction
        - Photic phenomena: Patient satisfaction in terms of dysphotopsia effects and visual acuity was excellent
- **Combination of diffractive & refractive**
    - The **Tecnis Multifocal** IOL (Abott Medical Optics, Inc., Santa Ana, DA)
        - *wavefrontdesigned, modified prolate, anterior-surface* optic that neutralizes the positive spherical aberration of the human cornea
        - biconvex
    - AcrySof **ReSTOR** (aspheric)
        - apodized diffractive IOL
        - A central aprodized diffractive region is 3.6mm wide and the peripheral refractive region contributes to distance focal point for larger pupil diameter and is thus dedicated to distance vision.
        - The central apodized diffractive region consists of 12 concentric steps of gradually decreasing (1.3-0.2 microns) steps heights provide a good range of vision for different distances. This lens incorporates +4.0D of additional power in lenticular plane for near vision, resulting in +3.2D at the spectacle plane.
    - **Refractive portion** of the optic functions like a standard IOL, with the optic periphery dedicated to distance vision and designed to optimize night vision when the pupil dilates under scotopic conditions.

        - **Diffractive portion** of the optic consists of 12 concentric rings on the anterior surface of the optic, and it is located within the central circle, which is 3.6 mm in diameter and is designed to provide distance and near vision in moderate to bright light.
        - **Apodization** is the radial variation in optical properties that comes from decreasing the height of each concentric ring from the center toward the periphery of the optic surface (from 1.3 to 0.2 μm). This balances the amount of light energy that is distributed between distance and near as a function of pupil size, which improves the efficiency and effectiveness of the quality of near vision achieved and reduces problems with glare and halos. Ring location, spacing and variation of height serve within the pupillary aperture to provide a satisfactory near image at approximately 25 to 33 cm.
    - **Segmental**
        - **Lentis Mplus**
            - Provides adequate distance, intermediate, and, to a lesser extent, near vision with high rates of spectacle freedom
- **Pre-operative Considerations**
    - *Strong desire* to be spectacle independent
    - *Functional & Occupational Requirements:*
        - Painting, playing the piano, playing cards
        - *Occupational night drivers*
    - *Pre-existing Ocular Pathologies*
    - *Hypercritical & Demanding Patients:* should be strictly avoided
    - *Strong urge for near reading without glasses*
- **Medical Exclusion**
    - Preoperative
        - Patients with more than 1.0 D of corneal astigmatism
        - Pre-existing ocular pathology
        - Individuals with a monofocal lens in one eye
        - History of previous Refractive Surgery
    - **Intra-operative**
        - Significant vitreous loss during surgery
        - Pupil trauma during surgery
        - Zonular damage
        - Capsulorhexis tear
        - Capsular rupture
- **Problems**:
    - Loss of contrast sensitivity
    - Small amount of glare and halos

Trifocal IOLs

- Bifocals can provide good vision at both distance and near, but intermediate vision is important for:
    - Computer work
    - Chatting with others in “normal” distance
    - Shopping / supermarket shelf
- A pioneering solution was proposed in 2010 with the introduction of the first trifocal diffractive lens (**FineVision, Physiol; Belgium**). This 25% hydrophilic acrylic IOL has, in addition to a near foci (+3.50 D), a foci for intermediate vision (+1.75 D) to provide treated patients with a full range of correction. A second diffractive IOL model (+3.33 D near add and +1.66 D intermediate add at the IOL plane) was introduced later in 2012 (**AT LISA tri 839MP, Zeiss; Germany**).
- AT LISA Trifocal (Carl Zeiss)
    - The AT LISA tri 839MP IOL has a trifocal diffractive design, the working principles of which have not been disclosed.
    - It is claimed to provide a +3.33 D near add and a +1.66 D intermediate add at the IOL plane, with an asymmetric light distribution for far, intermediate, and near focal points.
    - The IOL optic distributes light energy among the 3 focal points within the central 4.34-mm optical zone.
    - Beyond the 4.34-mm zone, the AT LISA tri 839MP IOL’s diffractive optic structure is exclusively bifocal (near and distance vision).
    - The lens has an aspheric aberration correcting design with an overall diameter of 11.0 mm, and a 6-mm optic zone diameter.
    - The IOL is available from +0.0 to +30.0 D in steps of 0.50 D, and it includes a UV blocker.
- Finevision Trifocal IOL (PhysIOL)
    - Optic: Aspheric trifocal diffractive
    - Material
        - 25% hydrophilic acrylic (25% of water content)
        - Copolymere of 2-hydroxyethylmethacrylate (HEMA) and 2-ethoxyethylmethacrylate (EOEMA) using ethylene glycol dimethacrylate (EGDMA) as linking agent
    - Filtration: UV and blue light blocker
    - Optic body diameter: 6.15 mm
    - Overall diameter: 10.75 mm
    - Angulation: 5°
    - Power: from +10 D to +35 D (0.5-D steps)

- Pupil-dependent trifocal IOL

EDoF (Extended Depth of Focus) intraocular lenses

- Also referred to as extended range of vision IOLs (EROV-IOLs)
- Advanced optical technology that allows increase the range of focus compared to standard monofocal IOLs.
- Enable clear vision ranging from far up to intermediate distances, like e.g. a computer monitor. For close-up activities such as reading fine print and precision work, patients treated with EDoF lenses may need to wear reading glasses
- However, they will experience less visual disturbances at night, which are sometimes caused by bright light sources with multifocal IOLs.
- EDoF lenses offer a high degree of spectacle independence. However, the achieved vision quality is very individual and may differ from patient to patient.
- **Available Lenses**
    - The **Mini Well Ready** is a single-piece, preloaded, multifocal IOL made of acrylic copolymer. The biconvex aspheric optic has a diameter of 6 mm and is divided into 3 annular optical zones, an outer monofocal zone and 2 inner zones, with spherical aberrations of opposite signs and an equivalent addition of +3.0 D corresponding to an addition of +2.4 D at the spectacle plain.
    - **Tecnis Symphony Lens**:

Accomodative IOLs

- **Historical aspects**
    - **Dr J Stuart**: observed intraocular axial movement
    - Pharmacological induction of ciliary muscle contraction and relaxation by pilocarpine and cyclopentolate respectively and noted average optic movement of 0.7 mm
- **Classification**
    - Single optic designAmount of accommodative effect is dependent on IOL power. E.gCrystalens Eyeonics, Human optics AG Akkomodative ICU, Kellan Tetraflex KH-3500,Opal IOL, Acuity Ltd C-Well IOL, Morcher IOL, Tekia Tek Clear, Flex optic IOL
    - Ring haptic designE.gBiocom fold 43A, 43E and 43S
    - Dual opticThe concept was proposed by Hara et al in 1989. These IOLS have an anterior optic that is plus powered and posterior optic that is minus powered, which move anteriorly and posteriorly respectively, with axial movement. This leads to a greater change in refractive power for a similar amount of axial movement. ExampleSarfarazi EA-IOL, Synchrony IOL

- Lens bag filling designCapsular bag is filled up with a material that can maintain its shape and optical power, and sustain a rapid, constant and predictable response to ciliary muscle action. Example Medennium Smart IOL, Fluid vision
- Lenses with abilir During accommodation, flexible anterior lens material is pressed through an aperture in a diaphragm, which decreases the radius of curvature of the anterior surface, while it increases the power of the lens. ExampleNu lens

- **Classification According to IOL Material**
    - SiliconeCrystalens, Sarfarazi Twin Optic EA IOL, Synchrony, Flex optic IOL,
    - AcrylicHuman optics AG Akkomodative, OPAL, Meddenium Smart (proprietary thermodynamic hydrophobic acrylic)
    - PMMANu Lens, morcher
    - HEMAKellan Tetraflex KH-3500, morcher

- **IOLswith flexible haptics that are designed to move forward with accommodative effort eg. crystalens**
    - **Crystalens**
        - The crystalens IOL (eyeonics) is the only accommodative IOL approved for clinical use by the FDA in 2003.
        - The IOL is designed to move forward with accommodative effort
        - Change in lens contour with ciliary contraction.
        - Modified **silicon plate** haptic lens. It has a hinge at the junction of its haptic and optic and T shaped **polyamide haptics** at the end of the plates. The lens is 11.5mm from loop tip to loop tip and the length as measured from the ends of the plate haptics is 10.5mm. The lens has a **biconvex optic that is 4.5mm** in diameter.
        - The amount of effective accommodation, however, varies from patient to patient. Some patients require reading glasses to see small print or to read in low levels of illumination, but the majority of crystalens patients are able to perform most of their daily activities without glasses.
        - Incidence of PCO is predicted to be higher **than current lenses**
    - **1CU intraocular lens (Human optics AG Erlanger, Germany)**
        - One piece, three dimensional, foldable, acrylic IOL
        - Optic is 5.5mm and the IOL has a diameter of 9.8mm
        - Problems: 'infolding' of 1CU haptics, greater PCO
    - **Dual optic accommodative lenses**
        - Accommodation per mm of lens movement
        - **Synchrony** (Visiogen, Menlo Park, California, USA) is one such dual optic lens in clinical -trial, and the company has announced that the FDA US trials will start in early 2005
            - Silicon lens with two optics joined by a spring mechanism

        - Anterior high powered plus optic, 5.5mm in diameter and a complementary minus power optic work together to produce an accommodative effort of more than +2.75D.
        - Plus powered anterior optic of power + 31 D and a minus powered posterior optic, the power of which varies as per the axial length. Posterior optic is fixed at posterior capsular bag and anterior optic moves forward to facilitate near vision
    - The **Sarfarazi dual optic lens** (Bausch and Lomb, Rochester, New York, USA) has been implanted in monkeys with objective signs of up to 8 diopters of accommodation.
    - Advantages
        - Allows more accommodation than the single optic IOLs, with less lens movement
        - Contrast or glare problems do not develop, unlike the multifocal IOLs.
    - Disadvantage:
        - Possibility of interlenticular opacification in between the two optics
        - Not as predictable as the multifocals in terms of visual outcome.
- **FluidVision Accommodating IOL (A-IOL):**
    - The FluidVision A-IOL is the first true shape changing, fluid-driven IOL.
    - Fluid movement translates into a true shape change, for A seamless change in vision from near to distance
    - Lens body is made from a proprietary hydrophobic acrylic.
    - Lens and hollow haptics are filled with a proprietary refractive index-matched silicone fluid.
    - Lens is implanted in 1 step into the capsular bag through a 3.5-mm incision with the PowerJet injector system.
    - Mechanism of the FluidVision A-IOL
        - When the eye moves to its natural accommodated state, the capsular bag squeezes fluid from the haptics at the periphery of the lens into the center.
        - This inflates the lens, giving near vision.
        - When the eye moves to its disaccommodated state, the capsular bag squeezes fluid back into the haptics, giving far vision.

- **IOLs with flexible optics that are designed to change in contour and increase in dioptric power with ciliary contraction eg. Smart Lens (Medenium, Irvine, California, USA)**
    - Placing a malleable material inside the capsule to produce a situation very close to our pre-presbyopic state.
    - This has been termed **ersatz phakia**

    - Thermodynamic, hydrophobic acrylic IOL designed to completely fill the capsular bag.
    - Made up of Smart material(proprietary thermodynamic hydrophobic acrylic material).
    - Packaged as a solid material 30mm long and 2 mm wide.
    - At room temperature, it is convertible to a thin rod that can be inserted into the eye through a small incision. Under the influence of body temperature, it reconstitutes its original power
    - Dealing with after-cataract formation, refractive precision, and whether the anterior capsule must largely be intact to truly transmit an accommodative effort.

- **IOLs that use dual optic systems and are designed to function like a Galilean telescope, eg Nu lens.**
    - It is based on the principle of compressible polymer between fixed plates so that on accommodative effort there is bulge in the polymer through an aperture in the anterior fixed plate
    - ***Merits***
        - Accommodative IOL implant may eliminate the need of any kind of refractive correction postoperatively.
        - There is no incidence of glare, haloes, ghost images and loss of contrast sensitivity.
    - ***Demerits***
        - The present concept is based on a single plate IOL and there is a high incidence of contraction of capsular bag.
        - Loss of pliability of material at the hapticoptic junction leads to poor movement of the optic in the long run and loss of function.

Extraocular (Corneal/Scleral) Approaches

Monovision LASIK & PRK

- Monovision LASIK performed in myopic presbyopes appears to have excellent visual results. Hyperopic presbyopes may require more enhancements and experience more side effects.
- Monovision PRK patients should be able to achieve visual results similar to the monovision LASIK group.

Multi-focal Presbyopic LASIK

- **PresbyLASIK:** The term “presbyLASIK” indicates a corneal surgical procedure based on traditional LASIK to create a multifocal surface able to correct any visual defect for distance while simultaneously reducing the near spectacle dependency in presbyopic patients.
- PresbyLASIK uses a multifocal ablation pattern to create discrete levels of pseudo-accomodation. Visual acuity data appears very promising in presbyopic hyperopes. Concern exists regarding the quality of vision at these multiple refractive states.
- Presbyopia excimer laser ablation (PresbyLASIK) utilizes **two methods**:
    - creating a central zone for near vision (central PresbyLASIK) or
    - leaving the center for distance and creating the zone for near at the periphery of the cornea (peripheral PresbyLASIK).
- The Difference between the two methods is the spherical aberration produced:
    - Central ablation creates a negative spherical aberration in the center of the cornea (Z40) and a positive spherical aberration in the periphery (Z60).
    - Peripheral ablation creates a central positive spherical aberration (Z40) and a negative spherical aberration (Z60).
- In both cases, the presence of these two aberrations **increases the depth of focus** and improves the near vision, making the patient less dependent on glasses.
- Advantage
    - It is a completely extraocular surgery with no sight-threatening complications
    - LASIK is a well-known surgery for ophthalmologists and therefore easy and accessible to many of them. The change is the laser software; techniques are similar to any other excimer surgery.
    - Complications of this surgery are very low and easily managed in the postoperative period. Technical improvements predict fewer complications.
    - Excimer laser ablation corrects all types of refractive defects with the precision characteristic of this surgery. This is done at the time of the surgery together with the presbyopia correction. In astigmatism, as is well known, there is no more precise method.
    - Of great importance is the fact that this surgery is completely reversible with a wavefront (CustomVue) ablation
- Disadvantages
    - It is a temporary solution (5 years as a mean), although can be repeated.
    - There is some concern about the presence of a future cataract, but new elevation topography softwares and formula calculations make this problem small at the time of cataract surgery in an already treated eye.
    - Visual symptoms are just as with multifocal lenses; however, they are less severe and usually not permanent.
    - Decrease of contrast sensitivity vision has been reported, as with other types of surgery. This is a temporary problem and studies have shown contrast vision returns to normal limits between 3 and 6 months.

- Platforms
  - **Micromonovision** (Zeiss Mel80 AG; Oberkochen, Germany)
    - Also known as ***Laser Blended Vision***
    - The building of a ***plus add of about +1.5 D in the nondominant*** eye, while the dominant eye is corrected to emmetropia. It can be titrated to meet individual needs.
  - **PresbyMAX** (Schwind AMARIS System AG; Kleinostheim, Germany)
    - PresbyMAX and PresbyMAX μ-monovision software developed by Alio
    - A bilateral procedure that builds a small plus add in the central cornea, gradually fading pericentrally to emmetropia. Currently there are 3 versions, including micromonovision to improve near vision.
  - **Supracor** (Technolas Perfect Vision TPV; Munich, Germany)
    - A bilateral procedure that builds a 1.5-mm small plus add in the central cornea, immediately fading pericentrally to emmetropia. Currently there are 2 versions: "regular," adding about +2.0 D, and "mild," adding about +1.5 D.
    - The procedure is designed for use with the Technolas 217P excimer workstation (Technolas Perfect Vision GmbH). Following creation of a standard LASIK flap of ≥ 9 mm diameter and 110-120 μm thickness, the stromal bed is ablated in a unique profile in a 6-mm optical zone centered on the pupil center.
    - The near addition is created by 2000 pulses fired to create a central "bump" on the cornea. The target spherical equivalent refraction is −0.50 D in both eyes. The procedure is "aberration optimized" and causes a shift in spherical aberration in a negative direction to enhance depth of focus. Standard post-LASIK care is given postoperatively.
  - **AMO Visx System**
    - Center near, hyperopic treatments
  - **Nidek System**
    - EC-5000 CXIII laser, distance-dominant central cornea algorithm called pseudoaccommodative cornea (PAC) for treatment of myopic, hyperopic, and emmetropic presbyopia
    - Inclusion of the OPA (Optimized Prolate Ablation) software
  - **WaveLight System**
    - Allegretto Eye-Q F-CAT profile
    - Off-label use in the United States. Myopic treatment at 5.5-mm optical zone followed by a 6.0-mm optical zone hyperopic correction; overcorrects by 1.00 to 2.25 and then plano with the second ablation.

Conductive Keratoplasty

- Initially approved for the treatment of spherical hyperopia in 2002.

- The procedure involves delivering electromagnetic energy at radio frequencies of 350kHz to the cornea via a needle-like probe that is 90μ in diameter and 450 μ long. The energy increases the tissue temperature in the cornea, leading to collagen shrinkage. When discrete spots are place in rings around the mid-periphery of the cornea, localized tissue contraction steepens the central cornea increasing its refractive power.
- In addition to being a safe and easy to perform procedure, visual results appear promising in presbyopic emmetropes and hyperopes.

Corneal Inlays (Intracorneal Lens for Presbyopia)

- **History**
  - **Jose Barraquer (1949-1960)**
    - Attempts flint glass and Plexiglas for the correction of aphakia and high myopia
    - Failed and transitioned to human tissue keratophakia
  - **Peter Choyce (1960-1985)**
    - Used impermeable PMMA and polysulfone implants to treat Fuchs corneal dystrophy and high myopia
    - Failed secondary to anterior corneal stromal necrosis and interface haze
  - G Barrett, P Binder, H Kaufman, S Lane, R Lindstrom, B McCarey, D Durrie, J Holladay, S Slade, T Werblin
    - Performed basic studies on glucose transmission, material biocompatibility, and participated in early clinical trials of intracorneal lenses

- **KAMRA Corneal Inlay (formerly ACI 7000) (Acufocus)**
  - 3.8mm diameter
  - 5 microns thick 1/10th the thickness of a sheet of paper
  - (7.5 mm radius), and flexible enough to bend to different curvatures without buckling
  - Mass is 71-142 micrograms about the weight of a salt crystal
  - **Inlay Design**
    - 8,400 micro-perforations (5-11μ)
    - Pseudo-random pattern
    - Maximize nutrient flow
    - Minimize visual symptoms
  - **Optical Principals of Inlay**
    - Light rays pass through the small aperture over a small angle, increasing the depth of focus
    - Distance vision is minimally affected

- **VUE+ (Formerly Presbylens) (ReVision) Presbyopic Corneal MicroLens**
  - Hydrogel corneal microlens implanted after creating a femtosecond flap
  - Restores near and intermediate vision in patients with myopic, hyperopic, and emmetropic presbyopia
  - Transparent, biocompatible and mimics a healthy cornea
  - Removal with reversible vision
  - Mechanism: Inlay has same refractive index as cornea but increases curvature in the centre of the pupil
- **FLEXIVUE MICRO-LENS (Presbia)**
  - Inlay Design
    - Thickness: 20µm
    - Diameter: 3mm
  - Inlay Characteristics
    - Acts changing the refractive index of the cornea
    - Donut shape bifocal refractive power
    - The lens is implanted into the stroma of the cornea on the non-dominant eye, inside a corneal tunnel created using femtosecond laser
    - The lens is “Invisible”
    - Biocompatible hydrophilic material with a central hole to increase more the nutrient flow
    - The refractive effect is pupil depended, increasing during near vision and decreasing during far vision, changing less the far vision in the operated eye than in a classic monovision procedure
- **Bausch + Lomb (Chiron), Refocus**
  - Hydrogel
  - 30 to 60 microns thick
  - Diameter 1.80-2.20 mm
  - Pocket incision
  - Select clinical outcomes
    - Mean vision: 20/25 and J2
    - Spectacle independence: 75%
    - Patient satisfaction: 100%
    - Material well tolerated
    - Side effects: ghosts, mild material yellowing, decentration, interface haze
- **Icolens (Neoptics AG; Hünenberg, Switzerland)**
  - Hydrogel microlens
  - Refractive optics

- Central zone for distance vision and peripheral zone for near

- **Common Complications**
  - Diffuse lamellar keratitis (DLK): No ophthalmic medications should be administered until after inlay and flap centration is adequate and no further flap manipulation is required.
  - Decentration: Patients should be assessed for steroid responsiveness preoperatively as increased IOP can cause corneal edema leading to decentration.
  - Haze: Regular follow-up visits are critical in detecting changes to vision, topography, and slitlamp examination so that treatment can be given in a timely manner to minimize complications and improve outcomes.
  - Persistent haze: Persistent complications should be treated aggressively and include explantation in some cases.

INTRACOR

- **INTRACOR™ (intrastromal correction of presbyopia)**
- INTRACOR is a procedure that traditionally involves placement of 5 intrastromal rings in the center of the visual axis using a femtosecond laser, leading to central corneal steepening, and an increased depth of focus
- This procedure is designed primarily for presbyopes and hyperopic presbyopes but is not suitable in myopic presbyopes due to subsequent myopic shift
- The primary advantage of INTRACOR lies in leaving Bowman's layer and the epithelium intact, thus reducing risk of infection or intraocular complication

Scleral Surgery

- anterior ciliary sclerotomy or ACS: Thornton first proposed weakening the sclera by creating 8 or more scleral incisions over the ciliary body
- scleral expansion bands.

Ciliary Muscle Electrostimulation Cycles to Restore Accommodation (CMERA)

- New Noninvasive Method for Presbyopia Treatment
- promising technique to delay accommodation loss, improving presbyopic symptoms

Laser Presbyopia Reversal

- Ron Krueger who first investigated the effect of intralenticular femtosecond laser surgery on accommodation.

- The Rowiak Femtosecond Laser for Presbyopia Reversal (Rowiak GmbH; Hannover, Germany) is a low-energy (2.0 µJ to 5.0 µJ per pulse) and high-frequency (100 kHz) infrared laser (1040 nm).
- The width of each single laser pulse is less than 400 femtoseconds. The laser process is controlled by an integrated OCT imaging system. The laser is able to cut 3-dimensional patterns with a working field diameter of up to 9.0 mm within the crystalline lens. The presbyopia reversal cutting process is characterized by an extremely low gas bubble production due to a low energy threshold.
- In the summer of 2013, the first human eye trial for LPR with a specifically designed femtosecond laser (Rowiak GmbH; Hannover, Germany) was performed at the Augenklinik.

Presbyopic Allogenic Refractive Lenticule (Pearl) Corneal Inlay

- By Soosan Jacob
- uses a femtosecond laser– carved allogenic corneal inlay for the treatment of presbyopia
- The PEARL inlay is prepared from a lenticule obtained from small-incision lenticule extraction (SMILE) surgery for between −2.5 and −3.5 D myopia. The lenticule is cut and fashioned into shape and inserted into a pocket within the presbyopic cornea to lie over the coaxially sighted light reflex.
- Prolateness induced by the inlay induces spherical aberration and provides increased depth of focus, thereby improving near vision.
- The small size of the inlay allows peripheral rays to pass through the pupil, maintaining good uncorrected distance vision.

