Evolution of Intraocular Lenses:

Related to Cataract Surgery

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Sir Harold Ridley Inventor of first Intraocular Lens

- English eye surgeon
- Born: 10 July 1906
- Died: 25 May 2001 (Aged 94 years)
- Institutions: University of Cambridge
  St. Thomas Hospital
  Moorfields Eye Hospital

- In World War 2, he saw air force casualties with eye injuries
- Observed splinters of Perspex plastic from air craft cocknit lodged in their eyes
- Noticed no inflammation in the eyes
- Proposed implanting artificial lenses made of Perspex after cataract extraction

- First implantation was Persrex, on 29 November 1949 at St. Thomas Hospital
- First IOL permanently left in the eye (by Rayner) was on 8 February 1950

Ridley Posterior Chamber Lens 1949

- First IOL in USA was in 1952 at Wills Eye Hospital
- First IOL in Egypt was implanted by Taher in mid 1950s

(Taher, 1955 and Ayoub, 1986)

- Ridley was strongly opposed and rejected, ridiculed and deemed heretic
- Ridley worked hard to overcome complications and improve his results

- He refined his technique by late 1960s
- With his pupil Peter Choyce , achieved worldwide support
- Finally in 1981 the IOL was FDA approved as

  " Safe and Effective"

Sir Harold Ridley was Knighted by Queen Elizabeth in the year 2000

Disadvantages of spectacle aphakic vision:

- Glasses are heavy and cosmetically disabling
- Diplopia in unilateral aphakia: 30 % magnification deprives binocular vision
- Magnification of familiar objects causes false spacial orientation

(Ridley, 1984)

- Restriction of visual field ,
  Ring scotoma of 12 – 15 °, around central focused field
- Jack in the box phenomenon
- Aphakic patients with maculopathy have magnified central scotoma with high convex lens, together with peripheral field constriction

(Jaffe, 1985)

Advantages of PC- IOL :

- Normal pupillary function
- Full pupillary dilatation
- Less iris pigment dispertion

(Pearce, 1977)

- Safe with keratoplasty
- No problem with shallow AC

(Olson and Kolonder, 1979)

- Less endothelial cell loss

(Azen et al, 1983)

- Minimum pseudophakodonesis

(Crawford, 1981)

- Less interruption of blood aqueous barrier

(Miyake et al, 1984)

- Less incidence of RD and CME

(Jayal et al, 1982, Fagadan et al, 1984)

IOL Material:
(Seales´ criteria for an ideal implant)

- Chemically inert
- Physically unchanged by contact with tissue
- Non carcinogenic
- Non allergenic
- Accepted by body with no FB reaction

(Packard et al, 1981)

- Fabricated to the desired shape
- Ready to resist mechanical strains
- Readily sterilizable
- Have perfect optical quality

(Arnott, 1984)

PMMA , until then stood successful:

- Very low scattering coefficient
- High direct transmission of light
- High tensile strength
- Non biodegradable so used in IOL haptic

(Apple et al, 1984)

- Inert in the eye

(Ropper-Hall and Rich, 1985)

PMMA disadvantages:

- Susceptible to heat and radiation : brownish discoloration and cracking
- Hydrophobic : endothelial cell damage on touch *(Packard et al, 1981)*
- Hard material : corneal decompensation, iris erosion, secondary glaucoma and hyphema (UGH syndrome), mainly in AC

(Barrett and constable, 1984)

- Not biologically inert: stimulates granulomatous reaction depending on species and state of blood-ocular barrier

(Sievers and Von Dumarus, 1984)

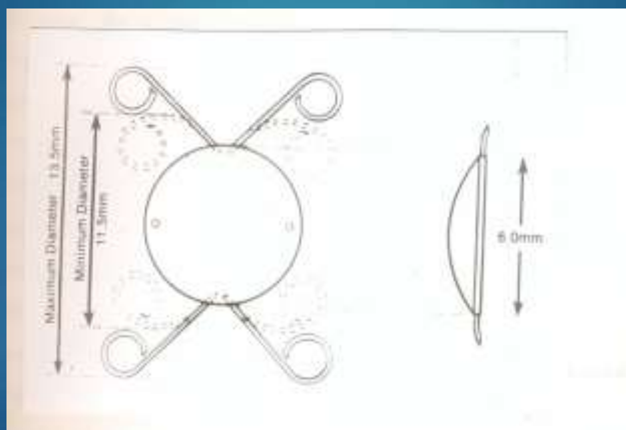
- Near UV light is filtered by crystalline lens, but passes through PMMA so the retina is vulnerable to phototoxicity