Presbyopic IOLs with Previous Corneal Surgery

- Previous corneal surgeries may have led to an increase in corneal higher-order aberrations (HOAs), however, with small optical zones, decentered optical zones, or a combination of the two. From experience, we all know that presbyopia-correcting IOLs work best in the presence of good corneal optics (ie, low HOAs and small angle kappa/angle alpha).
- If the corneal HOAs are above 0.4 microns hRMS, then the likelihood of delivering a highly satisfactory result is diminished. If the angle kappa is larger than 450 microns (0.45 mm), there is also an increased risk of glare and haloes with refractive and diffractive multifocal IOLs.
- In these previously treated cases, the management is more complicated and the following options exist:
    - Stay ***away*** from multifocal IOLs.
    - Think about monovision or blended vision instead.
    - In Europe and OUS, colleagues are achieving excellent results with pinhole optics IOLs.

    - First regularize the cornea with a topography-guided laser vision correction to recenter or enlarge the optical zone. Then, once the HOAs are sufficiently low, opt for IOL surgery.
    - The sequence can also be reversed: Do the IOL surgery first and then do the topography-guided laser vision correction (TG-LVC).
- Regardless of whether the LVC is performed first or second, there is an increased chance of requiring a top-up LVC enhancement to nail the refractive component.

Hooks, Rings & Retractors

Iris Hooks

- Flexible iris hooks has been introduced by de Juan E and Hickingbotham and Nichamin
- The Iris Retractors are the optimal temporary implant for use with patients who have cataract, contracted pupils or Intraoperative Floppy Iris Syndrome.
- The Flexible Iris Retractors, sometimes referred to as Iris Hooks can be used to dilate the pupil when pharmacological dilation does not work.
- Iris Retractors maintain a safe pupillary diameter during surgery.
- **Use**: small pupil, iris prolapse, and IFIS, they are also useful in the setting of iridoschisis and as a capsular support in cases of zonular loss or subluxed lenses.
- **There are some important pearls for their use:**
    - create a small limbal incision, narrower than a typical paracentesis incision, by not fully advancing your usual side-port blade
    - angle the incision from the limbus down to the pupil margin. this slight downward angle is different than a typical paracentesis when the blade tends to be parallel to the iris or angled slightly up
    - have a sufficient fill of viscoelastic in the anterior chamber
    - you can use either 4 or 5 iris hooks to create a square or pentagonal opening, respectively
    - place all hooks on the cornea first, then begin inserting them into the eye, one by one
    - place one hook around the pupil margin and then slide the retaining collar only part way down the shaft. do not advance to full tension until all 4 hooks are placed.
    - now you can tighten each hook to retract the iris and expand the pupil

CTR: Capsular Tension Rings

- Introduced by → **Hara**, 1991 known as **Equator ring (Closed ring)**
- They used a closed ring made of soft silicone with a groove on its inner surface for the loops of the intraocular lens (IOL). The ring was thought not only to maintain the circular contour of the capsular bag equator, but also to withhold lens epithelial cell (LEC) migration.
- Toshiyuki Nagamoto: Open ring but without holes,1990, PMMA
- Implanted in the first human eye during cataract surgery in **1993** by **Witschel and Legler**
- **Advantages:**

  - Capsular zonular anatomical barrier is partially reformed, so that **vitreous herniation decreased**
  - Taut capsular equator **offers counter traction for all traction maneuvers**, making them easier to perform and decreasing the risk of extending the zonular dialysis
  - The necessary **capsular support** for an in -the-bag centered implant
  - Bag **maintains its shape and do not collapse**, which can lead to proliferation and migration of epithelial cells.
  - Counters progressive contractile capsular force
- **Disadvantages**
  - Significant **compression is required** to implant the ring into the capsular bag because of its larger size. This may stretch the capsulorrhexis and potentially shear zonules by distorting or decentering the bag. Because of this compressive force, CTRs should never be inserted in the presence of an anterior or posterior capsule tear.
  - CTRs may impede aspiration by pinning and trapping cortex in the capsular fornix. For this reason, surgeons should consider using capsule retractors instead of a CTR to stabilize the bag during phaco.
- ***Indications***: trauma, pseudoexfoliation syndrome, previous ocular surgery (eg, vitrectomized eyes), mature/hypermature cataracts, and high myopia. Less common causes of zonular weakness include Marfan's syndrome, homocystinurea, Weill-Marchesani syndrome, microspherophakia, retinitis pigmentosa, lens coloboma, scleroderma, porphyria, hyperlysinemia, and intraocular neoplasms.
- **Various designs**
  - **Standard Morcher CTR** (intraoperative support also possible)
  - **Cionni Modified CTR**
    - To address moderate and profound cases of zonular weakness Dr. Cionni modified the standard CTR, adding the fixation eyelet attached to the central portion of the ring.
    - Sclera Fixation (only be placed after nuclear and cortical removal, so they cannot provide intraoperative support during phacoemulsification.)
    - The ring has different embodiments, having 1 or 2 fixation elements.
  - **Malyugin Modified CTR**
    - to address the microincisional cataract surgery
    - The idea of the Malyugin modified CTR is based on moving the fixation element to the very tip of the ring. This makes device completely retractable into the injector tube, subsequently allowing it to be inserted into the eye in a very controlled manner.
    - The second advantage deriving from the design is that the curved portion of the CTR slides along the equator of the capsular bag during its injection. Thus the risk of perforating the capsular fornix with the tip of the CTR is eliminated.

- **Ike Ahmed Capsular Tension Segments** [**CTSs**]→ 120° of arc length and a 5-mm radius of curvature. Model MR-6D is 9.61 mm in length, and the MR-6E is 0.14 mm in length.
  - Advantage:
    - can be ***implanted without a dialing technique***, which minimizes trauma to an alreadycompromised zonular apparatus
    - can be placed ***after the capsulorhexis and before cataract removal***
    - can be used in cases of a ***discontinuous capsulorhexis, anterior capsular tears, or posterior capsular rents***
- ***Assia' s Capsule Anchor***: designed by **Ehud Assia** from Israel, PMMA intraocular implant, intact ACCC is a prerequisite, two lateral arms of the device are inserted behind the anterior lens capsule whereas the central rod is placed in front of the capsule
- **Henderson CTR** (eight equally spaced indentations of 0.15 mm and an uncompressed diameter of 12.29 mm that is compressible to 11 mm. The main advantage of the Henderson CTR is that it ***allows for easier removal of nuclear and cortical material*** while maintaining equal expansion of the capsular bag)
- **Burkhard Dick**: 8 hydrophobic and 8 hydrophilic ring segments. The CFCRs have a 9.2 mm minimum overall diameter. The CFCRs were inserted using various cartridge systems or a two-folded technique
- **Capsular bending ring (CBR)**
  - Nishi and Menapace in 1996
  - equipped with a rectangular cross-section 0.7 mm in height, and only slightly tumble-polished to preserve the sharpness of the edges.
  - By inducing the capsular at the equator, a barrier is erected at the very origin of LEC migration
- **Geuder injector**
  - manufactured by **Morcher GmbH** (Stuttgart, Germany) and are distributed in the United States by **FCI Ophthalmics, Inc.** (Marshfield Hills, MA)

Timing of CTR Injection

- As late as you can but as early as needed (Ken Rosenthal)
- Prior to phaco
  - Better nuclear stability
  - can be difficult with dense nuclei
  - makes cortical removal challenging
- After phaco and cortex removal
  - Use of temporary support devices help

Injection of CTR

- One must be careful not to snag or tear posterior capsular folds with the leading tip of a CTR during its insertion. Fully expanding the capsular bag with OVD prior to injecting the ring is critical for this reason.
- Brian Little has described the fish tail method of reducing zonular stress when inserting a ring without injector
- Injector has the advantage of introducing the CTR into the capsular bag without excessively stretching the capsulorrhexis. One can either load the ring manually with a reusable metal injector or use a pre-loaded, disposable plastic injector (Morcher GmbH, Stuttgart, Germany; distributed in the United States by FCI Ophthalmics, Inc.). The injector tip should be positioned as far peripherally within the bag as possible in order to minimize lateral displacement of the capsular bag as the ring emerges.

- **Constuction of CTR**
    - CTR is a C-shaped, open ring made of polymethylmethacrylate
    - 12.3 mm (compresses to 10 mm, Morcher 14, used for axial length < 24 mm)
    - 13 mm (compresses to 11 mm, Morcher 14C, used for axial length of 24-28 mm)
    - 14.5 mm (compresses to 12 mm, Morcher 14A, used for axial length > 28 mm).

Capsule Retractors

- **Merriam** first reported use of self-retaining iris retractors through paracentesis openings to hook and fixate the capsulorrhexis However, because the hooked ends are very short and flexible, iris retractors may tend to slip off of the anterior capsular edge during phaco and will not support the equator of the capsular bag.
- **Richard Mackool** designed the "**Capsular Support System**" (Impex, FCI Ophthalmics, Inc., Marshfield Hills, MA) with capsular hooks that are elongated enough to support the peripheral capsular fornix and not just the capsulorrhexis edge . In this way, the retractors function as artificial zonules to stabilize the entire bag during phaco and cortical cleanup. Unlike capsular tension rings, capsule retractors provide much better support in the anterior-posterior direction and do not trap the cortex. This is because each retractor applies only point pressure to the capsular fornix without ensnaring the cortex. MicroSurgical Technologies' (MST; Redmond, WA) disposable nylon capsular retractors that are the preference of this author. They feature a double stranded design that creates a loop at the tip, which is less likely to puncture the equatorial capsule. The Chang modification closes the looped tip enough to prevent it from being ensnared by a CTR during insertion, and shortens the length of the retractor tip
- Capsule retractors can be inserted through limbal stab incisions at any stage including midway through the capsulorrhexis step. By anchoring the bag to the eye wall, the additional anteroposterior support and rotational stability facilitate hydrodissection and nuclear rotation. The selfretaining capsule retractors are also strong enough to center and immobilize a capsular bag that is partially subluxated due to a severe zonular dialysis. They also restrain the peripheral anterior and equatorial capsule from being aspirated and dehisced by the phaco or IA tip.

- As a single strategy for severe zonular deficiency, capsule retractors are significantly more effective than CTRs at preventing posterior capsule rupture. Because CTRs can only redistribute instrument and mechanical forces to the remaining intact zonules, the greater the zonular defect or deficiency is, the less effective a CTR is at stabilizing the bag. However, a CTR can be used in conjunction with capsule retractors, particularly if there is a sizable zonular dialysis. If, after first inserting retractors, the unsupported equatorial regions of the capsular bag tend to collapse inward toward the phaco tip, a CTR can be inserted to distend the equator of the bag to its proper anatomic configuration.
- Although the tip of the capsule retractor is dull, it is possible for the hooks to tear the capsulorrhexis margin during surgery. A key objective is to support the capsular bag without excessive tenting and stretching of the capsulorrhexis. There is a tendency to over tighten the capsular retractors because the tension is initially adjusted with a soft eye. Inserting the phaco tip with irrigation suddenly displaces the nucleus and capsular bag posteriorly, which effectively tightens the retractors further. After inserting the phaco tip, it is therefore important to momentarily assess whether the capsule retractors have become so taut that they tent the capsulorrhexis edge. If so, they should be loosened slightly so that the capsular rim does not tear during phacoemulsification. This is particularly important if the capsulorrhexis diameter is on the small side.

Intraoperative Complications of Cataract Surgery

Answer for Viva question of Complications

- **Retrobulbar hemorrhage**
  - Signs: tense globe, taut lids, resists retropulsion, SCH
  - Goal: decrease IOP to prevent CRAO
  - Management: lateral canthotomy
  - Prevention: blunt needle, topical
- **Perforation of globe**
  - Signs: acute hypotony or acute hypotension
  - Goal: early recognition
  - Prevention: recognize high risk eyes
- **Corneal abrasion**
  - Due to speculum,
  - Prevention: attention to prep, drape, speculum
- **Bridal suture complication**
  - Signs: vitreous under conjunctiva, VH, RD, or hypotony
- **Incision site**
  - Position: too posterior or too anterior
  - Width: too tight or too loose
  - Length: too short or too long
  - Depth: more imp for scleral incision
- **Clear corneal incisions:**
  - ? less forgiving ? high Endophthalmitis rate
  - Cons: burns, need proper length
  - Pro: easier to create, no hyphema, conserve conjunctiva
- **Anterior capsulotomy:**
  - ***Argentina flag sign:***
  - Small opening
- **Hydrodissection**
  - Capsule rupture possible
  - Correct pressure imbalance, depress wound lip
  - Watch for posterior polar cataract
  - **Singh sign for posterior polar cataract:**
- **Descemet's detachment**
  - Signs: visible flap – do not confuse with capsule

- Prevention: careful insertion of tools

- **Iris prolapse**
  - Problem: increased pressure
  - Prevention: speculum, SR suture, flow, wound, vitreous, visco
- **PC rupture**
  - Aggressive hydro
  - Phaco tip induced
  - Nucleus removal – extension of capsular tear, can-opener or rent in CCC
  - Cortex removal
  - Polishing posterior capsule
- ***Management***:
  - Recognise the signsdeepening of AC, loss of followability
  - Stop phaco: cant cut vitreous, infusion will enlarge the hole and vitreous prolapse, prevent deep sixing
  - Assess the size of hole: is it enlarging?
  - Plug the hole with viscoelastics.
  - Is anything left?
    - Nothing:
    - Vitreous:
      - Manage first and throughout cleanup
      - Where is it? Anterior or posterior
      - Does it need Vitrectomy? Dry, bimanual vs coaxial, low flow
      - When to stop? Round pupil, no vitreous in the wound
    - Nucleus:
      - Enlarge incision
      - Viscoelastic: float up remnant, protect endothelium
      - Insert sheet glides
      - Remove remnant without external pressure
    - Cortex:
      - Consider posterior rhexis
      - Low flow low vacuum low infusion
      - Strip towards the hole
      - Manual IA if very large
      - Don’t be aggressive, remove from visual axis only
  - ***IOL options***
    - PCIOL in the bagsmall hole well defined border, no dialing

        - PCIOL in the sulcus
        - ACIOL:
        - SFIOL
        - Aphakic

Retrobulbar Hemorrhage

- **Features**
    - Increasing proptosis
    - Lid ecchymoses
    - Unable to displace globe posteriorly
    - Intraocular pressure elevation
    - Subconjunctival hemorrhage and/or bloody chemosis
- **Mechanism**
    - Puncture or tearing of orbital blood vessel
    - Bleeding into an enclosed area (orbit) raises the orbital pressure which elevates intraocular pressure
    - This compartment syndrome may restrict vascular supply to the optic nerve and globe, resulting in central retinal artery and/or vein occlusion, or optic nerve compression or ischemia
    - Direct injury to optic nerve or compression of the nerve within the optic canal
- **Adverse sequelae**
    - Intraoperatively can cause loss of chamber and increased posterior pressure
    - Loss of Vision
        - Ischemic optic neuropathy or optic nerve compression
        - Loss of vision from vascular injury (central retina artery occlusion, central retinal vein occlusion)
- **Patient Management**
    - If occurs preoperatively, cancel surgery unless hemorrhage is minor/limited
    - If occurs intraoperatively, stop surgery and close incision temporarily if posterior pressure is progressive.
    - Treatment aimed at rapidly lowering orbital and intraocular pressure
        - Serial tonometry to measure success of treatment
        - Digital massage if globe intact
        - IV osmotic agents and aqueous suppressants
        - lateral canthotomy and cantholysis
        - Consider consultation with oculoplastic surgeon for orbital decompression if unable to lower intraocular pressure to acceptable range

Suprachoroidal Hemorrhage

- **Mechanism**
    - Site of hemorrhage likely a bridging blood vessel which crosses the suprachoroidal space
    - Decompression or prolonged hypotony during or following intraocular surgery can lead to choroidal effusion, which can stretch and break bridging blood vessels
- **Risk Factors**
    - Increased age
    - History of glaucoma
    - Axial length >25.8 mm
    - Prolonged hypotony during or following ocular surgery
    - Systemic hypertension
    - Arteriosclerotic heart disease
    - Elevated preoperative intraocular pressure (IOP) with rapid decompression
    - Drugs or conditions which affect coagulation (not true risk factor for hemorrhage, but hemorrhage will be worse in their presence)
    - Nanophthalmos
- **Intraoperative Signs**
    - Patient pain and agitation
    - Increased posterior pressure causing shallowing of anterior chamber
    - Firm eye to tactile pressure
    - Wound gape
    - Iris prolapse, spontaneous delivery of the lens, and expulsion of intraocular contents
    - Loss of red reflex or growing shadow appearing in red reflex
- **Intraoperative management**
    - Immediate closure of wound
        - Suture if not self-sealing
        - Manual compression of incision while awaiting sutures
    - If can't close incision, consider posterior sclerotomy over site of shadow
    - Consider re-operation once intraocular pressure normalized
    - Consider referral to posterior segment surgeon
- **Surgical plan for a patient who is high risk for choroidal hemorrhage**
    - Aggressive IOP control
    - Aggressive systemic blood pressure control preoperatively and intraoperatively
    - Position patient so eye is higher than heart

- Small incision surgery
- Pre-placed sutures if incision > 6 mm
- Minimize operating time
- Avoid hypotony and collapse of anterior chamber during surgery: Consider continuous anterior chamber infusion
- Discontinue anticoagulants preoperatively if approved by PCP
- Discussion with patient during informed consent regarding elevated risk for suprachoroidal hemorrhage and sequelae

Thermal Injury or Phaco Burns

- **Source:** Frictional forces created by the ultrasonic tip vibration causes heating of the phaco tip or needle
- **Dissipation :**
  - Through cool fluid flow around the tip
  - Through the cornea and ocular tissue
- **Intraoperative appearance of a thermal injury**
  - Pre-burn note appearance of non-aspirated lens emulsion ('lens milk')
  - Mild corneal epithelium sloughs at incision site
  - Moderate incision edges gape due to mild tissue shrinkage
  - Severe whitened, friable and absent tissue with significant tissue shrinkage leading to full thickness defect
- **Causes**
  - **Inadequate cooling fluid flow around phaco tip**
    - Lack of irrigation
      - Tight incision compressing infusion sleeve
      - Low or empty bottle
      - Infusion tubing improperly set up or kinked
    - Lack of aspiration
      - Inadequate vacuum level
      - Obstruction by viscoelastic
      - Clogged tubing or tip
  - **Prolonged, continuous use of ultrasound power**
- **How to Avoid?**
  - Test irrigation prior to insertion of phacoemulsification tip
  - Aspiration of some viscoelastic prior to engaging ultrasound power
  - Ensure incision size adequate for phacoemulsification tip

  - Consider adjusting phaco machine settings to minimize ultrasound power (pulse/burst modes, chop technique)
  - Consider continual or frequent external irrigation to incision site
- **Intraoperative Management**
  - Mild nothing if incision is still self-closing
  - Moderate suture closure
  - Severe suture plus patch graft of conjunctiva or sclera, partial thickness flap or relaxing incision. Cyanoacrylate glue may also be considered to seal wound

DMD: Descement Membrane Detachment

- Edge of Descemet membrane may be caught at any incision site by an instrument, intraocular lens (IOL), or OVD which can result in a small or large detachment of Descemet membrane
- **Intraoperative appearance**
  - May be torn but attached with a hinge and rolled-up free edge
  - May be detached completely centrally but attached peripherally
  - If completely detached, may appear as a free floating scroll of clear membrane, can appear similar to anterior capsule
- **Effects:**
  - If small area involved, may have transient localized overlying corneal edema
  - Larger area may have persistent epithelial and stromal edema until the area involved re-endothelializes over time
  - Large Descemet membrane detachment or low endothelial cell density may result in chronic pseudophakic bullous keratopathy.
- **Treatment**:
  - Observation even large detachments may resolve with time
  - Hypertonic saline drops
  - Removal of small free floating scrolls
  - Reattachment by air injection, expansile gas, or suture
  - Keratoplasty (penetrating or endothelial) for persistent corneal edema

TASS: Toxic Anterior Segment Syndrome

- Acute, non-infectious inflammation of the anterior segment of the eye following cataract and anterior segment surgery
- It was initially referred to as ***Sterile Postoperative Endophthalmitis***, accurately termed **TASS by *Monson*** *et al.* in 1992

- **TECDS**: toxic endothelial cell destruction syndrome, When the damage is restricted to corneal endothelial cells
- **Incidence:** not known
- **Causes**
  - ***Bacterial endotoxin residues:*** heat-stable endotoxins of GN bacteria
  - ***Viscoelastic residues:***
  - *Solutions and intraocular fluids:*
  - ***Preservatives****:* benzalkonium chloride, edetic acid, 0.1% sodium bisulfite, methylparaben of lidocaine, 0.01% thimerosal
  - *Medications:*
  - *Intraocular lenses:* Ethylene oxide residue, IOL polishing compound aluminum oxide
- **Clinical Features**
  - within 12-24 hours of the surgery
  - corneal edema which is characteristically “limbus to limbus”
  - nonreactive dilated pupil
  - moderate to severe anterior chamber reaction with cells, flare, hypopyon and especially fibrin
  - increased intraocular pressure
  - Pain is mild to moderate
  - B scan shows clear vitreous
- **Significant overlap between the clinical presentation of TASS and that of infectious Endophthalmitis**
  - *Onset:* Usually, TASS occurs within 12 to 24, endophthalmitis is within 4-7 days of surgery
  - *Pain:* Only mild to moderate pain occurs in TASS
  - *Corneal Edema:* limbus to limbus in TASS
  - *Inflammation:* marked breakdown of the blood-aqueous barrier, flare and significant fibrin formation in TASS
  - *Pupil:* Iris atrophy may occur significantly in TASS, poorly reactive pupil
  - *IOP:* as high as 40 mm Hg to 70 mm Hg in TASS
  - *Cultures:*
  - *B Scan: TASS* does not involve vitreous inflammation generally
- **Treatment**
  - Intraoperative (Immediate recognition of toxic agent): Irrigate anterior chamber with balanced salt solution to wash out all the toxic agent
  - Postoperatively managing from slight to progressively more severe inflammatory reaction

- Have a low threshold for vitreous and/or anterior chamber culture with injection of antibiotics if infection is suspected
- Mainstay is frequent topical corticosteroid drops (prednisolone acetate 1%) Frequent follow-up necessary to gauge response
- Lower IOP with aqueous suppressant drops if elevated
- Progressive steroid use as indicated
    - Sub-Tenons injection of corticosteroid
    - Intravitreal corticosteroid injection
    - Systemic corticosteroids if needed to control inflammation

- If the reaction is mild, there is rapid improvement in signs and symptoms of inflammation. Hypopyon resolves very fast. Within 24-48 hours there is improvement in visual acuity. From hand movement to counting fingers within a day is seen. Patient's vision improves remarkably thereafter. The inflammation usually clears within one to three weeks. Moderate cases take between three to six weeks to resolve. In severe cases, TASS can cause permanent damage.
- Most cases of TASS appear to result from inadequate instrument cleaning and sterilization. ASCRS 2006
    - Specified concentration of the recommended cleaning agent
    - Final rinsing sterile, distilled, or deionized water
    - Single-use brushes should be used and disposed
    - Sterilize per instrument manufacturer recommendations'
    - Avoid flash sterilization

Surgical Trauma Hyphema

- **Source of Hemorrhage**
    - Iris pupillary margin vessels
    - Iris stromal vessels
    - Iris root major arterial vessels
    - Ciliary body vessels
    - Incision related vasculature (limbal vasculature)
- **Consequences**
    - Decreased vision
    - Increased intraocular pressure (IOP) secondary to mechanical obstruction of trabecular meshwork by red blood cells
    - Corneal blood staining in the presence of high IOP
    - Chronic inflammation
    - Posterior synechiae

    - Diffusion of blood into vitreous
- **Management**
    - Intraoperative
        - Temporarily pressurize the globe
        - Tamponade with OVD or air injection into anterior chamber
        - Cautery if source of bleeding identified
    - Postoperative
        - Close follow-up during the early postoperative period with highest risk of rebleeding, activity restrictions
        - Slit lamp biomicroscopic observation, record level/grade of hyphema
        - Monitor IOP
        - Iris immobilization with pharmacologic agents if needed
        - Avoid anti-coagulating agents short term
        - Investigate for coagulopathy
        - Consider sickle cell testing for at risk patients
        - If non-clearing, watch for possibility of late onset ghost cell glaucoma

Microscope induced Light Toxicity

- Photochemical damage to retina and retinal pigment epithelial layers from unfiltered blue and near ultraviolet radiation
- **Causes**
    - Prolonged operating time
        - Reduce operating time
        - Oblique lighting
        - Use pupillary shield
    - High light intensity
        - Reduce light level to only that required for safe view
        - Use a filter to exclude light below 515 nm
- **Clinical Features**
    - Patients may have minimal to severe vision loss depending on location and severity of phototoxicity
    - Paracentral or central scotoma or central vision distortion
    - Retinal exam may not reveal any clinical abnormalities immediately
    - Retina exam may reveal
        - Varying degrees of retina edema and/or pigmentary changes during early postoperative period, usually in a discrete oval pattern in or near macula

        - Varying degrees of pigmentary mottling after early postoperative period

Postoperative Increased IOP

- **Mechanisms**
    - Decreased outflow facility
        - Obstruction by ophthalmic viscosurgical device (OVD)
        - Inflammation
        - Glaucoma suspects and glaucoma patients may be at higher risk
    - Pupillary block with an anterior chamber IOL (AC IOL) in the absence of peripheral iridectomy/iridotomy
    - Aqueous misdirection
    - Hyphema
- **Diagnosis**
    - Patient symptoms
        - May have minimal to no symptoms
        - Pain in and around eye
        - Headache
        - Foggy vision
        - Nausea and vomiting
    - Examine cornea for corneal edema / "steamy" corneal appearance
    - Measure intraocular pressure (IOP)
- **Management**
    - Short term ocular hypotensive agents
        - Topical or oral carbonic anhydrase inhibitors
        - Beta adrenergic antagonists
        - Alpha-2 adrenergic agonists
    - Laser peripheral iridotomy if pupillary block present
    - Side port decompression at the slit lamp
    - Vast majority resolve within days of surgery with medical management only

PCR (Posterior Capsule Rent)

- PCR or PCT
- Any breach in the continuity of the posterior capsular is defined as posterior capsular tear (PCT)

- It may be associated with vitreous loss, cystoids macular edema, uveitis, glaucoma, retinal detachment, vitreous touch syndrome, vitreous wick syndrome, and expulsive haemorrhage.
- **0.7% to 16% of phaco, 2 to 10% of ECCE**
- Potential seriousness is usually determined not by their occurrence per se, but by the way in which they are managed.
- **Risk Factors:**
    - Intrasurgical PCT (planned in PCCC, else accidental)
        - poor visibility
        - during capsulorhexis: small rhexis, discontinuous margin
        - during hydrodissection: capsular block or due to failure to ballotte the nucleus backwards
        - during phaco: learning phase, poor visualization
    - pre-existing PCT
    - spontaneous PCT: hypermaturity, posterior lenticonus intra ocular tumors and posterior polar cataract
- **Four cardinal signs:**
    1. sudden deepening of anterior chamber
    2. momentary papillary dilatation
    3. nuclear does not followed towards the Phacoemulsification tip
    4. nucleus falls away from the phaco tip.
- First tell–tale sign of PCT occurring during hydrodissection is "**Pupil snap sign**"
- **Stages of Surgery and PCR**
    - **PCR with hydrodissection**
        - In non-complex cataract cases as a blow-out of the posterior capsule due to build-up of pressure posterior to the crystalline lens:
        - Injecting too much fluid between lens and posterior capsule
            - Too fast
            - Too long
        - Blocking an escape of fluid to anterior chamber due to a small capsulorhexis
        - In complex cataract cases a rupture may pre-exist:
            - Posterior polaris cataract
            - Iatrogenic capsule tear (e.g., post-vitrectomy)
            - Post-traumatic capsule tear
    - **PCR with sculpting and cracking of the lens**
        - Sculpting too deep:
            - Centrally

            - Inexperience (more common in surgery by residents)
            - When switching from a straight tip to a Kelman (bent) tip
        - Peripherally
            - By making a groove that is as deep central as it is in the periphery (more common in surgery by residents)
    - With cracking of the lens in divide & conquer, damaging the PC with the phaco tip or second instrument
        - With chopping,
            - The phaco tip may be too deep while holding the nucleus
            - One may inadvertently touch the posterior capsule
- **PCR with emulsification and with cortex removal**
    - When emulsifying the lens, especially in brunescent cataracts, the nucleus will tumble and a sharp edge of the nucleus may hit the posterior capsule and puncture it.
    - With positive vitreous pressure, the PC may move anteriorly when emulsifying the last quadrant and the phaco tip may puncture the phaco tip.
    - While trying to grasp some cortex, the posterior capsule may be inadvertently sucked into the aspiration port and a burr in the aspiration port may puncture the posterior capsule.
    - The cortex may be attached very firmly to the posterior capsule and the posterior capsule may be ruptured when trying to aspirate the cortex.
- **PCR with implantation of the IOL**
    - When the bag is not fully inflated with OVD, the IOL may puncture the posterior capsule when implanting the IOL.
    - When aspirating residual OVD that is posterior to the IOL, one may puncture the posterior capsule.
    - When rotating the IOL while the anterior chamber (and lens bag) is not fully inflated, the posterior capsule may rupture.

- **Possible situations after PCR**
    - Posterior capsule tear with hyaloid face intact and nuclear material present
    - Posterior capsule tear with hyaloid face ruptured without luxation of nuclear material into vitreous
    - Posterior capsule tear with hyaloid face ruptured and luxation of nuclear material into vitreous.

- **Management**
    - DON'T PANIC
    - Decrease Bottle height, Aspiration and Vacuum

- **If PCT is identified during early stages of ECCE:**
    - plugged with viscoelastic substance followed by dry aspiration of the remaining cortex
- **PCT with intact hyloid face with nuclear material present:**
    - In cases of small nuclear material viscoelastic is injected to plug the PCT and nuclear material is moved into the anterior chamber with spatula and emulsified with short bursts.
- **Post capsular tear with ruptured hyloid face without luxation of nuclear material into vitreous:**
    - dry AV and aspiration
    - In case of large residual nuclear material: convert to routine ECCE
- **Post capsular tear with ruptured hyloid face with luxation of nuclear material into vitreous:**
    - 0-18%
    - ***Rescuing a partially descended nucleus***
        - Charles Kelman, MD popularized the posterior assisted levitation or "PAL" (Posterior Assisted Levitation) technique in which a metal spatula, inserted through a pars plana sclerotomy, is used to levitate the nucleus into the anterior chamber from below
        - Richard Packard and this author subsequently published our results of using Viscoat (Alcon Laboratories) and the Viscoat cannula to support and levitate the nucleus – the so-called Viscoat PAL technique
        - Once a fragment descends into the mid or posterior vitreous cavity, it is dangerous to blindly fish for it with any instrument. One should abandon the dropped nucleus and concentrate on performing an anterior vitrectomy and removing the residual epinucleus and cortex, while preserving as much capsular support as possible.
    - ***Managing Residual Lens Material***
        - resuming phaco over a temporary scaffold (e.g. Sheet's glide or Agarwal 3piece IOL technique)
        - converting to a large incision manual ECCE.
    - **Bimanual Pars plana Anterior Vitrectomy**
        - MVR Blade recommended by Steve Charles
        - Scott Burk: staining prolapsed vitreous with a triamcinalone suspension to improve visibility is an excellent option
- **Basics of Intraocular lens implantation in PCT**
    - If PCT <6mm / Margins are clearly visible with no vitreous prolapse – PCIOL implantation in the capsular bag may be performed.
    - If PCT >6mm / Margins are not clearly visible– ACIOL
    - If Anterior Rim available: PCIOL in the sulcus

IOLs in setting of Compromised Posterior Capsule

- 3 options
- **In the Bag**
  - Round posterior capsule tear: If there is a small linear tear, you can make a *small* (2-3 mm) posterior capsulorrhexis and place the IOL in the bag.
  - Good zonular support
  - Can use 1-piece IOL
- **In the Sulcus**
  - If irregular or large posterior/anterior tear + ***good zonular support***
    - Optic capture
      - IOL optic in the bag
      - Haptics in the sulcus
      - 3-piece IOL (PC-IOL options)
    - Reverse optic capture
      - IOL optic in the sulcus
      - Haptics in the bag
      - 3-piece IOL
      - Or 1-piece IOL (toric, PC-IOL, PC-IOL/ toric)
  - Irregular or large tear + ***poor zonular support :*** Must fixate the lens outside of the capsular bag— "extracapsular fixation"
    - Sutured IOL
      - **Iris sutured:** Gor-Tex suture (off label), Polypropylene
      - Downsides
        - Need enough iris tissue
        - Corectopia (suture peripherally)
        - Pigment dispersion
      - Upsides
        - Doesn't disturb conjunctiva
        - Small incision
        - Lower risk of endophthalmitis (no external suture/haptic)
      - **Scleral sutured:** Gor-Tex suture (off label), Polypropylene (belt-loop technique using 5.0 polypropylene)
        - Yamane Technique
        - Hoffman Technique: IOL choice: 3-piece IOL, or single-piece PMMA (CZ70BD).

- **In the Anterior Chamber**
  - If there is no zonular support and no capsular bag
  - Least desirable option
  - Endothelial loss
- Power Selection
  - In the bag: Same power
  - In the sulcus: 0.5 D less power
  - In the anterior chamber: AC-IOL calculation

Vitreous Loss & Management

- **Potential adverse consequences associated with vitreous loss**
  - Retina tear/detachment
  - Cystoid macular edema (CME)
  - Endophthalmitis
  - Retained lens material, creating glaucoma and inflammation
  - Vitreous strands to incision
  - Bullous keratopathy and endothelial decompensation
  - Misshapen pupil
  - Secondary glaucoma
- **Intraoperative appearance of vitreous in the anterior segment**
  - Clear, cohesive, egg white-like material
  - Displacement of other structures, iris, capsule, etc.
  - Other structures may move when vitreous is contacted or moved
  - Aspiration may seem less effective if vitreous entrapped in aspiration port
  - May be more easily visualized with intracameral triamcinolone or air
- **Management**
  - Limit amount of vitreous presented in the anterior segment by maintaining a pressure gradient with higher pressure in the anterior chamber
    - Fill anterior chamber (AC) with an ophthalmic viscosurgical devise (OVD) prior to removing irrigating instruments
    - Reduce irrigation flow, avoiding anterior displacement of vitreous
    - Maintain watertight incisions
  - Manual Vitrectomy
    - Cellulose sponge and scissors at incision site externally for diagnosis
    - Sweeping vitreous strands away from incision site using spatula through side port paracentesis

        - Constrict pupil to check for residual strands of vitreous
    - Automated vitrector be knowledgeable of fluidics and mechanics
        - Use infusion anteriorly and cut posteriorly to maintain pressure gradient: Limbal or a pars plana vitrectomy, depending upon the condition, training, and comfort of the surgeon
        - Maintain watertight incisions, often suturing keratome incision and creating second sideport incision
        - Sweep iris surface with spatula or cannula to find hidden strands lying on iris
        - Constrict pupil to reveal strands of vitreous which may have been overlooked
        - Don't cut under iris or into posterior vitreous cavity
        - Consider use of Preservative-Free intraocular triamcinolone to visualize vitreous strands
    - Postoperative Care
        - Subconjunctival corticosteroid injection at procedure's conclusion
        - Indirect ophthalmoscopy for tears or detachments
        - Oral acetazolamide for IOP control if suspect retained viscoelastic
        - High dose topical corticosteroids and non-steroidal anti-inflammatory drugs (NSAIDs) for long duration to reduce chance of CME

Posterior Dislocation of Lens Material

- **Preexisting pathologies and Intraoperative events**
    - Posterior polar cataract
    - Posterior lenticonus
    - Iatrogenic posterior capsule tear during vitreoretinal surgery or intravitreal injection
    - Zonular weakness
    - Broken posterior capsule intraoperatively
    - Prior trauma
- **Precautions to be Taken**
    - Have correct tools available; vitrector, lens loop, adequate viscoelastic
    - Consider local block and place incision where it can be enlarged if needed
    - Large anterior capsulorrhexis through which whole nucleus could be delivered if needed
    - Knowledge of a nuclear handling technique to
        - Avoid multiple lens fragments
        - Support and control entire nucleus without pressure or stresses on posterior capsule

- Attempt to leave posterior epinuclear shell in place
- Prolapse nucleus anteriorly before emulsification using manipulation or ophthalmic viscosurgical devices (OVD)
- Do not over-inflate during hydrodissection to decrease irrigation pressure
- Adjust fluidics to low flow settings
- Consider use of intracapsular tension ring if zonular dehiscence is noted

- **Consequences**
  - Increased inflammation
  - Cystoid macular edema
  - Elevated intraocular pressure (IOP)
  - Decreased vision and/or visual symptoms
  - Retinal detachment
- **Approaches to Remove Nucleus**
  - Stop phacoemulsification while maintaining intraocular pressure
  - Instrument elevation of nucleus and particles through pupil if not too posterior
  - If not proficient with vitreoretinal surgical procedures, close and refer to vitreoretinal specialist after removal of cortex and vitreous from anterior segment. Implant intraocular lens (IOL) when possible to accomplish safely and effectively

Iris Prolapse

- **Consequences**
  - Intraoperative
    - Pupillary constriction
    - Increased atonicity and floppiness of iris
    - Patient discomfort
  - Postoperative
    - Segmental loss of iris tissue, loss of pupil function, aesthetic deformity, glare disability
    - Adhesions to anterior capsule, posterior capsule, pupil distortion
    - Possible iris incarceration in wound increasing risk of wound leak and endophthalmitis
    - CME
- **Causes**
  - Incorrect incision
    - Too posterior, near iris root
    - Too short
  - Excessive inflation of anterior chamber with viscoelastic

    - Floppy iris
        - After pupillary stretch
        - Use of alpha 1-adrenergic antagonists, e.g., tamsulosin (Flomax®)
    - Increased posterior pressure
    - Excessive fluid flow under iris
    - Poor dilation
- **Management**
    - Adequate use of mydriatics pre-operatively
    - Reduce anterior chamber pressure: Remove excessive ophthalmic viscoelastic, through alternate incision if possible
    - Reposition iris with OVD or sweep prolapsed iris from alternate incision
    - Perform peripheral or sector iridectomy
    - Partially close incision if too large
    - Reduce irrigation flow
    - Move to alternate incision site after closing first incision
    - Insert iris restraining devices
    - Miotic injection at conclusion of surgery

Postoperative Complications of Cataract Surgery

Shallow or Flat Anterior Chamber

- **Etiology**
    - Wound leak
    - Pupillary block
    - Aqueous misdirection (ciliary block glaucoma)
    - Suprachoroidal hemorrhage
    - Suprachoroidal effusion
    - Capsular block syndrome
- **History**: Postoperative eye trauma (including eye rubbing), Ocular pain, Decreased vision, Redness, Tearing
- **Clinical Features**
    - Wound leak and choroidal effusion are associated with low intraocular pressure (IOP)
    - Shallow anterior chamber associated with normal or high IOP can be the result of pupillary block, aqueous misdirection, suprachoroidal hemorrhage or capsular block syndrome
- **Evaluation**
    - B scan ultrasound can demonstrate choroidal effusion or suprachoroidal hemorrhage
    - Anterior segment imaging (ultrasound biomicroscopy or anterior segment ocular coherence tomography) can show pupillary or capsular block or evidence of aqueous misdirection
    - Seidel test for wound leak
- **Risk Factors**
    - Pupillary block
        - Uveitis with posterior synechiae
        - Anterior chamber lens without patent peripheral iridotomy
        - Forward displacement of sulcus intraocular lens (IOL)
        - Incorrect orientation of IOL with angulated haptics leading to forward vaulting of optic
        - Iridovitreal synechiae
    - Suprachoroidal hemorrhage
        - Advanced age
        - Poorly controlled hypertension
        - Concomitant glaucoma procedure
    - C. Wound leak/choroidal effusion

            - Poorly constructed wound
            - Poor wound closure
            - Phacoemulsification burn
            - Eye rubbing or trauma
- **Management**
    - Medical therapy options
        - Cycloplegia (atropine) to decrease risk of choroidal effusion
        - If high IOP, aqueous suppression
        - If low IOP with wound leak, pressure patch or bandage contact lens
    - Describe surgical therapy options
        - Laser or surgical peripheral iridotomy for pupillary block (then permanent treatment of underlying etiology)
        - Disruption of anterior hyaloid face with neodymium yttrium-aluminum-garnet (Nd: YAG) laser surgery or vitrectomy for aqueous misdirection
        - Drainage of choroidal effusion or hemorrhage if non-resolving and associated with persistent flat anterior chamber
        - If wound leak present, repair wound with suture or tissue adhesive
- **Complications & Consequences**
    - Peripheral anterior synechiae
    - Corneal decompensation
    - Visual loss
    - Optic nerve damage with sustained elevated IOP
    - Endophthalmitis with wound leak

Corneal Complications

- **Etiology**
    - Acute postoperative endothelial dysfunction/corneal edema due to mechanical trauma, corneal incision burns, prolonged intraocular irrigation, inflammation, retained nuclear particles, elevated intraocular pressure (IOP) or introduction of toxic substances (TASS-Toxic Anterior Segment Syndrome)
    - Late endothelial dysfunction due to retained nuclear particles in the angle
    - Vitreocorneal adherence and persistent corneal edema after complicated extracapsular cataract extraction or phacoemulsification
    - Descemet membrane detachment
    - Suboptimal lens choice (Iris clipped or closed loop ACIOLs) or poorly positioned IOLs
- **Pertinent history**

- More common in patients with underlying corneal endothelial dysfunction such as Fuchs dystrophy
- Blurred, "foggy" vision worse in the morning than evening
- If corneal edema significant with associated bullous keratopathy, symptoms include foreign body sensation, epiphora

- **Clinical features**
  - Descemet folds
  - Corneal clouding
  - Microcystic edema
  - Subepithelial bullae
- **Risk Factors**
  - Fuchs dystrophy
  - Complicated cataract surgery with prolonged surgical time or vitreous loss
  - Phacoemulsification techniques with less control of dispersed ultrasound energy
  - Closed-loop or rigid anterior chamber IOL
  - Phacoemulsification of brunescent cataract with prolonged emulsification time
- **Medical Management**
  - Frequent topical corticosteroids and, topical hyperosmotic agents. Corneal edema generally resolves within 4-6 weeks.
  - Aqueous suppressants for elevated intraocular pressure
  - Bandage (therapeutic) contact lens if bullae are symptomatic
- **Surgical Management**
  - Penetrating keratoplasty or endothelial keratoplasty if edema is not resolving and patient is symptomatic after appropriate waiting period after surgery (several months)
  - Removal of retained lens fragments

Wound leak or Filtering bleb

- **Etiology**: Wound leak with filtration of aqueous through the wound
- **History**
  - May be asymptomatic
  - Possible symptoms: irritation, excessive tearing, blurred vision, contact lens intolerance, pain
- **Clinical features**
  - Depending on amount of wound leak, anterior chamber may be shallow or fully formed
  - Hypotony

    - Wound will be seen to leak after application of fluorescein
    - If a scleral wound is buried under conjunctiva, an inadvertent filtering bleb may form
    - Chronic wound leaks are associated with fistula formation and possible epithelial downgrowth
- **Risk factors**
    - Poorly constructed wound
    - Poor intraoperative wound closure
    - Poor patient wound healing
    - Vitreous or iris incarceration
    - Phacoemulsification burn
    - Eye rubbing
- **Medical management**
    - Pressure patching or use of bandage soft contact lens
    - Suppression of aqueous production (with carbonic anhydrase inhibitors or beta-adrenergic antagonists)
    - Stimulation of wound healing by decreasing topical corticosteroids and nonsteroidal antiinflammatory drugs
- **Surgical management**
    - If there is a significant wound leak with shallow or flat anterior chamber, obvious wound separation, iris prolapse, or no improvement with medical management within 24-48 hours, the cataract wound should be revised.
        - The wound should be sutured closed
        - Consider use of tissue adhesive in selected cases
    - Techniques to eliminate inadvertent bleb formation vary considerably and consist of procedures to enhance inflammation in the wound and seal the leak by cicatrization of the bleb
- **Complications**
    - Complication of decreasing corticosteroids: increased anterior chamber inflammation
    - Complication of wound revision: infection, induced astigmatism (prevented by avoiding tight suture closure)
    - Complication of bleb cicatrization: conjunctival buttonhole
    - Disease related complications: Infection, Hypotony maculopathy, Prolapse of uveal tissue through wound, Astigmatism, Contact lens intolerance, Corneal dellen, Choroidal effusion, Blurred vision

Postoperative Inflammation after Cataract Surgery

- **Etiology**

    - Low-virulence bacterial pathogens: Propionibacterium acnes, Staphylococcus epidermidis
    - Retained lens material
    - Under-treatment of surgical trauma
    - Mechanical trauma from an intraocular lens (IOL) due to lens design or incorrect placement
    - Exposure to contaminated instruments/fluids intraoperatively or IOL can cause toxic anterior segment syndrome (TASS)
    - Uveitis: initial presentation of endogenous or exacerbation of preexisting
- **Clinical Features**
    - In delayed endophthalmitis, infection begins as low-grade inflammation which is transiently responsive to corticosteroids, but returns or persists when the medication is tapered
        - Later, granulomatous keratic precipitates may appear on the corneal endothelium and the IOL surface
        - White plaques are commonly found on the capsular bag in cases of *Propionibacterium acnes*
    - In cases with retained lens material, granulomatous uveitis is present often with increased intraocular
      pressure (IOP) and corneal decompensation
- **Tests**
    - If any suspicion of endophthalmitis, aqueous and vitreous cultures should be taken
    - If capsular plaques are present, an attempt should be made to culture this material
    - Gonioscopy and/or ultrasound biomicroscopy, to detect lens fragments in the angle/ sulcus and confirm IOL malposition
- **Risk factors**
    - Patients with history of uveitis
    - Complicated cataract surgery (e.g., vitreous loss)
    - Improper cleaning/sterilization of instruments
- **Differential Diagnosis**
    - Delayed endophthalmitis
    - Uveitis due to other etiologies
    - Retained lens fragments
    - TASS
    - Uveitis-Glaucoma-Hyphema (UGH) syndrome secondary to IOL design or poor position
- **Medical Management**