(Mc Donald and Irvine, 1983)

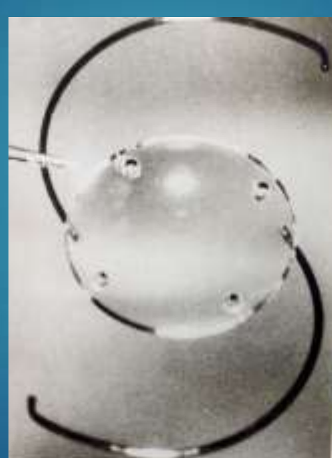
Later PMMA was manufactured with UV absorber

- Tremendous progress in lens designs has taken place.
- This attempts to respond to needs of ophthalmologists and patients
- Sometimes new designs solve the problem, yet they need further modifications

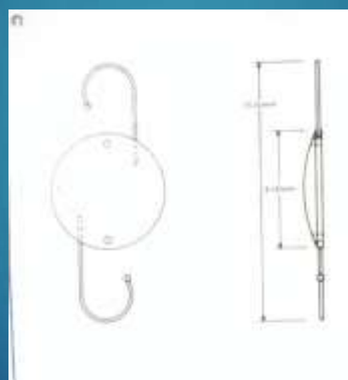
Shepard, 1974



Simcoe, 1975

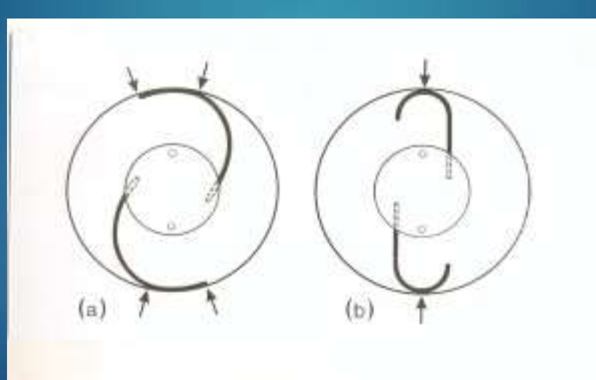


Shearing, 1984

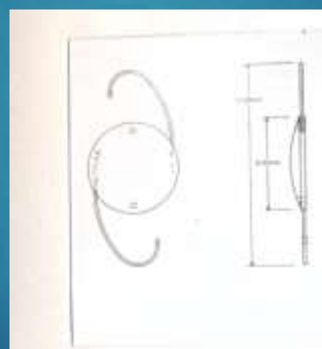


A) Broadly curved C - loops spread pressure safely over large area

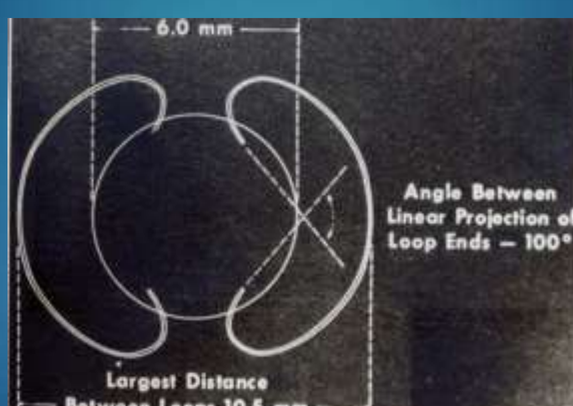
B) Sharply curved J – loops cause focal pressure on ocular tissues