  - If infection not suspected and no significant retained lens material: topical corticosteroids, non-steroidal anti-inflammatory drugs and cycloplegics, ocular IOP lowering drops if needed
  - Sub-Tenons corticosteroids
- **Surgical Management**
  - If infection suspected
    - intravitreal/intracapsular injection of vancomycin for treatment of *Propionibacterium acnes*
    - Removal of IOL and lens capsule may be required
  - Retained lens fragments causing significant inflammation should be removed
  - Intraocular lenses causing chronic inflammation should be explanted, repositioned, or fixated

Vitreous incarceration in Wound

- **Etiology**
  - Migration of vitreous through the pupil with adherence to the wound
  - Usually occurs in setting of posterior capsule rupture, but may also occur with an intact capsule in the setting of zonular dehiscence
- **Clinical Features**
  - Vitreous strand seen on slit lamp exam extending to main wound or paracentesis site
  - Pupil often peaked
- **Risk Factors**
  - Incomplete removal of vitreous from the anterior segment during surgery
  - Posterior capsule tear
  - Zonular dialysis
- **Medical Management:** Corticosteroid and non-steroidal anti-inflammatory drug (NSAID) drops for secondary cystoid macular edema (CME)/inflammation
- **Surgical Management**
  - Nd: YAG laser for lysis of fine vitreous strands
  - Anterior or posterior vitrectomy
    - If considerable vitreous is incarcerated in the wound
    - If there is associated CME or uveitis unresponsive to medical or laser surgical therapy.
- **Complications**
  - Chronic inflammation
  - CME

  - Cosmetic pupil deformity
  - Glare symptoms
  - Endophthalmitis
  - Retinal tear or detachment
  - Corneal decompensation

Induced Astigmatism

- **Etiology**
  - Cataract incision (longer and more anterior incisions induce astigmatism)
  - Tight sutures causing steepening in that meridian
  - Corneal wound burn
  - Incorrect axis of limbal relaxing incision performed at time of cataract surgery
  - Tilted implant due to malposition or compromised zonules/capsular bag
  - Incorrect axis of toric intraocular lens (IOL)
- **History**
  - Blurred vision unless optical correction in place
  - Toric lens malposition may be noted immediately, or the lens may rotate later in the postoperative period
- **Clinical features**
  - Steep cylindrical axis points to the tightest suture
  - Corneal striae may emanate from tight sutures
- **Risk factors**
  - Tight sutures or wound burn
  - Wound gape if suture tension is unevenly distributed
  - Inattention to precise toric IOL alignment and placement of limbal relaxing incisions; careful preoperative planning and upright preoperative marking to identify cyclotorsion are essential
- **Medical Management**
  - Eyeglasses
  - Contact lenses
- **Surgical Management**
  - Suture lysis
  - Astigmatic keratotomy
  - Limbal relaxing incisions
  - Photorefractive keratectomy (PRK), laser in situ keratomileusis (LASIK)
  - Repair of a wound dehiscence

- Reposition tilted IOL or rotate misaligned toric lens

Posterior Capsular Opacification

- Physiological postoperative consequence of an uneventful uncomplicated extracapsular cataract surgery
- Referred to as 'secondary cataract' or '**after cataract**', develops over the clear posterior capsule a few months to a few years
- The term “after-cataract” should be preferred over “capsule opacification”, since the capsule itself remains transparent

Etiopathogenesis

- In the normal crystalline lens, the LECs are confined to the anterior surface at the equatorial region and the equatorial lens bow. This single row of cuboidal cells can be divided into two different biological zones
- The **anterior-central zone** (corresponding to the zone of the anterior lens capsule) consists of a monolayer of flat cuboidal, epithelial cells with minimal mitotic activity. In response to a variety of stimuli, the anterior epithelial cells **("A" cells)** proliferate and undergo fibrous metaplasia. This has been termed "pseudofibrous metaplasia" by Font and Brownstein.
- **E cells** migrate posteriorly along the posterior capsule and often forms large balloon like bladder cells, known as **Wedl cells**. These are clinically termed as **Elschnig pearls**. Each pearl represents the failed attempt of epithelial cell to differentiate into a new lens fiber.
- E cells are also responsible for a dumb bell dough-nut-shaped opacification, known as **Soemmering’s ring.** The Soemmering's ring, a dumb-bell or donut shaped lesion that often forms following any type of rupture of the anterior capsule, was first described in connection with ocular trauma. The pathogenetic basis of a Soemmering's ring is rupture of the anterior lens capsule with extrusion of nuclear and some central lens material.
- Can be in form of **PCO/ ACO/ ILO**

Incidence & Assessment

- As high as 50% to as low as <5%
- Presence or absence of PCO within the central visual axis
- Comparing the neodymium:YAG (Nd:YAG) capsulotomy rates
- PCO-induced loss of contrast sensitivity
- **POCOman software:**
- **EAS-1000 system** (Scheimpflug videophotography)

Risk Factors

- **Nonmodifiable**
    - Age: younger individuals at a higher risk
    - At the 1-year follow-up, diabetic patients had significantly severe PCO
    - Myopia
    - hydrophobic acrylic IOLs ??
    - myotonic dystrophy
    - retinitis pigmentosa
    - traumatic cataracts
- **Modifiable Surgical Techniques**
    - **Continuous Curvilinear Capsulorhexis:** fusion between the edge of the continuous curvilinear capsulorhexis to the posterior capsule, forming a Soemmering's ring. This ring provides a closed environment, which restricts the migration of the LECs toward the central posterior capsule
    - **In-the-Bag Fixation:** primarily to enhance the IOL optic barrier effect, reducing the incidence of central PCO
    - **Anterior Capsule Overlap of IOL Optic:** IOL optic keeps the anterior lens epithelium away from the posterior capsule. This would decrease the incidence of migration of the anterior LECs behind the IOL optic.
    - **Cortical Cleaving Hydrodissection:**
    - **Hydrodissection Combined With Rotation:**
    - **Cortical Clean Up:**
    - **Bag-in-the-Lens Implantation:**
    - **Polishing (Scraping) the Anterior Capsule**

IOL Factors

- **IOL Design**
    - **Plate-haptic versus Loop-haptic IOLs:** high rate of ACO/ PCO in plate → lens tilt, Z syndrome and decentration
    - **Single-piece versus Multipiece IOL Design:** No statistical difference
    - Round optic edge versus sharp optic edge IOL optic design: sharp optic edges of the IOL appeared to induce contact inhibition of migrating LECs
    - **Haptic Designs & Angulation:**
    - Accommodating IOL: increase PCO
- **IOL material**
    - **Biocompatibility:** PMMA IOL, silicone IOL and AcrySof IOL, it was found that all three IOLs were sufficiently biocompatible for uvea. For capsular compatibility, AcrySof was better.

    - **Bioadhesive IOL Materials:** Bioactive materials are those that allow a single LEC to bond both to the IOL and the posterior capsule i.e. acrysof lens prevent PCO more than PMMA and silicone IOLs, which are biocompatible but also bioinert. Hydrophobic acrylic material binds more firmly to fibronectin, a plasma protein that is also secreted by LECs, compared with PMMA, silicone and hydrophilic acrylic materials.

Treatment

- Nonsurgical Nd:YAG laser capsulotomy
    - The need for performing capsulotomy depends on the patient's functional impairment of vision, discomfort, demand and the presence of associated risk factors such as high myopia, history of retinal detachment, high risk of cystoids macular edema and only functioning eye.
    - A size that is larger than the pupil diameter under scotopic conditions may prevent disturbances of vision such as monocular diplopia
- **Prevention of posterior capsule opacification (PCO):** SIX Important factors given by **David J Apple**
    - **Surgery-related factors** that help in the prevention of PCO
        - **Hydrodissection-enhanced cortical clean-up**
            - Dr I Howard Fine: cortical cleaving hydrodissection
            - tenting up of the anterior capsule during subcapsular (or cortical cleaving) hydrodissection
        - **In-the-bag IOL fixation**
        - **Performance of a capsulorrhexis slightly smaller than the diameter of the IOL optic.**
    - The same studies helped in the definition of three **IOL-related factors** for PCO prevention.
        - **Use of a biocompatible IOL to reduce stimulation of cellular proliferation**
        - **Enhancement of the contact between the IOL optic and the posterior capsule**
        - **An IOL with a square truncated optic edge.**

Pharmacological Prevention of Posterior Capsule Opacification

- Antimetabolites (such as methotraxate, mitomycin, daunomycin, 5-FU, colchicine, and daunorubicin)
- Anti-inflammatory substances
- Hypo-osmolar drugs
- Immunological agents

- **Sealed capsule irrigation of maintaining postoperative capsular bag transparency:** In dealing with capsular contracture or after-cataract formation, the **Perfect-Capsule**, developed by **Anthony Maloof**, may be a significant breakthrough. By sealing the capsule, irrigated sterile water will produce hypotonic lysis of the lens epithelial cells and may be able to provide an acellular capsule such that capsular contracture and aftercataract formation can be avoided in the future.

Anterior Capsular Fibrosis & Phimosis

- **Etiology**: Anterior capsule opacification (fibrosis) and/or contraction (phimosis)
- **History**:
    - May be asymptomatic
    - Decreased vision when capsular phimosis results in intraocular lens (IOL) decentration, tilt, or extends into visual axis
    - Glare
    - Sensation of peripheral cloud or haze
    - Refractive shift with change in effective lens position
- **Clinical features**
    - Anterior capsular opacification and variable amount of capsular contraction
    - Zonular traction and potential weakening
    - IOL subluxation or tilt
    - Poor visibility of the peripheral retina
- **Risk factors**
    - Small capsulorrhexis
    - Abnormal or asymmetric zonular support
    - Pseudoexfoliation
- **Management**: Relaxing incisions in the anterior capsule may be created radially with a neodymium yttrium-aluminumgarnet (Nd: YAG) laser

IOL Decentration & Dislocation

- **Etiology**
    - Asymmetric haptic placement with one haptic in the capsular bag and the other in the sulcus
    - Posterior capsular tear
    - Amputated or damaged haptic
    - Broken intraocular lens (IOL) fixation suture
    - Eccentric, excessively large, or torn capsulorrhexis
    - Insufficient zonular support

    - Irregular fibrosis of the capsular bag
    - Implantation of IOL with insufficient haptic length in ciliary sulcus
- **Epidemiology**
    - More common in patients with weak zonular fibers due to pseudoexfoliation syndrome or trauma
    - May be associated with axial myopia and a large anterior segment
    - Potentially more symptomatic in patients with multifocal lens implants
- **Symptoms**
    - May be asymptomatic
    - May complain of severe glare, diplopia (monocular) and reduced vision
    - If the IOL dislocates posteriorly, patients will note sudden blurred vision
- **Clinical features**
    - Refractive error associated with change in effective lens position
    - In symptomatic patients, the edge of the IOL is typically seen within the undilated pupil
    - In cases of late dislocation, the entire IOL-capsule complex may be displaced into the vitreous
- **Risk factors**
    - Pseudoexfoliation syndrome or any condition with progressive loss or weakening of zonule
    - History of trauma or posterior segment surgery
    - Complicated intraoperative course with loss of zonules or capsular rupture
    - Poorly dilating pupil with uncertain placement of IOL haptics during surgery
- **Medical management:** Use of pilocarpine or brimonidine to keep pupil constricted so edge of IOL is no longer in visual axis
- **Surgical management:**
    - Surgical correction may be more difficult after YAG capsulotomy
    - Place both haptics in capsular bag if one is in the sulcus
    - If zonular fibers are intact, consider reposition of IOL into ciliary sulcus: One-piece acrylic lenses should not be placed in the sulcus due to the potential for iris chafing and inflammation
    - If zonule is compromised, iris or scleral fixation may be used to secure and center the implant
    - The IOL may be removed and replaced with either an anterior chamber intraocular lens (ACIOL), a sclerally fixated posterior chamber intraocular lens (PCIOL) or an iris-fixated IOL

IOL Glistening

- Fluid filled micro vacuoles that form with in the IOL optic when IOL is in an aqueous environment
- PMMA, Silicone hydrophilic, hydrophobic acrylic
- **2 theories for the formation of glistening**
  - **Microvoid theory**
    - Microvoids can be found within network of polymers depending on their architectural structure. water is absorbed which remains invisible, because it is in form of water vapor → detaches from the surrounding polymer and accumulates in a void (phase separation) to visible water drops. sparkling appearance of fluid-filled vacuoles (thus, the term Glistening).
  - **Theory of Impurities**
    - slow moving hydrophilic impurities from aqueous to IOL. segregate in to polymers voids, which create osmotic pressure difference – leads to influx of water in to voids.
- **Grading of Glistening**
  - **Miyata Grading system**: high magnification with full dilated pupils, amount of glistening -0-50-100-200corresponding grade 0-1-2-3.
  - Semi quantitative Slit lamp grading (10*2 mm)
    - Trace fewer than 10
    - 1+ 10 to 20
    - 2+ 20 to 30
    - 3+ 30 to 40
    - 4+ > than 40
  - Scheimpflug Photography (pentacam) Grading
- **Factors influencing on glistening**
  - Effect of temperature: Glass Transition time (Tg)
  - Manufacturing technique: Cast molded technology made lenses have higher tendency to have glistening due to incomplete polymerized chain reaction in mold
    - cast molding: Alcon, Matrix, Hydromax
    - lath cutting: Sensor, Hoya, Bausch Lomb, Aurolab, OII
  - Packaging material
  - Break down of B-A-B
  - Dioptoric power IOLs
- Progression of glistening
- **Effect on visual function**
  - Grade 1 & 2: no statistically significant effect on Visual acuity, Contrast sensitivity, Glare & wave front analysis

- Grade 3+ or 4: borderline correlation with high spatial (12cycle/degree) contrast sensitivity observed.

- In hydrophobic IOLs, glistening are more in high Tg Value IOLs, cast molded IOL, Acrypack packing material, more with 10% saline as compare to 0.9% saline, surgery with high BAB disturbances.

Refractive Surprise

- **Causes (Jones 2007)**
  - Preoperative factors
    - Incorrect biometry (axial length measurement or keratometry readings)
    - Improper lens power calculation due to use of inaccurate data or imperfect predictive power of formula
    - Prior refractive surgery
    - Manufacturing defects or mislabeled intraocular lens (IOL), rare
  - Intraoperative causes
    - Use of incorrect implant
    - Intraocular lens (IOL) inversion or improper placement in sulcus
  - Postoperative conditions
    - Capsular block syndrome
    - Shallowed anterior chamber
    - Instability or change in position of IOL
- **Risk factors**
  - Simultaneous keratoplasty or retinal detachment repair
  - Prior refractive surgery
  - Staphyloma or extremely short/long eyes
  - Dense cataracts with unreliable measurements
  - Failure of surgeon to confirm proper IOL selection in operating room
- **Management**
  - **Intraocular: IOL Exchange, Piggyback IOL**
  - **Extraocular: LASIK, Surface Ablation, CK, LRI**
- **IOL Exchange**
  - If error in lens calculation is known, IOL XC is viable option
  - Challenging with higher complication rate
- **Laser refractive surgery**
  - Special set-up required or have to co-manage with other surgeon
  - Added cost

  - Many surprises are hyperopic and hyperopic LASIK-PRK is not as predictable
  - Wait 3-4 months after cataract surgery to perform LASIK
- **Piggyback IOL**
  - Best for cases with spherical error
  - Collamer or silicone 3-piece IOL with smooth anterior surface
  - Never piggyback an acrylic lens over another acrylic lens
  - can correct error in relatively short period after surgery
  - works well for relatively large errors
  - no need to worry about corneal problems like dry eye etc.
  - for myopic error: multiply 1.1
  - for hyperopic error: multiply 1.4

Visual Disturbances after Cataract Refractive Surgery

- Two types: Entoptic Phenomenon and Dysphotopsias
- **Entoptic Phenomenon**
  - From the Greek "ento", "within," and "optic", "visual," entoptic phenomenon are visual effects whose source is within the eye itself.
  - They are most commonly seen as peripheral or central light flashes (occasionally referred to by the patient as flickering) and are usually a result of partial peripheral or central vitreous collapse that causes traction on the retina, resulting in the perception of light without any light stimulus. The flashes occur with the eye closed in complete darkness when the head or eye is moved quickly from side to side (or up and down).
  - It has nothing to do with the IOL except that it frequently occurs immediately after cataract surgery because the IOL occupies a much smaller volume than the crystalline lens, resulting in a larger posterior compartment for the same original volume for the vitreous body.
- **Dysphotopsias**
  - A general term that indicates unwanted *optical* phenomenon seen by the patient. It does not include entoptic phenomenon.
    - **Negative dysphotopsia**
    - A dark, temporal crescent that gives the impression of a shade over the temporal region of patients' vision, normally seen in photopic or high mesopic conditions. It is exaggerated by pupil constriction and reduced by dilation.
    - Treatment
      - Remove nasal overlapping capsule.
      - Reverse optic capture, or

- Exchange with silicone IOL. Rounded edge optics are no longer available in the USA.

- **Positive dysphotopsias**
- Unwanted optical images including halos, glare, fog, light scatter, reflections, steaks, starbursts, rings, monocular double vision, crescents and wobbling, jiggling, wiggling, or shimmering images.
- **Causes**
  - Cause from poor patient optics when Chord Mu >0.6 mm or HOA RMS WE > 1.0 µm. ***Do not use diffractive multifocal IOL.***
  - Cause from IOL optics
    - ✓ Diffractive optics: Glare in the form of "snowballs," "halos," "streaks," or "starburst". The only treatment is ***exchange for monofocal IOL***.
    - ✓ Truncated edge (square): IOL edge reflection at nighttime and daytime arcuate flashes. Treatment is exchange for Round edge optic IOL.
  - Pseudophakodonesis (unstable fixation of IOL): Give a few weeks to stabilize. If IOL → exchange IOL. If capsule → capsular tension ring (CTR).

Cornea Modulations in Refractive Surprise

- Multifocals, diffractive, and EDOF IOLs are more sensitive to refractive error, especially astigmatism. 0.75 D of astigmatism can cause reduction in visual quality and performance even with monofocals, but more with multifocals.
  - Correct sphere to within 0.25-0.30 D of emmetropia
  - Astigmatism up to <0.75 D tolerated, but there are exceptions.
  - Early postop: Adjust toric IOL (**Berdahl-Harden Astigmatism Fix Calculator**)
- **Limbal Relaxing Incisions (LRIs)**
  - Helpful for <1.25 D mixed astigmatism
  - Peripheral relaxing incision: Avoid going too central <8 mm; it causes coma.
  - Donnenfeld or Nichamin nomograms at 11 mm ~600 microns typically
  - LRIs excellent for astigmatism <1 D (0.5-1.0)
  - Single incisions are often sufficient.
  - Can combine with cataract extraction (CE) or after CE
  - Femtosecond LRIs are very helpful for astigmatism <1 D.
  - Can make open or closed incisions and titrate closed incisions postop
- **PRK/LASIK**

- Helpful for astigmatism and sphere >1 D
- Mini PRK 7-mm epithelial removal diameter
    - 25% quicker recovery
    - Less persistent epithelial defect risk
    - Less discomfort
- PRK-LASIK: Do lens trial prior to surgery.
    - Trial lenses In the lane works great to demonstrate the improvement.
    - Soft contact lens trial
    - Consider a temporary spectacle lens if unsure.
    - Test level of trial satisfaction *prior* to PRK/ LASIK.

Complex Cases

Diabetes Mellitus Patient and Cataract Surgery

- **Effect of Diabetes Mellitus**
  - Diabetes mellitus hastens cataract development
  - Neovascularization of the iris and associated complications
    - Poorly dilating pupil
    - Neovascularization of the angle
    - Posterior synechiae development
    - Spontaneous hyphema and/or bleeding during cataract surgery
  - Diabetic macular edema changes preoperative axial length measurements for IOL
- **Increased Risk for**
  - Neovascular glaucoma with hyphema
  - Worsening of retinopathy with vitreous hemorrhage
  - Clinically significant macular edema
  - Impaired corneal epithelialization
- **Steps to Reduce Operative Risk**
  - Pre-operative blood sugar control
  - Careful preoperative slit-lamp biomicroscopic examination including gonioscopy (when indicated) to detect iris neovascularization
  - Consider pre-operative evaluation by retinal specialist for treatment of diabetic retinopathy with laser or injections or combined pars plana vitrectomy with endolaser
  - Topical steroids and nonsteroidal anti-inflammatory drug agents (NSAIDs) preoperatively and postoperatively as needed
  - Silicone intraocular lenses should be avoided in diabetic eyes at high risk for subsequent vitreous surgery in which silicone oil might be injected
  - Pre-operative optical coherence tomography (OCT), fluorescein angiography, or both should be considered for clarification of macular pathology
- **Implications on Output**
  - Accelerate the progression of diabetic retinopathy
  - Trigger the development of rubeosis, particularly in the setting of significant retinal nonperfusion and posterior capsule rupture
  - Increased posterior capsule opacification
  - Aggressive treatment of postoperative inflammation to reduce the risk of diabetic macular edema

Small Pupil and Phacoemulsification

- **Importance of Pupil size**
  - Increases visualization of operative field
  - Allows normal sized capsulorrhexis
  - Easier cortical removal
  - Reduces complications
    - Capsule rupture and vitreous loss
    - Damage to iris
- **Preoperative factors causing Small Pupil**
  - Pseudoexfoliation
  - Diabetes mellitus
  - Chronic miotic therapy
  - Synechia from previous inflammation
  - Alpha 1-adrenergic antagonists (e.g., tamsulosin, (Flomax ®))

Techniques for manipulation of the pupil

- Pharmaceuticals:
  - phenylephrine 10% and cyclopentolate 2%
  - preoperative nonsteroidal anti-inflammatory agents (NSAIDs), such as flurbiprofen sodium 0.03%
  - intracameral preservative-free epinephrine 1:10,000
- Viscoadaptive agents
  - Healon 5
  - inject viscoelastic in order to disrupt the iridocapsular adhesions.
- Instrumentation
  - retract the proximal portion of the pupil through the incision with the **sleeve**
  - **Stretch pupilloplasty: second handpiece** in such a way as to stretch the pupil in advance of the phacoemulsification tip
  - **portion of the lens** may be manipulated through the pupil to maintain the pupil in a semi-dilated state
  - **Beehler pupil dilator** (Moria #19009) is uniformly applicable in the presence of small pupils
- Pupil dilating hooks and expansion rings
  - **iris hooks** as described by McReynolds.
  - **Mackool** has designed ***self-retaining titanium hooks***
  - **De Juan** has designed ***disposable nylon hooks*** with an adjustable silicone retaining sleeve that can be used through smaller paracentesis

- ***Hydroview Iris Protector Ring*** (Grieshaber) forms a compressed oval in its dehydrated state, expands with hydration, and captures the pupillary margin by means of flanges
- **Morcher Pupil Expander Ring** Type 5S is a solid polymethylmethacrylate (PMMA) ring
- The **Perfect Pupil** (Becton-Dickinson) represents a new and effective option for both maintaining mydriasis and protecting the pupillary margin during surgery. This polyurethane device features a 7mm internal diameter
- **Malyugin ring** (Microsurgical Technology (MST). This ring is supplied with a disposable injector that compresses the ring to allow its insertion and then its controlled expansion within the eye.
    - Boris Malyugin
    - square shaped, transitory implant with four circular 'scrolls" that holds the iris at equidistant points
- **Agarwal Modification of the Malyugin Ring:** 6-0 polyglactic vicryl suture in the leading curl of the ring and tied a knot. The ring is then injected in the pupillary plane with the leading curl touching the iris margin at 6'o clock

Compromised Cornea and Cataract Surgery

- **Surgical challenges**
    - Compromised visualization during surgery
    - Prolonged postoperative corneal edema
    - Pseudophakic bullous keratopathy (PBK)
- **Care to be taken**
    - Minimize the amount of phacoemulsification energy
    - Protect the corneal endothelium
        - Pachymetry and endothelial cell counts may be used to help define risk of PBK
        - Use of dispersive or visco adaptive OVD
        - Reapplication of OVD during surgery
        - Consider use of scleral tunnel to minimize Descemet membrane trauma
    - Poor multifocal IOL candidates
        - Decreased contrast sensitivity
        - Emmetropia less likely after PK or endothelial keratoplasty
- **Long Term Implications**
    - Potential for long-term PBK despite uncomplicated cataract surgery
    - Some patients may achieve a satisfactory post op outcome even in the presence of early corneal edema preoperatively

  - Consider mild myopic refractive target if anticipating additional corneal procedure (endothelial keratoplasty)

- **Basement Membrane Dystrophy, Salzmann Nodules, Pterygia, and Ocular Surface Disease**
  - Can create subtle or overt irregular astigmatism
  - IOL calculation errors
  - Dissatisfied patients postop due to “imprecise vision”
  - Train staff to spot irregular keratometry before dilation. Surgeons should view such corneas before dilation to identify ocular surface disease and corneal pathology.
  - Remove pathology before cataract extraction (CE).
  - Aggressively treat dry eye and ocular surface diseases to allow for more accurate keratometry and safer surgery.
  - If a keratectomy is performed to remove corneal pathology, allow a minimum of 6 weeks to then remeasure keratometry for IOL calculations.

- **Fuchs Dystrophy and Endothelial Compromise**
  - Scleral incision is not an arcane concept. More protective of the endothelium than standard clear cornea incisions.
  - Use dispersive viscoelastics.
  - When in doubt, opt for CE alone. The cornea can be fixed later if needed.
  - Preop pachymetry and cell counts can be helpful for creating a risk-analysis for corneal decompensation, counseling patients, and for medicolegal protection.
  - Use low-energy, low-flow, and in-the-bag emulsification techniques.
  - If moderate or high risk for corneal decompensation, aim −1.00 to −1.50 more myopic than final intended refraction as Descemet-stripping endothelial keratoplasty (DSEK) creates a hyperopic shift.

- **Keratoconus**
  - Toric IOLs can be of great value if reasonable congruity of axis is established via manual keratometry, automated keratometry, and topography.
  - Must use scleral incisions. Clear cornea incisions can act as a limbal relaxing incision “on steroids” and create significant shifts in astigmatism axis and magnitude.
  - Do not use toric IOLs if rigid gas permeable contact lenses are a consideration postop.

- **Penetrating Keratoplasty (PK)**
  - Triple procedure (PK, extracapsular cataract extraction, IOL) is becoming much less common.

  - Perform PK alone in the majority of cases, even if cataract is present.
  - After sutures are out in 12 to 18 months, CE with toric IOLs is a reliable way of reducing astigmatism and fine-tuning the final refractive error.
  - Maximally protect the endothelium with a scleral incision and dispersive viscoelastic.
  - Preop specular microscopy is of great value to identify grafts at risk for corneal decompensation.
  - If decompensation of the PK is a likely possibility, plan −1.00 to −1.50 more myopic with CE than the final intended refraction in case DSEK over the PK is needed.

- **Post-Refractive Surgery (RK/LASIK)**
  - Challenging IOL calculations
  - For RK, use a scleral incision to minimize the risk of intersecting with an RK incision (especially in 16-incision RK, where there is "no room" between incisions). Intersecting with an RK incision can create unpredictable, large astigmatic swings and irregular astigmatism.
  - For LASIK, obtain historical data if at all possible.
  - Use the American Society of Cataract and Refractive Surgery online calculator to facilitate IOL calculations.
  - Consider utilizing multiple methods to predict corneal refractive power (manual keratometry, automated keratometry, topography: Nidek, Pentacam, HAZ).
  - Carefully advise patients on the difficulties with IOL calculations, the potential for refractive surprises, and the possible need for IOL exchange, piggyback IOL, or laser refractive surgery after CE.

Intraoperative Floppy Iris Syndrome (IFIS) & Cataract Surgery

- **David Chang and John Campbell, 2005**
- poor dilation of the pupil, **intraoperative progressive miosis, billowing of the iris tissue, and iris prolapse** through the ocular incisions during cataract surgery
- alpha 1-a inhibitor, tamsulosin (Flomax), IFIS may be associated with other alphablockers (Doxazosin, Terazosin, Alfuzosin) psychotropic drugs, and over-the-counter agents such as saw palmetto. Tamsulosin is considerably more likely to induce IFIS than are other medications.
- IFIS does not occur until patients have been on tamsolusin therapy for approximately **4 to 6 months** but chronicity is not necessary to cause this syndrome
- ***DM is not associated. (??)***
- **Grading**
  - mild (billowing only)
  - moderate (billowing and intraoperative miosis)
  - severe (billowing, miosis, and iris prolapse)

- **Classification of pupillary behavior (S. Manvikar and D. Allen)**
  - Type 1 Pupil: good mydriasis preoperatively.
  - Type 2 Pupil: good mydriasis preoperatively but pupils constrict later during surgery.
  - Type 3 Pupil: a mid-dilated pupil initially that sometimes constricts later.
  - Type 4 Pupil: poor dilation at the beginning of surgery.
- **Pathogenesis:**
  - Alpha 1 Receptor antagonists cause relaxation of the iris dilator muscle and cause disuse atrophy of this muscle in the long-term.
  - Alpha-1 antagonists are most commonly prescribed to treat the lower urinary tract symptoms of benign prostatic hyperplasia (BPH). They do so by relaxing the smooth muscle in the bladder neck and prostate, permitting more complete bladder emptying. There are at least three different human alpha-1 receptor subtypes alpha-1A, alpha-1B, and alpha-1D.
  - Doxazosin (Cardura), terazosin (Hytrin), and alfuzosin (Uroxatral) are socalled non-selective alpha-1 antagonists. In contrast, tamsulosin is highly selective for the alpha-1A receptor subtype, which predominates in the prostate as well as in the iris dilator smooth muscle. Because it does not block the vascular smooth muscle alpha-1D receptor subtype, tamsulosin should be less likely to cause postural hypotension. Remember that tamsulosin may also be prescribed for urinary retention in women. Effect of a new alpha-1 antagonist silodosin (Rapaflo) for the treatment of BPH symptoms on IFIS is not known yet.
- **Preoperative evaluation**
  - History (specifically ask for BPH/Tamsulosin)
  - Dilatation
  - Ophthalmologists who decide to stop tamsulosin preoperatively might consider consulting the patient's urologist because of the potential to cause acute urinary retention. This is particularly true if preoperative atropine is used.
- **Signs**
  - Classical triad of IFIS includes:
    - Fluttering & billowing of iris stroma
    - propensity if iris to prolapse through phaco and side port incisions
    - progressive constriction of pupil
  - Pupil dilates poorly in response to the routine preoperative mydriatics
  - Starts to constrict soon after the first incision
  - Iris tends to prolapse despite well-constructed incisions
  - Iris stroma can be seen to be fluttering
- **Management**:

- Problem with IFIS is that partial thickness sphincterotomies and manual pupil stretching, two popular methods of surgically enlarging small pupils, are ***ineffective*** and can worsen the iris billowing and prolapse
- Preoperative topical atropine sulfate 1%: 2 days prior to surgery, continue their tamsulosin therapy, due to the risk of acute urinary retention with the use of atropine.
- Construct incisions that have long tunnels
- Direct stimulation of the iris dilator muscle by intracameral epinephrine (Joel Sugar)
- High-viscosity OVDs → Healon5 and DisCoVisc
- Avoid irrigating large volumes of balanced salt solution infusate under the iris, as this will increase the likelihood that the tissue will billow and prolapse
- Mechanical iris retraction → standard iris retractors and the Malyugin Ring
- Pupil expansion rings e.g. PerfectPupil
- Manual stretching and ***sphincterotomies have not been found to be effective and may actually increase the floppiness*** of the iris
- The **Dewey Radius Phaco Tip** provides a first-line defense against unexpected cases of IFIS, and reduces iatrogenic damage to the iris.
- It is important to remember that ***stopping the tamsulosin does not help*** as the effect of the drug persists even after discontinuation. Acute urinary retention maybe precipitated if the drug is abruptly stopped.
- **Arshinoff's strategy to manage IFIS**:
  - IFIS Soft Shell
  - Tight incision, long tunnel, outer soft shell with viscodispersive and inner with viscocohesive, water pocket is next made over the lenticular surface by injecting BSS.

Uveitis and Cataract Surgery

- Anterior and intermediate uveitis
  - the frequent relapses and chronic intraocular inflammation
  - the chronic use of corticosteroid therapy
- 50% in juvenile rheumatoid arthritis and other forms of posterior uveitis, and up to 75% in chronic anterior uveitis
- **Complicated cases of uveitic cataract:** those are essentially on systemic or periocular medication to control the uveitis as well as to maintain a quiescent state
- **Uncomplicated cases of uveitic cataract:** excellent control of uveitis as well as near normal anterior segment with adequate pupillary dilatation and minimal distortion of pupillary sphincter.
- ***SYMPTOMS***
  - DOV
  - Glare

- ***SLE***
    - Bulbar conjunctival hyperthymia, ciliary flush, comeal edema, an even anterior vitreous reaction.
    - Laser flare cell meter, fluorophotometry, or an inflammation severity score (USS).
- ***Main indications for cataract surgery***
    - Visually significant cataract if prospects for substantial improvement in visual acuity are good
    - PAM, LI
    - Glare
    - Cataract that impairs fundus assessment in a patient with suspected fundus pathology.
- ***Preoperative Consideration***
    - Pupil dilatation
    - Status of the nonoperative eye
    - Uveitis controlled with topical steroids only
    - Vitreous inflammation to require vitrectomy
    - Uveitis inactive, chronic, or recurrent
    - Granulomatous
    - Glaucoma
    - Cystoid macular edema
    - Zonular dehiscence
    - Patient can tolerate aphakia or not
    - Risk of amblyopia
- ***Preoperative management***
    - Active inflammation control for at least 3 months
    - The single most important sign of inflammation is the presence or absence of inflammatory cells in the anterior chamber or vitreous. Aqueous flare in anterior chronic uveitis simply denotes vascular incompetence of the iris and ciliary body, a consequence of vascular damage from recurrent uveitis.
- **Preoperative Regimen**
    - Absolute control of uveitis for at least 3 months (use immune-suppressants if needed)
    - High-dose oral corticosteroids 2-3 d preoperatively (prednisone 1 mg/kg per d)
    - Intensive topical corticosteroids 1 wk preoperatively (eg, prednisolone acetate 1% every 1Y2 h while awake)
    - Topical or oral nonsteroidal anti-inflammatory drugs starting 1 wk preoperatively
    - Vigorous pharmacological synechiolysis
    - Intravenous methylprednisolone 62.5-125 mg at the start of surgery

- **Surgical Goals**
    - Preservation of capsular integrity
    - Meticulous cortical cleanup
    - In-the-bag IOL placement
    - Removal of all viscoelastics
    - Minimize trauma to iris
- **Management**:
    - Clear corneal or scleral tunnel incision
    - Viscoelastic substances
    - CCC
    - phacoemulsification procedure is accomplished by the most suitable technique for each case
    - Type of IOL: Heparinized PMMA > PMMA > Acrylic > Silicone
- **Post operative treatment**
    - topical steroids ,cycloplegics and Antiglaucoma
    - NSAIDs controversial
    - Systemic steroids
- **Complications**
    - Surgical
        - Small pupil with posterior synechiae requiring pupil/iris manipulation
        - Weakened zonule possibly leading to zonular dehiscence or IOL dislocation
        - Hyphema
    - Postoperative
        - Intraocular inflammation aggravated
            - Postoperative corneal edema
            - Cystoid macular edema
            - Synechiae leading to iris bombe, glaucoma, and pupil capture behind part of IOL optic
            - IOL removal necessary due to effect of inflammation, with cyclitic membrane, unresponsive low grade inflammation, hypotony, and maculopathy
        - Posterior capsular opacification
        - Elevated IOP
        - Epiretinal Membrane
        - Corneal and scleral melt
        - Phthisis bulbi

Cataract surgery following Glaucoma filtering surgery

- **Implications**
  - Glaucoma filtration surgery may
    - Accelerate cataract development
    - Cause the development of anterior or posterior synechiae
    - Be associated with a large iridectomy
    - Be associated an intraocular drainage tube
    - Be associated with weak zonules
  - Eyes with glaucoma often dilate poorly
    - Previous miotic therapy
    - Pseudoexfoliation syndrome
    - Neovascularization of the iris
    - Posterior synechiae
  - Presence of filtration bleb or drainage tube may require alternate location for surgical incisions
- **Surgical Complications**
  - Increased filtration through the bleb or drainage device during surgery
  - Variable IOP in the week postoperatively
  - Decreased filtration or bleb failure following surgery and long-term loss of intraocular pressure control
  - Zonular damage
  - Damage to integrity of filtration bleb
    - Bleb leak
    - Increased risk of endophthalmitis
- **Care to be taken**
  - Assure adequate pupil dilation
  - Avoid making the cataract incision near the glaucoma filter or drainage device.
  - Clear cornea incision to avoid incising the conjunctiva and Tenon capsule
  - Minimize postoperative inflammation by appropriate use of anti-inflammatory agents
    - Often longer than in a standard procedure
    - Reduce chance of bleb fibrosis
  - Avoid additional zonular stress during surgery
  - Suture corneal wound postoperatively
  - Avoid over-pressurizing the eye at the conclusion of the case to prevent bleb rupture

Pseudoexfoliation and Cataract surgery

- Age-related disease causing deposition of fibrillar amyloid-like material throughout tissues of the body
- Ocular deposition: Lens capsule, Iris, Ciliary body/zonules, Endothelium simulating KP
- **Demographics**
  - Patients tend to be 60 years or older
  - Geographic clustering suggests a hereditary pattern: Scandinavians, Eastern Europeans, Russians, Ethiopians
- **Clinical features**
  - Concentric deposition of fibrillar material on anterior lens capsule
    - Rings noted on the lens capsule
    - Best viewed with dilated pupil
  - Transillumination defect and fibrillar material at the pupillary margin
  - Open angle with brown clumps of fibrillar material on trabecular meshwork or near Schwalbe line
  - Flakes of fibrillar material on corneal endothelium
  - Evidence of zonular weakness
    - Phaco or iridodonesis
    - Lens subluxation or even luxation
- **Surgical Complications**
  - Intraoperative miosis
  - Zonular laxity or instability
  - Floppy iris and iris prolapse
  - Vitreous loss
  - Anterior capsulorrhexis contraction or phimosis
  - IOL tilt and decentration
  - Postoperative intraocular inflammation due to changes in blood aqueous barrier
  - Corneal decompensation
  - Increased intraocular pressure during the immediate postoperative period
- **Care to be taken**
  - Take appropriate steps to assure an adequate pupil size for safe cataract surgery
    - Mechanical stretch, sphincterotomies
    - Devices such as hooks, rings
    - Viscomydriasis
    - Intraoperative epinephrine
  - Avoid excessive stress to the zonules during surgery, i.e. chop technique

- Consider capsular tension ring implantation if mild to moderate zonular laxity is present
- Consider sulcus fixation, scleral fixation, iris fixation, capsular tension ring, or anterior chamber IOL implantation if moderate to severe zonular laxity is present
- Avoid an overly small capsulorrhexis, which may increase the chances of phimosis
- Consider intraoperative carbachol/acetylcholine or post-op topical antihypertensive drops/oral meds to control immediate IOP spikes

IOL Implantation in Eyes without a Capsule

- Posterior capsular rent with inadequate sulcus support
- Large zonulodialysis or large subluxations of the lens or IOL
- Primary aphakias

- **Sutured Scleral Fixated IOL**
    - **Ab INTERNO:** needles are passed from the inside of the eye outwards
    - **Ab EXTERNO:** needle is passed from outside to inside the eye
    - **COMPLICATIONS:**
    - Improper passage of the needle can result in retinal detachment
    - Degrade, erode and the knot may give way
    - Decentered IOL and consequent diplopia, edge glare effects, etc.
    - Loose suturing can give rise to excessive intraocular mobility of the IOL which can results in pseudophakodonesis.
    - Lens rubbing on the iris which can result in pigment dispersion and uveitis-glaucoma hyphema syndrome

- **Sutureless PCIOL Fixation with Intrascleral Haptic Fixation**
    - Combines the control of a closed-eye system with the postoperative axial stability of the posterior chamber IOL
    - 3 piece/ multipiece PCIOL with heptice used for intrascleral fixation
    - **Advantages**:
        - No contraindication
        - Standardized technique
        - Standard PCIOL with no extra storage, easy logistic, routine biometry
        - Excellent centration
        - Sutureless
        - Scleral fixation
        - Minimal uveal contact

    - Independent from iris changes
    - Also for special IOL like multifocal and toric
    - In combination with refractive surgery (Bioptics).
- **Glued PCIOL implantation with Intralamellar Scleral Tuck**
  - Reliseal (Reliance Life Sciences, India).
  - Tisseel (Baxter)
  - **Reconstitution of Glue (Reliseal)**
    - freeze dried human fibrinogen (20 mg/0.5 ml), freeze dried human thrombin (250 IU/0.5 ml), aprotinin solution (1500 kiu in 0.5 ml), one ampoule of sterile water, four 21G needles, two 20 G blunt application needles and an applicator with two mixing chambers and one plunger guide.
  - **Advantages of Glued IOLs**
    - *No special IOLs*
    - *No tilt*
    - *Less pseudophacodonesis*
    - *Less UGH syndrome*
    - *No suture related complications*
    - *Rapidity and ease of surgery*
    - *Stability of the IOL Haptic*

- **Advantage of SFIOLs:**
  - sutured PCIOLs are appropriate for patients with glaucoma, diabetes, cornea guttata or low endothelial cell count, peripheral anterior synechiae, or known or suspected cystoid macular edema.
- **Complications of SFIOLs:**
  - IOL Tilt:
  - Late IOL Dislocation:
  - Suture knot erosion:
  - Haemorrhage:
  - Transient rise in IOP
  - Retinal Detachment
  - Cystoid Macular Edema
  - Late Endophthalmitis

- **Iris Suture Fixation of Intraocular Lenses**
  - The advantages of iris fixation compared to trans-scleral fixation are as follows:
    - ***Absence of conjunctival*** surgery.

    - The ability to perform the ***suturing through the small side-port*** incisions and, if the lens needs to be inserted, the insertion of a foldable IOL through small incisions.
    - ***Absence of any external sutures*** that can later erode to the surface and be the source for foreign body irritation and a track for organisms to enter the eye, causing endophthalmitis.
    - The apparent ***lower rate of late postoperative suture breakage*** and dislocation of the implant compared to trans-scleral suture fixation.
  - **Concerns**: potential for inflammation, However, the peripheral iris does not appear to have this potential for chronic inflammation, at least when the implant is secure and not moving against the uveal tissue.
  - Peripheral Short Suture Bites
  - Suture from the Concave Side of the Haptic
  - Use a Three-Piece IOL
  - Use a Dense Cohesive Viscoadaptive Device to Visualize the Haptic
  - Tying the Suture

Phaco Modifications in Zonulopathy

- The most common predisposing risk factors for zonular weakness include pseudoexfoliation, advanced age, prior trauma, retinopathy of prematurity, and prior intraocular surgery (e.g. prior vitrectomy or trabeculectomy). Less common risk factors would be conditions such as Marfan syndrome, retinitis pigmentosa, and myotonic dystrophy.
- **Preoperative signs of zonulopathy**
  - Traumatic mydriasis, angle recession, iridodialysis, and vitreous herniation
  - Subtle signs described by Robert Osher: wider iridolenticular gap (space between the iris and the anterior lens surface), a decentered nucleus, focal iridodonesis, and visibility of the peripheral lens equator upon lateral gaze
- **Capsulorrhexis**
  - Zonular stress test
  - Earliest sign of severe or diffuse zonular weakness is difficulty incising the anterior capsule with the cystotome.
  - Cystotome tip will tend to first dimple, wrinkle, and indent it, rather than immediately puncture it and a halo-shaped light reflex around the cystotome tip may be noted
  - Smaller capsulorrhexis may hinder subsequent surgical steps, it is far preferable to a torn anterior capsular, particularly when other risk factors are present.
  - Secondary enlargement can be done if required
- **Hydrodissection**

    - Difficult to turn the nucleus because of deficient capsular rotational stability and counter fixation
    - Use two instruments to bimanually rotate the nucleus
- Use of Capsular Tension Rings & Retractors as per the need
- **Nuclear Emulsification**
    - Avoid causing excessive nuclear movement with sculpting, chopping, or rotation.
    - Phaco chop significantly reduces the stress placed on the zonules and capsule by replacing sculpting and cracking motions with the manual forces of one instrument pushing inward toward another. Because of the centrally directed instrument forces, horizontal chopping is particularly effective at avoiding nuclear tilt or displacement
    - Anticipate that deficient centrifugal zonular tension will result in greater posterior capsule laxity
    - 20-gauge tip significantly reduces the risk of inadvertently aspirating the peripheral or posterior capsule than 19-gauge tip
    - Guard Phaco-tip opening by placing chopper tip beneath it
- **Cortical Clean-up**
    - Continually reinflating the capsular bag with a dispersive OVD is an excellent strategy when removing cortex from a floppy bag
    - Bimanual IA instrumentation provides several advantages in the presence of weak zonules.
- **Secondary Capsulorrhexis Enlargement**
    - Capsulorrhexis can be enlarged by first making an oblique cut with scissors, and grasping the resulting diagonal cut edge with capsule forceps.
    - The cut should be oblique, rather than radial, to better incline the resulting flap to tear in a circumferential direction.
    - Curved Uthoff-Gills capsulotomy scissors with blunt tips (Katena K4-5126) have the perfect shape for creating an initial curved cut to either side of the phaco incision. The flap is maneuvered and advanced with capsule forceps under a generous amount of OVD.
    - In some cases, one need only trim a part of the remaining anterior capsular rim where it is excessively wide. Other times, one can re-tear the entire 360degree circumference of the opening. If the pupil is small enough to conceal the optic edge, it can be locally retracted with a Lester hook or by maneuvering a Malyugin ring.
    - The safest time to enlarge the capsulorrhexis is following IOL insertion. This is true regardless of whether a capsular tension ring was inserted as well. Executing the second stage enlargement is generally easier than the primary capsulotomy for several reasons. Following removal of the cataract the red reflex is improved, and there is no convexity to the anterior capsule to promote downhill radial extension of the tear. The optic provides a perfect visual template for re-sizing the capsulorrhexis diameter. Finally, in cases of weak zonules, the presence of stiff 3-piece PMMA haptics or a capsular tension ring increases outward tension on the capsular bag, which improves control of the anterior capsular tear. It is reassuring that, should the

tear escape peripherally, the risk of a posterior wraparound tear is negligible because all of the most forceful surgical steps have been completed. However, the IOL should not be rotated in the presence of a single anterior capsular tear for this reason.

Phaco in Subluxated Cataracts

- Partial displacement of the lens from its central position in the pupil
- **Classification**
    - Congenital
        - isolated ocular finding (Simple Ectopia Lentis)
        - systemic disorders like Marfans syndrome & its variants, Homocystinuria, Weil-Marchesani syndrome, Spherophakia, Atopic dermatitis, Hyperlysinemia, Ehlers Danlos syndrome, & Sulfite Oxidase deficiency
        - ocular disorders such as Ectopia Lentis et Pupillae, Congenital Glaucoma, Aniridia & Megalocornea
    - Acquired
        - Trauma, Pseudo-Exfoliation, High Myopia, Hypermature Cataract, Syphilis, Ectasias, Glaucomas, previous Scleral Buckling surgery, and Staphylomas
        - Iatrogenic subluxation following zonular dialysis, detected intraoperativly
- **Pathophysiology**:
    - Zonules are composed of Cystiene rich Glycoproteins, the chief component being Fibrillin. Poor secretion of Zonular Fibrils, Cystiene Deficiency or a Fibrillin gene defect are some of the theories to explain the Zonular weakness in Congenital diseases
    - excess Zonular stretching, Zonular damage and weakness occur in the Acquired Sub-luxations
- **Investigations**
    - Sodium nitroprusside test (in urine) for Homocystinuria (Thromboembolic episodes during general anesthesia)
    - FTA-ABS for syphilis
    - UBM
    - ECHO for Aortic Aneurysms
    - musculoskeletal evaluation
- **Management**
- ***Clear Lens***
    - Medical
        - Observation

        - complete refraction
        - Spectacle correction, aphakic glasses, contact lenses
        - Medical intervention can be in form of cycloplegics to enlarge the aphakic part or miotics to minimize diplopia and decrease the pupil aperture. ***Miotics pose the danger of pupillary block and should be used with caution***
        - Laser iridotomy / iridoplasty
    - Surgical
        - Lensectomy (Pars Plana route/ Limbal route)
        - LE
- ***Cataractous Sub-luxated lens***
    - Surgical only
        - Less than 3 clock hours: Slow phacoemulsification
        - 3-5 clock hours: Phacoemulsification with Intraocular Lens Implant with CTR/ Iris or Capsular support hooks
        - 5-7 clock hours: Phacoemulsification can be attempted with the help of a combination of Capsular support system (iris hooks/ Capsular retractors) with fixation of Capsular bag by a Cionni CTR
        - >7 clock hours: ICCE-AV/ PPL Vit
- Complications
    - Intra-operative: posterior capsular rupture, nucleus drop, CTR drop with the bag, and IOL drop.
    - Postoperative: Glaucoma, Iritis, Hyphaema, delayed IOL Sub-luxation or Decentration, Capsular Phimosis, Capsulorhexis contraction, Anterior Capsular Fibrosis, Vitreous Haemorrhage, Retinal Detachment, and Macular Oedema

Severe Hyperopia/Small eyes and Cataract surgery

- Optical defect above +4D
- **Two categories:**
    - Those with small anterior segment and
    - Those with a normal anterior segment
- **Preoperative treatment**
    - Stop miotic therapy 48 hours prior to surgery
    - Add oral acetazolamide
    - Add topical non-miotic hypotensive
    - Administer 20% mannitol,10 ml/kg body weight i.v. 2-4hours before surgery
    - Avoid excessive administration of phenylephrine to overcome miosis

- **Surgical complications**
    - Endothelial trauma
    - Iris trauma and prolapse
    - Intraocular lens (IOL) implant power calculations
    - Intraoperative suprachoroidal effusion
- **Care to be taken**
    - Use highly dispersive ophthalmic viscosurgical device (OVD) carefully to maintain adequate space
    - Maintain adequate infusion bottle height throughout surgery to prevent hypotony
    - Careful construction of corneal entry site for the cataract incision to avoid the iris root
    - Calculate lens implant power using a latest generation power formula
    - Select IOL with flexible haptics and shorter overall length based on size of capsular bag/anterior segment
    - Consider dry PPV to create space in extremely shallow anterior chamber
    - If uncomfortable with the surgical techniques in nanophthalmic eyes, consider referral

High Myopia and Cataract Surgery

- **Surgical Implications**
    - Difficulty measuring axial length and calculating intraocular lens (IOL) power, especially if posterior staphyloma is present
    - Perforation of the globe during the retrobulbar or peribulbar block
    - Errant capsulorrhexis
    - Excessive movement of the iris-lens diaphragm causing an deep anterior chamber
    - Greater patient discomfort if surgery is performed under topical anesthesia due to iris movements and reverse pupillary block
    - Damage to iris or capsule from dynamic anterior chamber
- **Care to be taken**
    - Preoperative: Carefully examine peripheral retina to ensure retinal integrity and consider treatment of pathology that might predispose to retinal detachment
    - Intraoperative
        - Reduce irrigating bottle height to avoid overinflated anterior chamber
        - Avoid incision leakage
        - Ensure adequate, but avoid overpressurization of AC with OVD during capsulorrhexis construction

    - Avoid repeated collapse of AC when exiting the eye to avoid distortion of the vitreoretinal interface
    - Use spatula or cannula to elevate pupil margin, providing path for irrigation fluid thus breaking the 'reverse pupil block' which can cause an excessively deep AC
    - Avoid silicone IOL
    - Attempt optic capture if haptics placed in the sulcus
  - Postoperative
    - Careful indirect ophthalmoscopy to check for retinal breaks
    - Give the patient specific information on the signs and symptoms of retinal detachment symptoms (flashes, floaters, shadow)

Ectopia Lentis

- Displacement of the lens
  - Congenital
  - Developmental
  - Acquired
- Trauma is most common cause
- Greater than 50% of patients with Marfan syndrome exhibit ectopia lentis
- **Symptoms**
  - Decreased vision
  - Monocular diplopia
  - Glare
  - Poor near vision
- **Clinical Features**
  - Subluxed or total luxation of the lens
  - Phacodonesis
  - Marked lenticular astigmatism
  - Iridodonesis
  - Impaired accommodation
  - May dislocate into anterior chamber and cause pupillary block
  - Amblyopia
- **Risk Factors**
  - Traumatic
  - Non-traumatic

- Primarily ocular
  - Pseudoexfoliation
  - Simple ectopia lentis
  - Ectopia lentis et pupillae
  - Aniridia
  - Congenital glaucoma
  - Chronic uveitis
- Systemic
  - Marfan syndrome
  - Homocystinuria
  - Other rare systemic congenital syndromes

- **Management**
  - Eyeglasses for subluxed lenses
  - Aphakic contact lens in cases of significant subluxation or luxation
  - Surgery
    - ICCE
    - Phaco/ECCE
    - Pars Plana Lensectomy

Ghent Criteria

Revised Ghent Criteria

- ***In the absence of family history:***
  1. Ao (Z ≥ 2) and EL = MFS
  2. Ao (Z ≥ 2) and FBN1 = MFS
  3. Ao (Z ≥ 2) and Syst (≥ 7pts) = MFS
  4. EL and FBN1 with known Ao = MFS
- ***In the presence of family history:***
  5. EL AND FH of MFS (as defined above) = MFS
  6. Syst (≥ 7 pts) and FH of MFS (as defined above) = MFS
  7. Ao (Z ≥ 2 above 20 yrs old, ≥ 3 below 20 yrs) + FH of MFS (as defined above) = MFS

- **Systemic score**
  - Wrist AND thumb sign – 3 (Wrist OR thumb sign – 1)
  - Pectus carinatum deformity – 2 (pectus excavatum or chest asymmetry – 1)
  - Hind foot deformity – 2 (plain pes planus – 1)
  - Pneumothorax – 2

    - Dural ectasia – 2
    - Protrusio acetabuli – 2
    - Reduced US/LS AND increased arm/height AND no severe scoliosis – 1 (The combined presence of reduced upper to lower segment ratio (for white adults <0.85; <0.78 in black adults; no data have been assessed in Asians) and increased armspan to height ratio (for adults >1.05) in the absence of significant scoliosis)
    - Scoliosis or thoracolumbar kyphosis – 1
    - Reduced elbow extension – 1
    - Facial features (3/5) – 1 (dolichocephaly, enophtalmos, downslanting palpebral fissures, malar hyoplasia, retrognathia)
    - Skin striae – 1
    - Myopia >3 diopters – 1
    - Mitral valve prolapse (all types) – **1**
- Maximum total: 20 points; score ≥7 indicates systemic involvement

- EL + FBN1 mutation without Ao and Syst (< 7) → **ELS** (ctopia lentis syndrome)
- Syst (≥ 5), absent EL and Ao → **MASS** (myopia, mitral valve prolapse, aortic root dilation, skeletal findings, striae syndrome)
- MVP and Syst (< 5) without Ao and EL → **MVPS**

Microspherophakia

Weill-Marchesani syndrome (WMS):

- Short stature
- Brachydactyly
- Joint stiffness
- Characteristic ocular findings → microspherophakia, ectopic lentis, cataract formation, severe myopia, and acute or chronic glaucoma.
- AD → fibrillin-1 gene, chromosome 15q21, ectopic lentis
- AR → ADAMTS10 mutation, chromosome 19p13, microsherophakia

Intralenticular foreign bodies

- IOFBs account for approximately 40% of all penetrating ocular traumas
- 7-10% of all intraocular foreign bodies
- Metallic
- Nonmetallic: cilia, glass, stone, vegetable matter and coal

- Cx: altered capsular integrity which results in the formation of visually significant cataract. There is usually a minimal accompanying globe disruption but complications like uveitis, glaucoma, abscess formation, endophthalmitis and intralenticular metallosis
- **Management**:
  - ICCE
  - ECCE with PCIOL combined with extraction of lenticular magnetic foreign body

Management of Preexisting Astigmatism

- Aim of modern cataract surgery is to have UCVA as good as BCVA.
- **Incidence**
  - 36 to 45% of patients have astigmatism of > 1D (78% have < 1.5D, 20% have 1.5 3.0D and 2% have >3.0 D.)
- The chief methods of correcting preexisting astigmatism during cataract surgery are:
  - Limbal relaxing incisions (LRIs)
  - Astigmatic keratectomy
  - Opposite clear corneal incisions(OCCIs)
  - Toric intraocular lens (Toric IOLs)

Limbal relaxing incision

- Can treat upto 4D of astigmatism
- Various Nomograms
  - Gills Nomogram
  - NAPA Nomogram (Nichamin Age and Pachymetry Adjusted Intralimbal Arcuate Astigmatic Nomogram)
  - Donnenfeld Nomogram
- Limitations
  - Regression
  - Mechanical instability
  - Ocular surface discomfort
  - Infection
  - Perforation
  - Decreased corneal sensation
  - Induced irregular astigmatism
  - Misalignment/axis shift
  - Operating upon the wrong (opposite) axis

On Axis Cataract Incision and Opposite Clear Corneal Incisions

- Phaco-incision is considered to be astigmatically neutral
- 3.2 mm incision induces 0.25 to 0.50 D of astigmatism.
- biggest advantage of this technique is the stability of the cornea which is achieved in 2 weeks time
- Minimum fluctuations in vision and minimal regression.
- The amount of correction depends upon:
    - Types of incisions: Hinged > Triplanar > Biplanar > Uniplanar
    - Site and location of the incision: (Superior > superotemporal/superonasal >Temporal)
    - Size of the incision: The lesser the width of the incision, the more will be the correction.
    - Amount of astigmatism: The more is the preexisting astigmatism, the greater is the correction achieved.
- Not need to change IOL power due to the coupling effect
- **Coupling Effect**: ***Cravy*** has described ***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 behavior is known as the coupling effect.
- **Limitations**: limited amount of correction induced

Toric IOL

- Do not require the additional surgical skills needed to create clear corneal incisions
- Implanted using standard cataract surgical techniques
- Complications associated with toric IOLs
    - Movement of IOL may reduce efficacy
    - Rotation typically occurs early in the postoperative course and may be more common in myopic patients with large anterior segments
    - Incorrect marking may worsen preoperative astigmatism
- Prevention and management of complications associated with toric IOLs
    - Careful preoperative measurements and corneal marking are essential
    - Complete removal of viscoelastic may lessen the likelihood of lens rotation
    - Lens rotation may be corrected by surgical repositioning
- Residual astigmatism may be addressed by astigmatic keratotomy or use of glasses or contact lenses

Cataract surgery with/after keratoplasty

- When faced with a situation of co-existing cataract and advanced corneal pathology, one could either perform a cataract surgery with IOL implantation along with a keratoplasty (a TRIPLE procedure); OR one could initially address the corneal pathology by a keratoplasty, followed a few months/years later by cataract surgery.
- Cataract surgery with keratoplasty (**TRIPLE procedure**): 3 types
    - Penetrating Keratoplasty with cataract surgery (PK Triple)
    - Deep Anterior Lamellar Keratoplasty with cataract surgery (DALK Triple)
    - Endothelial Keratoplasty with cataract surgery (EK Triple)
- **PK Triple Procedure:**
    - Closed Chamber Phacoemulsification first followed by routine penetrating keratoplasty:
        - Closed chamber technique is preferable due to lower incidence of complications such as capsulorhexis extension, vitreous loss and suprachoroidal haemorrhage.
        - To improve visualisation during phacoemulsification, one can employ various tricks such as removal of corneal epithelium, use of trypan blue dye or endo-illuminator.
        - If there is significant stromal scarring, one can perform lamellar keratectomy to improve visibility to perform a safe phacoemulsification in most cases.
        - In case of poor visibility, one can safely bring nuclear pieces anteriorly and emulsify them in the anterior chamber, as the endothelial safety is not really a concern in PK triple surgery.
    - Excision of host corneal button, followed by open sky cataract surgery, and finally suturing of donor button:
        - Pre-op mannitol, Pinky application & Fleiringa ring is mandatory in all cases to minimise positive vitreous pressure intra-operatively
        - Prefer CCC to minimise chances of vitreous loss and for safe cortical removal.
        - In the bag IOL implantation preferable
        - High chance of capsular dehiscence, vitreous loss & suprachoroidal haemorrhage take adequate precautions and appropriate consent.
- **DALK Triple:**
    - Closed chamber phacoemulsification can be performed after stromal excision and before donor stromal button is sutured.
    - If descemetic dissection is performed, then there is risk of Descemet's membrane rupture during phacoemulsification hence low bottle height is advisable.
- **EK Triple:**
    - First perform closed chamber phacoemulsification under cohesive viscoelastic later endothelial keratoplasty by routine technique.
    - Similar tricks can be employed to improve visualisation during phaco as in PK triple

    - IOL material: prefer hydrophobic over hydrophilic acrylic materials, as hydrophilic IOLs have been shown to exhibit calcification on prolonged contact with air, which is often necessary in EK.
    - IOL power: Aim for 1-2D myopia as EK tends to induce a hyperopic shift, due to the concave meniscus shape of the lenticule.
- **Cataract surgery after Keratoplasty:**
    - To be performed preferable after all sutures are out.
    - IOL calculation is challenging and can be aided by used of advanced topographers and optical biometry. Toric IOLs can be used if there is high regular astigmatism. Avoid multifocal IOLs.
    - Preferred cataract surgical technique should be based on surgeon's comfort with various techniques, pupil size & density of cataract.
    - Incision: Scleral incision with internal entry outside the graft host junction is preferable.
    - Visco-elastic: Soft shell technique is preferred for good maintenance of anterior chamber(by cohesive OVD) and endothelial protection (by dispersive OVD).
    - Synechiolysis may be necessary performed using Iris repositor.
    - Low phaco parameters with gentle in-the-bag phacoemulsification.
    - Suturing of main wound & paracentesis is often necessary.

Pupilloplasty

Single-Pass Four-Throw Pupilloplasty

- Single-pass four-throw (SFT) pupilloplasty technique involves a single pass in the anterior chamber followed by 4 throws taken through the loop that is withdrawn from the anterior chamber.
- The procedure comprises the approximation loop with no securing loop taken to ensure a traditional knot formation. It works on the principle of creating a helical configuration by intertwining the loop that has a self-locking and a self-retaining mechanism. SFT technique creates a helical configuration that prevents it from opening up.
- **Indications**
    - Corneal indications
        - Endothelial keratoplasty like **pre-Descemet endothelial keratoplasty**, especially in aphakic eyes or those with a deficient posterior capsule, so as to prevent the graft from getting displaced in the posterior segment, and to maintain an adequate anterior chamber for graft unrolling and placement
    - Glaucoma related
        - Angle-closure glaucoma
        - Plateau iris syndrome

- Broad peripheral anterior synechiae
- Pupil-related indications
  - Traumatic mydriasis
  - Urrets-Zavalia syndrome
  - Iatrogenic iridectomies
  - Iris defect (congenital coloboma iris / correctopia / polycoria)
- IOL-related indications
  - Optic capture
  - Glued IOL
  - Prevention of posterior synechiae
- **Relative Contraindications**
  - Phakic eyes with clear lens
  - Atrophic iris

Pinhole Pupilloplasty (PPP)

- Pinhole pupil can be achieved with the procedure of surgical pupilloplasty
- **Principle**
  - Pinhole visual acuity is the best possible vision that can be attained in a patient. PPP works on the same principle as a pinhole that helps to focus the central and paracentral rays in cases with higher-order corneal aberrations. PPP wards off the peripheral unfocused rays, thereby enhancing the visual quality and image (see Figure 1). It also works on the principle of StilesCrawford effect where the light entering the eye from the center of the pupil creates a greater photoreceptor response compared to light entering from the peripheral edge of the pupil. As the pinhole is created, only central rays are focused that create a greater cone photoreceptor response.
- **Role of Purkinje Images in PPP**
  - Theoretically there are 4 Purkinje images—P1, P2, P3, and P4—but clinically, as P1 and P2 overlap each other, only 3 are appreciated—P1, P3, and P4. The P1 image is right and upright, and it emerges from the anterior surface of cornea (see Figure 2). The P3 image, formed by the anterior surface of the lens or IOL, is large and upright, whereas the P4 image is formed by the posterior surface of the lens or IOL and is inverted. In a pseudophakic eye, the P1 image should be ideally placed between the P3 and P4 image. Deviation from this or proximity of the P1 image to either the P3 or P4 indicates the element of tilt or decentration of the IOL.
- **Surgical Technique of Achieving a Pinhole**
  - The procedure of PPP can be performed with any technique that can be a McCannel, Siepser, or Cerclage, but the authors employ the single-pass four-throw technique (SFT)5 for achieving a pinhole pupil. A multiple-quadrant approach is necessary to achieve a pinhole pupil. The SFT procedure is performed, and 3 attempts or more are required to create a pinhole pupil. Often the iris tissue

overlaps the P1 reflex of the Lumera microscope. Under these circumstances, a vitrectomy probe is used to reshape the pupil.

- **Advantages**
  - that no special device is needed to create the pinhole effect and
  - the procedure is surgeon dependent and is effective and can be mastered easily.
- The option of performing PPP offers a pragmatic solution in cases with higher-order corneal aberrations, offering immense improvement of visual quality. One can also examine the fundus in patients after PPP, as the pupil dilates a little bit if done using the single-pass four-throw pupilloplasty technique.
- The ideal pinhole size is about **1.5 mm** and not smaller than that, otherwise diffraction will occur.

IOL Exchange

- **Indication**
  - Dysphotopsia
  - IOL power issues
    - Wrong calculation
    - Previous refractive surgery
    - Following retinal buckle surgery
  - Silicone oil deposits on silicone lenses
  - Damaged IOL: Surgery of YAG damage
  - Failure of Neuroadaptation – Multifocal IOLs
  - UGH syndrome
  - Opacified IOL
- **Principles**
  - Early is easier, but if overlapping continuous curvilinear capsulorrhexis (CCC) and no cortex, can easily reopen within 6-8 months.
  - If CCC diameter is small or CCC is partially "off" the optic and fused to posterior capsule, removal will be more difficult, and earlier timing of exchange is better.
  - Use dispersive ophthalmic viscosurgical device (OVD) (eg, Viscoat) to re-expand the capsular bag.
    - May need to first lift capsulorrhexis edge off of an AcrySof lens optic with #30 needle or flat spatula
    - Use 3 paracentesis sites to expand 3 sectors of equatorial capsular bag.
    - Intermittently burp out OVD to avoid overfilling the anterior chamber (AC).
  - Bring optic and haptics into AC. With smaller CCC, may need "chopstick" maneuver with 2 hooks to deliver optic through the CCC. Try not to cut CCC if possible.

- Microsurgical IOL cutters (eg, MST, Geuder AG) optimize intraocular control and better avoid wound gape that will allow OVD to burp out. The **Packer-Chang IOL cutter** from MST is strong enough to cut the rigid Tecnis or ReZoom acrylic material. Intraocular IOL holding forceps prevent optic from tilting and migrating as it is being cut. These can be inserted via a separate paracentesis.
- Haptic of AcrySof platform has a terminal bulb that will become fibrosed within the capsular equator after several months. Care must be taken not to dehisce the zonules by excessive traction on the haptic. One must be prepared to amputate and leave behind the haptic in this situation.
- If posterior capsule has been YAG-ed, expect vitreous loss. Attempt to preserve the anterior capsule during the vitrectomy, which can allow optic-CCC capture. Have backup IOLs for non-capsular bag fixation as a contingency.

- **Strategies Before Explanting**
    - Treat dry eye
    - Rule out maculopathy (eg, OCT)
    - Consider laser pupilloplasty if diffractive optic poorly centered with pupil
    - If appropriate, implant second eye with monofocal or accommodating IOL to see if halos/ghosting in first eye are more tolerable.
    - Avoid posterior YAG capsulotomy if IOL exchange may be necessary.

Bag-IOL Dislocation

- Recently Late In-Bag IOL dislocation after routine uneventful cataract surgery has been reported.
- Generally after 5-10 years of surgery
- Pseudoexfoliation (PXF) and intraoperative zonular weakness are major risk factors.
- 1.7% of PXF patients over 25 years
- **PCIOL decentration can be as follow**
    - Out of the bag
        - Sulcus
        - Vitreous
    - In the bag
        - Capsule contracture
        - Soemmerring ring
- **Management can be done by Repositioning or Exchange**
    - Each option to manage IOL dislocation has its own pros and cons.
    - Repositioning is less invasive but typically requires suturing (risk of breakage).
    - If capsule fixation (ie, optic capture) is possible, this is preferred.
    - Exchange provides alternative IOL designs and fixation methods.

  - More vitrectomy is likely required for exchanges.
- **Iris Suture Fixation**
  - Preferred choice for sulcus or vitreous subluxed IOLs
  - Suitable for out-the-bag 3 piece PC-IOLs
  - If in bag, should remove capsule
  - Do not recommend for single-piece foldable PCIOLs
  - Requires *both* haptics to be sutured
  - Requires stable iris
  - Preferably to Avoid in uveitis
- **Scleral Suture Fixation**
  - When iris fixation is not desirable
  - Single haptic suture fixation
  - In-the-bag IOL dislocation
  - Single-piece foldable PCIOLs
  - Polymethyl methacrylate (PMMA)
  - Capsular tension ring

Pediatric Cataract

- **Infant Eye is Different:**
  - Vertical palpebral fissure: ½ the size of adult
  - Diameter of eyeball: 66% of adult (grows rapidly in first 2 yrs)
  - Hyperopia is common
  - AL changes from 17 to 24 mm
  - Corneal diameter: 6.6-7.4 to 7.4-8.4 mm
  - Average K: 52 D at birth (adult: 42-44 D)
  - Infant sclera is ½ as thick as adult
  - Excellent VA on VER by 6 months

- **Preoperative evaluation**
  - visual acuity
  - strabismus, fixation and nystagmus
  - assess the cataract, measurement of intraocular pressure (IOP), corneal diameter, posterior segment evaluation, keratometry, biometry and gonioscopy.

- **Investigations**
  - Unilateral cataract, posterior lenticonus, familial cataract need no investigation except for detailed examination.
  - TORCH serology, VDRL titer, urine for reducing substance to rule out galactosemia.
  - Systemic workup and investigations are carried out when any metabolic disease
  - Blood assay for sugar, calcium and phosphorus and urine aminoacid for Lowe's syndrome.

- **Decision to operate**
  - Unilateral cataract: immediately.
  - Total cataract or more than 2.5 mm posterior sub capsular, posterior polar, posterior lenticular, zonular or any cataract which occludes the visual axis in normal light or dim light on distance direct ophthalmoscopy.

Etiology and Morphology

- ***Congenital cataracts**: present at birth but may go unnoticed until an effect on the child's visual function is noticed or a white pupil reflex develops.*
- ***Infantile cataracts**: develop in the first 2 years of life*
- ***juvenile cataracts**: onset within the first decade of life.*

- ***presenile cataract:*** *onset prior to 45 years of age.*
- ***Age-related or so-called "senile" cataracts****: at/ after age 45 years*

Etiological Classification

- Isolated Findings
- Hereditary: AD (75%), AR, XR, Sporadic
- Part of Syndrome or Systemic Disease
- **Hereditary**
  - With renal disease:
    - Lowe's oculocerbrorenal syndrome
    - Alport syndrome (autosomal dominant)
  - With central nervous system disease
    - Marinesco Sjögren's syndrome (autonomic recessive)
    - Sjögren's syndrome (autosomal recessive)
    - Smith-Lemli-Opitz syndrome
    - Laurence-Moon-Bardet-Biedel syndrome
  - With skeletal disease
    - Conradi's syndrome (presence of cataract indicates worse prognosis)
    - Marfan's syndrome
    - Stippled epiphysis
  - With abnormalities of head and face
    - Hallermann-Streiff syndrome
    - Francois dyscephalic syndrome
    - Pierre Robin syndrome
    - Oxycephaly
    - Crouzon's disease
    - Acrocephalosyndactyly (Apert's syndrome)
  - With polydactyly
    - Rubinstein-Taybi syndrome
  - With skin disease
    - Bloch-Sulzberger syndrome
    - Congenital ectodermal dysplasia of the anhidrotic type
    - Rothmund Thomson syndrome
    - Schafer's syndrome
    - Siemen's syndrome

        - Incontinential pigmenti
        - Atopic dermatitis
        - Cockayne's syndrome
        - Marshall syndrome
    - With chromosomal disorders
        - Trisomy 13 (usually die within 1 year)
        - Trisomy 18: Edward's syndrome
        - Trisomy 21: Down's syndrome (often cataract formation delayed until approximately age 10)
        - Turner's syndrome
        - Patau's syndrome
    - With metabolic disease
        - Galactosemia (autosomal recessive): vomiting and diarrhea and may develop “oil droplet” cataracts. It is thought that 10% to 30% of newborns with classic galactosemia develop cataracts in the first few days or weeks of life. Once a newborn is put on a galactose-restricted diet, cataracts usually clear.
        - Galactokinase deficiency
        - Congenital hemolytic jaundice
        - Fabry's disease
        - Refsum's disease
        - Mannosidosis
    - With miscellaneous hereditary syndromes
        - Norrie's disease
        - Hereditary spherocytosis
        - Myotonic dystrophy
- **Nonhereditary**
    - Prenatal causes
    - Postnatal causes
    - Associated with another ocular abnormality

Morphological Classification

- **Term “zonular cataract” is used to describe lens opacities, which are localized to one part of the lens; the term may encompass nuclear, sutural and lamellar opacities. Its no more used now and particular term like sutural or lamellar is used.**
- Diffuse/total
- Anterior polar

- Lamellar
- Nuclear
- Posterior polar
- Posterior lentiglobus
- Posterior (and anterior) subcapsular
- Persistent hyperplastic primary vitreous
- Traumatic
- Anterior Polar Cataract (APC): symmetrical and discrete lesions
- Posterior Polar Cataract (PPC): stationary and progressive
- Nuclear: opacification of embryonal and/or fetal nuclei.
- Coppock cataract: opacities within a 6-mm nucleus
- Coppock-like cataract: fetal nucleus, approximately 2.5 mm in diameter, early insult
- Lamellar: the concentric deposition of newly differentiated secondary fiber cells around the embryonal nucleus during normal lens
- Pulverulent: characterized by powdery (pulverized) opacities that may be present throughout the lens
- Aceuliform: rare form of congenital cataract is associated with needle-like projections extending from the nucleus into the anterior and posterior cortex. Also called "speisskatarakt" and "needleshaped cataract"
- Cerulean: discrete pinhead-shaped blue-and-white opacities are distributed throughout the lens
- Total: Complete opacification of the fetal nucleus at birth and the cortex after birth is referred to as total cataract
- Cortical: late insult as there is opacification in the newly formed secondary fibers.
- Polymorphic:
- Sutural: isolated sutural opacities may be seen in female carriers of X-linked cataract, particularly Nance-Horan Syndrome

Genetics

- Most inherited nonsyndromic cataracts show an **autosomal dominant**
- Nearly **one-third** of congenital cataract patients have a ***positive family history***.
- Mutations in 11 genes, **including 6 genes for crystallins** (αA, αB, βA3/A1, βB2, γC, γD), 2 for gap junctional proteins (GJA-3 and GJA-8), 1 for beaded filament chain protein (BFSP-2), 1 for major intrinsic protein (MIP), and 1 for heat shock factor (HSF-4), have been identified for its different phenotypes

Epidemiology

- **Prevalence of childhood cataract**: **1 to 6 per 10,000** children
- The prevalence of **BL from cataracts in children** in developing countries is probably **1 to 4/10,000**, compared with approximately 0.1 to 0.4/10,000 children in the industrialized world.

Preoperative Workup

Evaluation

- **Presentation**
  - White pupillary reflex
  - Strabismus
  - Nystagmus or poor visual fixation
  - School/ preschool vision screening
- **Visual Acuity**
  - Assessed by history, observation of the ocular fixation and following reflex, behavioral testing, and electrophysiologic examination.

Indications for Treatment

- Central cataracts >3 mm in diameter (visually significant)
- Dense nuclear cataracts
- Cataracts obstructing the examiner's view of the fundus or preventing refraction of the patient
- If the contralateral cataract has been removed
- Cataracts associated with strabismus and/or nystagmus.
- The threshold for surgical removal of a partial cataract: 20/50 or worse.
- Unilateral cataract: immediately.

IOL Power calculations

- Axial length (AL): A-Scan ultrasound can be done using either contact or immersion methods
- Cornea power (K): handheld keratometry,

Pediatric Cataract Surgery

History

- 1950s: complications of Surgery → thick secondary membranes, glaucoma, and corneal decompensation. So other methods were invented as follow:
- Optical Iridectomy
- Discission/Needling: **Aurelius Cornelius** (Roman physician)
- Through-and-Through Discission: **Ziegler** → Ziegler knife
- Linear Extraction: needling procedure f/by irrigation; **Gibson**
- Aspiration of Cataracts: 1960, **Scheie**
- Irrigation-Aspiration Technique: double-barreled cannula
- Intracapsular Extraction
- Automated vitrector
- Phacoemulsification: 1970
- IOL Implantation

First implant in a child for aphakic correction	1958	Epstein/Choyce
Manual aspiration of congenital/juvenile cataract	1960	Scheie
Iridocapsular implant	1969	Binkhorst
Advancement in vitreous cutting instrument	1972	Machemer
Binkhorst intraocular lenses (IOLs)	1977-1982	Hiles
Posterior chamber IOLs	1982	Hiles
Iris-claw lenses	1983	Singh
Pathophysiology of amblyopia	1977-1985	Weisel/Raviola
Posterior chamber IOLs	1983-1993	Sinskey/Hiles
Posterior capsulotomy/anterior vitrectomy	1983	Parks
Epikeratophakia	1986	Morgan
Epilenticular IOL/pars plana endocapsular lensectomy	1988	Tablante
Retropseudophakic Vitrectomy via limbus	1991	Mackool/Chhatiawala
Pars plana posterior capsulectomy and vitrectomy	1993	Buckley et al.
Primary posterior capsulorhexis/optic capture	1994	Gimbel/DeBroff
IOL biomaterials/Designs/sizing in children	1994	Wilson et al.
Primary posterior capsulotomy & anterior vitrectomy	1994-2000	BenEzra/Cohen Vasavada/ Desai/Trivedi
Anterior capsulotomy for pediatric cataract surgery (vitrectorhexis)	1994	Wilson et al.
Heparin in BSS to decrease postoperative inflammation	1995	Brady et al.
Dye-enhanced pediatric cataract surgery	2000-2002	Pandey et al.
BSS, balanced salt solution.		

Incision Construction

- Location: Superior/Temporal/Meridian of Steepest Curvature
- Scleral/Corneal:

- Shape of the Incision: Straight/Frown/Circumlimbal

Anterior Capsule Management

Anterior capsulotomy & IOL	1949	Sir Harold Ridley
Can-opener capsulotomy	Unknown	Little and Pearce
Envelope (horizontal)	1979	Galand/Baikoff
CCC for adults	1992	Gimbel & Neuhann
Vitrectorhexis	1994	Wilson et al.
Push-pull CCC in rabbit model	1994	Auffarth et al.
Radiofrequency diathermy	1994	Kloti
Fugo plasma blade	1999	R. Fugo
Dye-enhanced CCC/cataract surgery	2000	Pandey/Werner/Apple/Wilson

- The anterior capsule in children is very elastic, and therefore it may be difficult to perform a controlled manual continuous curvilinear capsulorhexis (CCC). However, manual continuous curvilinear capsulorhexis remains a gold standard for resistance to tearing and should be accomplished whenever possible.
- Difficulties of performing manual CCC in infantile eye led researchers and surgeons to search for alternative methods to open the anterior capsule in children.
- Alternatives to manual CCC currently available include vitrectorhexis, radiofrequency diathermy with a Fugo plasma blade, the two incision push pull technique, and the four incision technique. Wilson analyzed paediatric anterior capsulotomy techniques using porcine model and found that manual capsulorhexis produced the most extensible capsulotomy with most regular and stable edge.
- In eyes with poor anterior capsule visibility, trypan blue (0.0125%) may be used to stain the anterior capsule. The shape, size and edge integrity of anterior capsulotomy are very important for long-term centration of the IOL.

Multiquadrant Hydrodissection

- **Faust** coined the term hydrodissection in 1984
- 1992, **Fine** published his classic description of the "cortical-cleaving hydrodissection" technique
- **Signs of Successful Hydrodissection**
  - Forward bulge of the nucleus
  - Visible presence of a fluid wave: This is considered a definitive sign of successful hydrodissection, but it may not always be visible in pediatric eyes. Strong corticocapsular adhesions in pediatric eyes may prevent the appearance of a visible fluid wave.
  - Prominence of the capsulorhexis edge
  - Release of trapped fluid from the rhexis margin following decompression of the nucleus

Lens Substance Aspiration

- Not only to aspirate the lens substance, but to aspirate it thoroughly.
    - Single-Port Versus Bimanual Approach
    - Manual Versus Automated Approach

Posterior Capsulotomy and Anterior Vitrectomy

- Proponents & Opponents
    - <5 years: PCC+AV
    - 5-8 years: PCC
    - >8 years: intact PC
- Primary capsulotomy versus secondary capsulotomy
- Surgical capsulotomy versus YAG laser capsulotomy
- Type of surgical opening: Capsulorhexis or capsulotomy?
- Limbal versus pars plana approach
- Before versus after IOL implantation
- Architecture of the posterior capsule opening: size, centricity, and shape
- Does no-suture vitrectomy technology have a role?
- Are special aids or techniques for visualization needed?
- How is the end point of the vitrectomy defined? How much vitreous should be removed?

Lensectomy and Anterior Vitrectomy

Posterior Chamber Lens Implants

- One of the most important preoperative considerations is whether to implant an IOL or not. Surgeons should be prepared for the common question "Would you implant an IOL if this were your child?" The capability of the IOL to offer constant visual input is an important advantage for the better visual outcome after paediatric cataract surgery. Use of IOL provides at least a partial optical correction at all times. Because of the advantage it offers, primary IOL implantation has slowly gained acceptance for the management of childhood cataracts. However, as of 2007, use of IOL remains controversial for the management of infantile cataract.The important concerns about primary IOL implantation during infancy are the technical difficulties of implanting an IOL and selecting an IOL power, and the higher rate of visual axis opacification (VAO). At present, only adult sized IOLs are available, which are often difficult to implant in these small eyes and may cause complications over the long run. Currently available adult sized IOLs are slightly oversized and at times may not fit into small infantile eyes.
- The size of the posterior capsulorhexis should be large enough to provide a clear central visual axis, but smaller than the IOL optic, so as to allow stable in-the-bag IOL fixation. Even if the surgeon is not planning to implant an IOL in a specific eye, it is important to

leave behind sufficient anterior and posterior capsular support at the time of cataract surgery to facilitate subsequent IOL implantation. The common practice is to perform posterior capsulectomy and anterior vitrectomy before IOL implantation if the limbal approach has been used whereas, if a pars plana vitrectorhexis is performed, it is done after the IOL is implanted. Further there is no agreement on whether the IOL should be implanted before or after the primary posterior capsulectomy. Some surgeons perform a pars plicata capsulectomy and vitrectomy with the vitrectome after implanting the IOL in the bag. Both PMMA and hydrophobic acrylic foldable IOLs have been widely used in paediatric eyes. However, several studies have now shown that hydrophobic acrylic IOLs are preferable as they offer better uveal biocompatibility and decreased incidence of VAO, with hydrophobic acrylic IOLs causing a delayed onset of PCO.For bilateral cataract during first year, aphakic glasses and/or contact lens use may be a reasonable option; however, for unilateral cataract, we are truly equipoised between whether or not to offer primary IOL implantation at the time of infantile cataract surgery. A large randomized clinical trial the Infant Aphakia Treatment Study (IATS) is currently underway to compare primary IOL implantation to contact lens correction in children undergoing unilateral cataract surgery in the first six months of life.

Newer Approaches in Pediatric cataract surgery

- **Sealed Capsule Irrigation:** Maloof and associates have designed a sealed capsule irrigation device (Perfect CapsuleTM) that can help to selectively irrigate the capsular bag. This may help paediatric cataract surgeons to eliminate or delay VAO by using such chemicals through this device.
- **Manual PCCC via Pars plana approach:** Vasavada and coauthors recently introduced a technique of performing manual PCCC via pars plicata. After implantation of the IOL in the capsular bag all the incisions are sutured with 10-0 nylon and residual OVD is left in the anterior chamber. The pars plicata entry is made 1 - 1.5 mm behind the limbus and an initial puncture is made in the center of the posterior capsule and later a coaxial capsulorhexis forceps is introduced and a flap is generated .The edge of the flap is grasped and then re-grasped every 2 clock hours fashioning the PCCC in a clockwise manner.
- **Bag-in-the-lens implantation:** Tassignon and colleagues reported the outcome of a surgical procedure they called ‘bag-in-the-lens’ in paediatric cataractous eyes In this technique, the anterior and posterior capsules are placed in the groove of a specially designed IOL after a capsulorhexis of the same size is created in both capsules The principle behind this IOL design is to ensure a clear visual axis by mechanically tucking the two capsules into the IOL, thereby preventing any migration of proliferating lens epithelial cells.
- **Heparin in irrigating solution:** Heparin has been used in intraocular irrigating solutions to reduce inflammatory reactions after paediatric cataract surgery. It has been documented that infusion of enoxaparin, a low molecular weight heparin, during paediatric cataract surgery may minimize the postoperative inflammatory response.
- **Posterior capsulorhexis combined with optic buttonholing:** Recently R. Menapace introduced Posterior optic buttonholing (POBH) a safe and effective technique which not

only excludes retro-optical opacification, but also withholds capsular fibrosis by obviating direct contact between the anterior capsular leaf and the optic surface.

Associated Anatomical Anomalies

Type I Diabetes Mellitus

- **1%**
- Acute cataracts have been described in young people as a presenting feature of their diabetes. band of anterior or posterior subcapsular vacuoles or dense white cortical "***snowflake" opacities***.
- **osmotic hypothesis**→ The polyol pathway involves intracellular excess glucose being reduced to sorbitol by aldose reductase. Sorbitol is then reduced by sorbitol dehydrogenase to fructose, which can penetrate the cell membrane. The increase in intracellular sorbitol causes an osmotic gradient leading to swelling of lens fibers and subsequent alterations of membrane permeability. There is a resultant loss of potassium ions and amino acids, with a rise in sodium ions and a cessation of lens protein production. Continued lens hydration and electrolyte disturbances result in lenticular opacification.

Persistent Fetal Vasculature

- **Goldberg** replaced term PHPV to PFV in his **1997** Jackson Memorial Lecture
- some, or all, components of the fetal intraocular vasculature remain after birth.
- several clinical variants
  - Persistent pupillary membrane.
  - Iridohyaloid blood vessels.
  - Persistence of the posterior fibrovascular sheath of the lens.
  - Mittendorf dot.
  - Persistent hyaloid artery
  - Bergmeister papilla.
  - Congenital tent-shaped retinal detachment.
  - Macular abnormalities.
  - Optic nerve abnormalities.
  - Microphthalmos.
- **5-10% bilateral**
- **Management**:
  - Posterior Approach
  - Anterior Approach
- **Complications**: glaucoma, secondary membrane formation, vitreous hemorrhage, retinal detachment, and strabismus.

Retinopathy of Prematurity

- **Transient**: Focal opacities (either punctate or vacuolated) insignificant and often resolve spontaneously.
- **Progressive and visually significant**: Progressive lens opacification generally leads to total cataract and completely obstructs the visual axis.
- **Associated with retinal detachment**.
- **Etiopathogenesis**
    - Tunica vasculosa lentis
    - Anterior segment ischemia
    - Thermal injury
    - Uveal effusion
    - Vitreoretinal pathology
    - Rent in lens capsule

Eyes Treated for Retinoblastoma

- In cataract caused by irradiation there is a tendency toward a ***proliferation of the epithelium under the anterior capsule into a metaplastic fibrous layer***. This strengthens the anterior capsule and makes this type of cataract particularly suitable for intracapsular extraction. **Extracapsular extraction in such cases is contraindicated** because the lens epithelium remaining after the nucleus is extracted may continue to proliferate and form dense fibrous tissue, which tends to produce iridocyclitis and secondary glaucoma.

Preexisting Posterior Capsule Defects -PPCD

- **10%**
- **Singh signs**
    - A deep anterior chamber
    - White to chalky-white spots are produced, which are seen in front of and around the posterior capsular defect.
    - The capsule behind the opaque lens may show a partial or a complete white ring-shaped opacity. This opacity is contained within the posterior cortex, while the posterior capsule shows a hole with chalky-white spots on and around the defect.
    - Rarely, an opening in the posterior capsule shows pigment along the margins. Fine dustlike pigment along with fine dense white opacities may be seen in the Berger space. The presence of pigment suggests widespread movement of the fluid beyond the posterior capsular defect.
- Membranous cataract
- Mostly empty capsular bag.

- Opaque posteriorly displaced fetal nucleus.
- Milk bag cataract.
- Partial or complete opacification of the lens.
- Posterior lenticonus.
- Thick fibrovascular membrane in the pupil in place of a cataract.
- Large ciliary processes attached to the back of a normal-sized lens
- Pearly white thick membrane presentation of the posterior capsule.
- Posterior subcapsular cataract with attached hyaloid vessel.
- Dumbell cataract.
- Onion ring cataract.
- Posterior capsular plaque.

Anterior Lenticonus in Alport Syndrome

- ***less common than posterior lenticonus*** and most often found in association with **Alport syndrome** (AS)
- However, isolated cases have been reported, as well as a rare association with **Lowe syndrome** and **Waardenburg syndrome**
- The **anomalous basement membranes** of the ocular, auditory, and renal systems cause the characteristic triad of abnormalities in patients with AS (i.e., ***ocular signs, sensorineural deafness, and hereditary nephritis***).
- genetic defect within one of **the α chains of Type IV collagen**,
- **Management**:
    - Conservative Management
    - Surgical Approach

Aniridia and Cataracts

- **1 in 64,000** to 1 in 96,000 live births
- **panocular syndrome** in which the most dramatic manifestation is partial or nearly complete absence of the iris
- **bilateral in 98%**
- ***Genetics***
    - AD 85%
    - Congenital sporadic aniridia: WAGR 13%, 11p13
    - AR 2%, a/w cerebellar ataxia and mental retardation (Gillespie's syndrome).
- Cataracts develop in **50 to 85%**

Lowe Syndrome

- X-linked recessive, **Xq25** (**Lyon's hypothesis**, which implies that, very early in embryogenesis, one of the two X chromosomes in females is deactivated.)
- **oculocerebrorenal syndrome**
- mental retardation, Fanconi syndrome of the proximal renal tubules, and congenital cataract. Other findings include glaucoma, corneal opacity (keloid), enophthalmos, hypotonia, metabolic acidosis, proteinuria, and amino aciduria.
- degeneration of the primary posterior lens fibers account for their loss and for the flattened, discoid, or ring-shaped cataract. The other findings, such as anterior polar cataract, subcapsular fibrous plaque, capsular excrescences, bladder cells, and posterior lenticonus

Dislocated Crystalline Lenses

- Marfan syndrome, homocysteinuria, and Weill Marchesani syndrome

Eyes with Uveitis

- juvenile idiopathic arthritis (JIA), inflammatory bowel disease, ankylosing spondylitis, Reiter's disease, and sarcoidosis.

Intraoperative Complications

- Incision-Related Complications:
- Formation of the Capsulorhexis → "**runaway rhexis**" , Inappropriate size and shape, radial tear during surgery
- Positive Vitreous Pressure
- Intraoperative Miosis → iris hooks, using the Beehler dilator, performing multiple sphincterotomies with microscissors, using iris retractors, and using the Graether pupil expander, Perfect Pupil Injectable (some infants usually have nearly cryptless irises with a poorly formed pupillary ruff and no collarette.)
- Complications of the Posterior Capsule: tear
  - pars plana posterior capsulotomy and anterior vitrectomy → laceration of the equator of the capsular bag, bleeding into the vitreous cavity
- Zonular Dialysis:
- Intraocular Lens Complications → malplacement or malpositioning, Displacement of the IOL through a primary posterior capsulotomy
- Miscellaneous: rupture of the posterior capsule may occur during the surgical step of hydrodissection

Postoperative Complications

- **Early-Onset Postoperative Complications**
    - **Postoperative anterior uveitis** (fibrinous or exudative)
        - 5 units of intravenous heparin in 500 mL of irrigating solution.
        - heparin-surface-modified (HSM) IOLs
        - intraocular streptokinase (500-1,000 IU)
    - **Corneal Edema**
    - **Endophthalmitis:** 7 in 10,000
    - **Noninfectious Inflammation:** excessive photophobia, tearing, and even the inability to open the eyes postoperatively. It may persist for days or even weeks and may preclude early contact lens fitting in aphakic patients.

- **Late-Onset Postoperative Complications**
    - **Capsular Bag Opacification**: universal, beginning at 18 months after surgery and reaching nearly 100% over time
        - PCC
        - PCC + AV
        - square-edge IOL profile
        - posterior capsulorhexis with optic capture without anterior vitrectomy.
        - Predisposing Factors for Recurrent Opacification
            - Capsulotomy Size: <3 mm, increased risk
            - Age at Surgery: 4.7 times higher in children <1 year of age
            - Sulcus Versus Bag Fixation: no significant difference??
            - Type of Cataract: traumatic > congenital
            - Associated Ocular and Systemic Conditions: PFV (persistent fetal vasculature) or microcornea; ocular conditions such as rubella syndrome, toxocariasis, toxoplasmosis, and pars planitis; and systemic diseases such as juvenile rheumatoid arthritis are associated with a higher incidence
    - **Secondary Membrane Formation**: closure across a previously open space such as the pupillary membrane after anterior capsulotomy or a posterior membrane after posterior capsulotomy.
    - **Pupillary Capture**: 8.5 to 41%, when IOL is in the sulcus or small optic IOL implanted
    - **Deposits on the IOL Surface**: pigments, inflammatory cells, fibrin, blood breakdown products
    - IOL Decentration:
    - Delayed Postoperative Opacification of Foldable IOLs
    - **Postoperative Glaucoma:**

  - 6.1% (Chrousos study)
  - 3 to 32%
  - More in aphakia than in pseudophakia
  - **Mechanism**:
    - ***Open-angle mechanism (Walton's)*** → circumferential repositioning of the iris insertion anteriorly at the level of the posterior or mid-trabecular meshwork with resultant loss to view of the ciliary body band and scleral spur occurred.
    - ***Pupillary block and chronic angle closure*** from peripheral anterior synechiae as the typical mechanism following cataract removal by the "aspiration" mechanism. (theory not accepted now)
  - **Risk Factors**
    - microcornea, poorly dilating pupils, surgery at <1 year of age, the presence of other ocular disease (e.g., congenital rubella syndrome), nuclear cataract, persistent fetal vasculature (PFV), and performance of a posterior capsulorhexis.
  - **Treatment**
    - A surgical or laser peripheral iridectomy is standard treatment once pupillary block is recognized.
    - seton implantation, trabeculectomy, and cyclodestructive procedures.

- **Retinal Detachment:**
  - **1 to 1.5%.**
  - higher incidence of RD in males, myopes, those in the second and fourth decades of life, and those with a longer interval after cataract surgery
  - **Post YAG Cap: 2.5% in 1 year, 3.6% in 2 years.**
- **Cystoid Macular Edema**
  - Typically CME is noted 4 to 16 weeks after cataract surgery
  - Relatively less than adults due to better vascular stability
  - Angiographical CME: as high as **70%**
  - clinical CME: **0.2 and 0.4%**
  - CME in c/o vitreous loss during cataract surgery: **10 to 20%**
  - main etiologic factors: direct vitreous traction on the macula, ocular inflammation, increasing age, and other contributory factors such as hypotony
- **Hemorrhagic Retinopathy:** flame-shaped retinal hemorrhages during the first 24 hr following surgery, are nonprogressive, and resolve within a few weeks.
- **Strabismus**:
  - 33.3% of patients preoperatively
  - 78.1% of patients postoperatively (aphakia)

- 9% of children with unilateral pseudophakia

Management of Residual Refractive Error

- After Surgery in Infancy
  - small soft eyes will not yield a reliable refraction
  - marked temporary astigmatism (often 3 to 5 D [diopters]) will be seen initially
  - axial growth in a normal eye is 4.5 mm = 10D over the first 2 years
  - **maximum single IOL**: **30 D → up to 40 D** can now be ordered
- After Surgery in Toddlers
  - 2 to age 6 years: 0.4 mm per year
  - Unlike infants, these children are prescribed their full cycloplegic refraction for distance and a +3.00-D bifocal for near viewing.
- After Surgery in School-Aged
  - plano refractive aim when surgery was done at age 10 years

Aphakia

Contraindications to Intraocular Lens Implantation

1. Institutional factor: Nonavailability of an IOL
2. Surgical factor: Surgeon prefers not to implant a lens in the patient.
3. Patient factors: Minimum age at surgery for an IOL implantation varies from surgeon to surgeon and varies between unilateral and bilateral cataracts.
4. Ocular factors: Vary from surgeon to surgeon: ***associated uveitis, severe microphthalmia such that IOL size is not feasible to implant, persistent fetal vasculature, inadequate anterior and/or posterior capsular support***, etc.
5. Parental factor: Permission/consent denied

Different Modalities to Correct Aphakia

- **Aphakic glasses**
  - three primary types of high-power plus-lenses
  - Lenticular lenses
  - Aspheric lenticular lenses
  - Multidrop lenses
  - Selecting a Frame: smallest frame, strong color, proper bridge, Cable temples (earpieces) that wrap around the back of the ear, Spring hinges

- **Contact lenses**
  - PMMA
  - Soft material
  - Silicone
  - Complications
    - Lens Loss
    - Noncompliance
    - Infection
    - Corneal vascularization
    - Power changes
    - Parental stress

- **Epikeratophakia**: The only theoretical indication for this procedure is probably a patient with unilateral aphakia who cannot have an IOL implant (because of serious intraocular inflammation, uveitis) and is intolerant of contact lenses.
- Intraocular lens

Assessment of Visual Functions

- Resolution acuity: ability to resolve the spatial separation of contrasting visual stimuli
- Recognition acuity: knowledge of the stimulus shape and/or ability to match the shape

Symbol and Letter Recognition

- LEA symbols (3 meters)
- New York Lighthouse Acuity Test (3 meters)
- Glasgow acuity cards (3 meters) → progression of letter size in equal steps, equivalent letter spacing on each line, and an equal number of letters per line.
  - Crowding reduces recognition acuity significantly, when stimuli are at high contrast but at low contrast the effect of crowding is negligible.

Preferential Looking Technique

- **Keeler and Teller** cards
- **forced-choice PL**:
- **Cardiff Acuity test**: Instead of a grating pattern, the stimuli consist of simple, recognizable shapes. The stimuli are known as "***vanishing optotypes***" because the shapes disappear at the observer's resolution limit.

Visual Electrophysiology

- ERG to assess retinal function
- VEP to assess function of the retino-cortical visual pathway

Optokinetic Nystagmus

- Slow pursuit phase, during which a moving target is smoothly tracked, followed by a fast saccadic phase, allowing refixation when the eye meets its limit of movement in the direction of pursuit.
- Catford drum
- VEP acuity up to four times higher than PL acuity in early infancy16 and PL acuity two to three times higher than OKN acuity during the first 3 years

Contrast Sensitivity

- Enhancement Game
- Hiding Heidi (HH) test
- LEA low-contrast symbols

Amblyopia Management

- Postoperative compliant occlusion therapy
- Pharmacological penalization

Phakic Intraocular Lenses in Children

- Three basic types of lenses
  1. posterior chamber ciliary body sulcus-supported
  2. anterior chamber angle supported
  3. anterior chamber iris fixated: whether the iris will tolerate fixation of the lens haptics
- Posterior chamber is a triangular space of about 65 μL
- Zero depth at the pupillary margin
- Angle-supported lens: said to be supported by the scleral spur (which is situated at a depth), actually rest and press against the corneoscleral trabeculae, Schlemm canal, ciliary body in the angle recess, and, sometimes, blood vessels and nerves nearby.

Patient suitability

- **Corneal diameter <11 mm** is not suitable for angle-supported
- **2.7-mm ACD** is the lowest acceptable limit

- Preferably two YAG-PI

Complications

- **Early**: Pupil block glaucoma, Inflammatory reactions, Size mismatch, Hyphema, An injury to the crystalline lens
- **Late**: Acute or subacute inflammation, Cataract formation, Erosion of iris and ciliary body, Ovalization of the pupil, Endothelial loss

Pediatric Refractive Surgery

Hutchinson's review Questions

1. Does the pediatric cornea respond differently to the excimer laser than the adult cornea?
2. What is the ideal laser refractive procedure for children?
3. Are refractive outcomes predictable and stable in children?

Hutchinson's review Answers

1. Complications such as haze, regression, diffuse lamellar keratitis, and even corneal flap problems have not occurred in children to a greater extent than in adults.
2. The ideal procedure for children would be one that is painless, requires little cooperation, has a precise refractive predictability that is stable over time, has a low risk for loss of best corrected visual acuity, and is adjustable (or can be advanced). ***NO IDEAL PROCEDURE EXISTS.***
3. Refractive outcomes are less predictable and are likely to be less stable than in adults.

Traumatic Cataracts in Children

- Trauma has been reported to be responsible for up to **29%** of all childhood cataracts
- **Blunt trauma**: coup, countercoup, and equatorial expansion
  - classically form stellateor rosette-shaped posterior axial opacities
- **Penetrating trauma**:
  - disruption of the lens capsule forms cortical changes that may remain focal if small or may progress rapidly to total cortical opacification
- **Examination**
  - ***Before Dilation***: BCVA, Fixation preference, Pupillary reflex, IOP, Iris, Zonule
  - ***After Dilation***: Slit-lamp examination, posterior segment examination, Gonioscopy
  - AL, Keratometry
- **Timing of Surgery:**

    - IOL implantation at the time of primary repair.
    - not necessarily required at the time of initial repair even when anterior capsular rupture is present.
- IOL Implantation
- **Postoperative Complications**: PCO and/or secondary membrane formation, pupillary capture, IOL precipitates, and decentration/dislocation of the implant.

Approach

- **The Incision:** MVR for Bimanual, "near clear" incision for IOL, The superior approach allows the wound to be protected by the brow and Bell's phenomenon in the trauma-prone childhood years. Both scleral tunnels and corneal tunnels can be easily made from a superior approach since children rarely have deep-set orbits or overhanging brows.
- Anterior Capsulotomy:
- CCC
- Vitrectorhexis
- high-frequency endodiathermy (Kloti radiofrequency endodiathermy)
- Fugo plasma blade
- Phacoaspiration:
- Primary IOL Implantation:
- Secondary IOL Implantation:
- IOL Power Selection:
- Management of the Posterior Capsule
- Postoperative Management

Tips & Tricks for Pediatric Cataract Management

- **Pre-existing Incompetent Posterior Capsules Are Common in Children**
    - When in doubt, don't hydrodissect.
    - Look for the "fishtail sign" intraoperatively.
    - Make a careful anterior capsulorrhexis; it may be the only support you have by the end of the surgery.
    - When doing bimanual irrigation and aspiration, substitute the vitrector for the aspiration handpiece if there is any chance you will encounter pre-existing lens/ vitreous admixture.
- **Vitrectomy**: Highest Cut-Rate (7500 or More Cuts/ Minute) for Safety
    - Vitrectomy doesn't cause retinal holes and detachment; vitreoretinal *traction* causes retinal holes and detachment. Learn to use proper technique and the highest cut-rate available. I now use the same cut rate for cutting capsule and for cutting vitreous. There is no need to vary the cutting speed.

- *Never ever* place a Weck-Cel sponge in contact with vitreous. If vitreous presents at the wound, hold the vitrectomy cutter up to the wound to safely amputate vitreous without traction. Do not pull on vitreous.
- Learn to do bimanual surgery. Separate the infusion from the cutting handpiece; Venturi-pump machines work best for what we do.
- Use tight-fit incisions for less chamber bounce. This leads to less inflammation postoperatively.
- Become comfortable switching hands. Practice placing the vitrector or aspirator in your nondominant hand. When you need it in a tough case is not the time to learn.
- Become comfortable with both the anterior and the pars plana approach. Trocars are for tool transfer; just use an MVR blade and don't bother with a trocar.
- Check for vitreous using intracameral preservativefree triamcinolone whenever you can.

- **Wound Management:** Use 10.0 Vicryl
  - Incisions often leak in pediatric eyes, even wellmade incisions.
  - Soft tissues mold into the round shape of the instrument placed through them.
  - Suture the operative wounds (10.0 Vicryl) and even add a sealant when needed.
  - The exceptions are wounds that only iris hooks or forceps have entered; these can often be left unsutured.
- **Aphakic Contact Lens Management:** Put the Lens On at the Completion of Surgery
  - When choosing to leave an infant aphakic at surgery, consider placing a silicone elastomer contact lens on the operating table at the conclusion of surgery and leaving it untouched for the first postoperative month. No patch or shield is needed since the contact lens acts as a bandage and the incisions are very small and are sutured.
  - To calculate the needed contact lens power, I perform A-scan ultrasound biometry in the operating room just before the surgery starts. I use 111.9 as the lens constant and use a common IOL formula like the Holladay, SRK/T, or Barrett.
  - The rule of thumb for base-curve of the silicone elastomer contact lens is to use a 7.5 base curve in infants and a 7.7 base curve after 18-24 months (modify based on K-readings when needed, but rarely is modification from the above rule of thumb needed).
  - Leave the contact lens in place day and night and use the postoperative drops as prescribed. At the 1-month postoperative visit, one of our technicians teaches the parents how to insert, remove, and clean the contact lens. After that visit, the parents remove the contact lens weekly.
- **Secondary IOLs:** Plan Ahead
  - Plan the first surgery with the second surgery in mind. The result is that most secondary IOLs can be placed within the capsular bag.
  - Placing an IOL in the ciliary sulcus is not bad, but late decentrations are more common than you think. Consider optic capture for stable centration when the sulcus is chosen.

- **Parental Compliance With Postoperative Drops Is Variable**
  - For more consistent healing, consider using intracameral or intracanalicular delivery options for steroids to reduce reliance on compliance. These are rapidly becoming commonplace for cataract surgery in children (triamcinolone or dexamethasone).
  - Anti-inflammatory drop of choice is prednisolone acetate 1% given q.i.d. for 4 weeks.
  - Intracameral preservative-free moxifloxacin is preferred antibiotic.

Miscellaneous

Iris Defect Management

- Traumatic cataracts are frequently associated with traumatic mydriasis, iridodialysis, or even iris tissue defects due to prolapse or excision during primary surgical repair. To address the associated glare, photophobia, and abnormal contrast sensitivity, cataract surgery affords the opportunity for simultaneous repair of the iris abnormality. One alternative to use an artificial iris implant. However there is usually sufficient iris tissue present with a traumatic mydriasis to permit a pupil cerclage procedure.
- **Tools for Management**
    - Bonn Hook, Kuglen Hook
    - Suture 10-0 Polypropylene
    - MST Microsurgical Forceps And 23 Gauge Scissors
    - Dispersive Viscoelastic
    - Dock Needle Into 27 Gauge Cannula If Using Cif-4 Needle (Ethicon) To Avoid Corneal Damage (Leak).
    - Can Also Use 10-0 Polypropylene Pc-7 Needle (Alcon) Or Ctc-6 10-0 Polypropylene (Ethicon)
- **Iris Suture Fixation (ISF) of IOL**
    - Don't Dilate Pre-Op To Allow For Intracameral Control Of Pupil Size
    - McCannel Technique To Start And Then Siepser
    - This Is Best With Some Capsule Support Particularly Is Post Ppv
- **McCannel's Technique**
    - Midperipheral or peripheral iris defects
    - Use of 10-0 monofilament nylon in a curved needle to repair iridodialysis was first described by McCannel.
    - Make paracentesis at the midpoint of the suture throw
    - Free iris and knot from paracentesis with spatula to avoid synechiae
- **Siepser Knot**
    - Siepser described an elegant technique for repair of iris and pupil defects using 10-0 polypropylene suture. This technique involves creation of two paracentesis wounds, 180 degrees apart along the line of pupillary defect. The 10-0 prolene suture needle is introduced through one paracentesis and taken out through the other. The trailing end of the suture is then pulled out to form a loop and a sliding knot is made. The knot is secured and then trimmed.
- **Modified McCannel Iris Suturing Technique**
    - McCannel technique was further modified by Wacheler and Krueger who demonstrated use of a 17mm straight double arm polypropylene suture to repair iris defects. This technique can be easily adaptable to even by beginners to repair iris defects.

- **Iridodialysis Repair**
    - Can Dock Into 26 Gauge Needle Or Exit Ab Interno
    - Determine Location Of Scleral Fixation By Limbal Landmark (1.5-2.0Mm)
    - 10-0 Polypropylene (Cif-4/ Pc-7 Curved Vs Stc-6 Straight Needle) Or 9-0 Polypropylene (Ctc-6 Curved)
    - Fix Iridodialysis Prior To Cerclage
    - Use A Mccannel Or Siepser Sliding Knot Technique.

Nd:YAG Laser Capsulotomy

- **Indications**
    - Visually symptomatic posterior capsule opacification (PCO)
    - To enhance view of fundus
    - Posterior capsular distension syndrome
- **Contraindications**
    - Lens implant exchange likely
    - Unstable intraocular lens (IOL)
    - Untreated acute retinal tear
    - Uveitis, including inflammation associated with *P. acnes* or other low virulence organism
- **Complications & Management**
    - Retinal tear/detachment: Pretreatment examination of peripheral retina, Treatment of preexisting retinal breaks
    - Prolapsed vitreous into the anterior chamber: Apply laser so the capsulotomy does not extend beyond the optic
    - Transient elevation of IOP: Preand posttreatment with IOP lowering drops
    - Diabetic retinopathy
        - Pretreatment retina exam
        - Careful post-treatment exam for progression of retinopathy or appearance of neovascularization of the iris
    - Uveitis/cystoid macular edema can be induced by liberation of retained lens material: Requires frequent observation and treatment with topical corticosteroids and IOP lowering medication
    - Damage to IOLs

        - Laser damage may induce pitting of lens optic with potential for reduced visual function
        - May be prevented by posterior defocus of laser beam and with the aid of a contact lens
    - Dislocation of the IOL
- **Follow-up care**
    - Patients should be made aware of symptoms related to retinal tear or detachment and encouraged to report such changes immediately
    - In cases where retained lens material has been liberated, follow-up is necessary to evaluate inflammation, macular edema and/or elevation of IOP
    - Consider post-operative topical anti-inflammatory drug, especially in high-risk patients
- **Patient instructions**
    - Patients can return to full activities immediately following laser treatment
    - Patients must be encouraged to report any reduction in vision, alteration in field of vision, and onset of light flashes followed by "floaters"
    - Patients should be made aware that small "floaters" are commonly noted transiently following laser capsulotomy

Dysfunctional lens syndrome

- “Dysfunctional lens syndrome” (DLS) describes the natural changes in the crystalline lens after age 42 and has been ***helpful in educating patients, staff,*** and doctors about these changes.
- **There are 3 stages of DLS**
    - Stage 1 DLS
        - Typical age of patients: 42-50 years old
        - Lens changes: Disulfide bonds crosslink the lens fibers, causing it to lose flexibility and focusing power. Lens optics are still very good and BCVA is not affected.
        - Patient symptoms: Decreased near vision and having to hold reading material farther away. Reading glasses and/or bifocals become necessary.
    - Stage 2 DLS
        - Typical age of patients: 50-65 years old
        - Lens changes: Yellow discoloration and increased lens density, especially in the cortical/nuclear junction, causing increase light scatter
        - Patient symptoms: Night vision decreases and there is more need for increased illumination to read. Overall quality of vision decreases. May see increase in refractive error (either myopia or hyperopia).
    - Stage 3 DLS

- Typical age of patients: 65 or older
- Lens changes: Increased density and light scatter with loss of light transmission to a level of cataract
- Patient symptoms: Loss of high-contrast vision, contrast sensitivity, and quality of vision, especially at night

Updates on Infection & Inflammation Prevention in Cataract Surgery

- **Infection Prevention**
- Intraocular antibiotics can significantly reduce the risk for infection with lens surgery. The two main classes are:
  - Fluoroquinolones: **Moxifloxacin**
  - Cephalosporins
- Vancomycin has been largely abandoned due to the rare but serious risk for ***hemorrhagic occlusive retinal vasculitis (HORV)***.
- There are currently no antibiotics that are FDA approved for prevention of infection.
- While topical antibiotics started 1 to 3 days ahead of time may potentially reduce the levels of bacteria in and around the ocular surface, there are no controlled studies that have definitely proven that topical antibiotics lower the risk for infection.
- **Inflammation Prevention**
  - Inflammation if unchecked, can lead to cystoid macular edema (CME), corneal swelling, and other findings.
  - Most centers in the United States use a combination of a topical NSAID and topical steroid, as the combo appears to lower the risk for CME.
  - Some surgeons use only steroids for inflammation control. Other surgeons use only NSAIDs for inflammation control.
  - Phenylephrine and kerorolac intraocular solution (**Omidria**) was approved in 2016 and is effective at keeping the pupil large during surgery, as well as reducing pain postoperatively.
  - Dexamethasone intraocular suspension 9% (**Dexycu**) was approved in 2018. It is a small pellet of sustained-release dexamethasone that is placed behind the iris at the conclusion of the procedure. It is effective for lowering intraocular inflammation.
  - Dexamethasone ophthalmic insert (**Dextenza**) was approved in 2019. It is placed in the lower punctal system and provides sustained release of dexamethasone for 30 days.
  - Some surgeons place intracameral or intravitreal dexamethasone that is created at a compounding pharmacy.