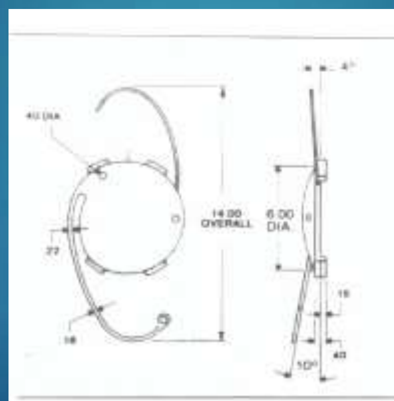
Sinskey modified Shearing Lens, 1984



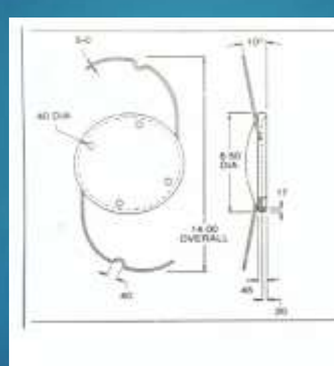
Anis, 1984



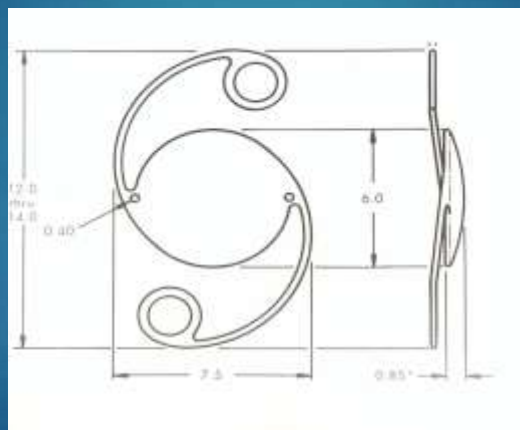
Kelman PCL



Modified C- loop with notched loop



Pannu PCL, all PMMA



ECCE, PMMA IOL:

- The use of small incision cataract surgery through clear corneal incision has been continuously increasing through the past several years
- This led to the invention of soft or foldable IOL

Advantages of small incision cataract surgery:

- Faster healing
- Rapid visual rehabilitation
- Less surgically induced astigmatism
- Less incidence of infection
- Considered now a vision correction (refractive) surgery

(Newland et al,1994 and Auffarth el, 1995)

- Epstein made experiments on soft IOLs in monkeys in 1970s
- He implanted the first soft IOL in human in 1976

(Newland et al, 1994 and Auffarth et al, 1995)

- First generation silicone IOLs: showed high incidence of giant cell ppts
- Second generation silicone IOLs: had higher RI and thinner optic and higher biocompatibility. Showed to be comparable to acrylic

(Chang, 2000)

Foldable Acrylic IOL:

Three piece:

- Optic is square edged(truncated), made of copolymer of phenyl acrylate and methacrylate.
- Haptics made of PMMA

One piece acrylic was later introduced

Hydrophylic acrylic:

- One piece with open loops
- Water content about 25%
- Softer than hydrophobic acrylic
- Easier in implantation and centration

(Frohn et al, 2004)

Characteristics of *IDEAL foldable IOL*:

- Highly compatible
- Easily flexed and folded
- Slow and controlled unfolding
- Chemically and physically stable
- Mechanically resistant

- 100% memory
- Transparent
- High RI
- Resistant to YAG laser damage
- No visual or optical unwanted images

(Buratto, 1998)

IOL Implantation:

- Silicone IOLs were first inserted without special instruments through 4.5 - 5 mm

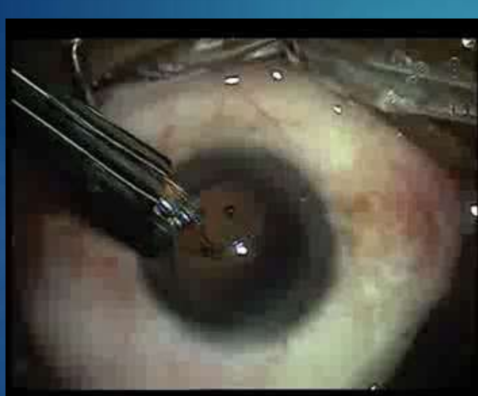
  (Mazzocco, 1985)

- Insertion forceps were introduced

- Later injectors

  (Mazzocco and Davidson, 1986)

Folding and holding forceps :



Disadvantages of forceps:

- ✓ Larger incisions
- ✓ More IOL manipulation and contamination
- ✓ IOL cracking in high powers
- ✓ More traumatic to AC contents
- ✓ Stucked IOL
- ✓ Imprint on IOL optic, may cause opacity

(Carlson and Johnson,1995 and Apple et al,2000)

Imprint on IOL:

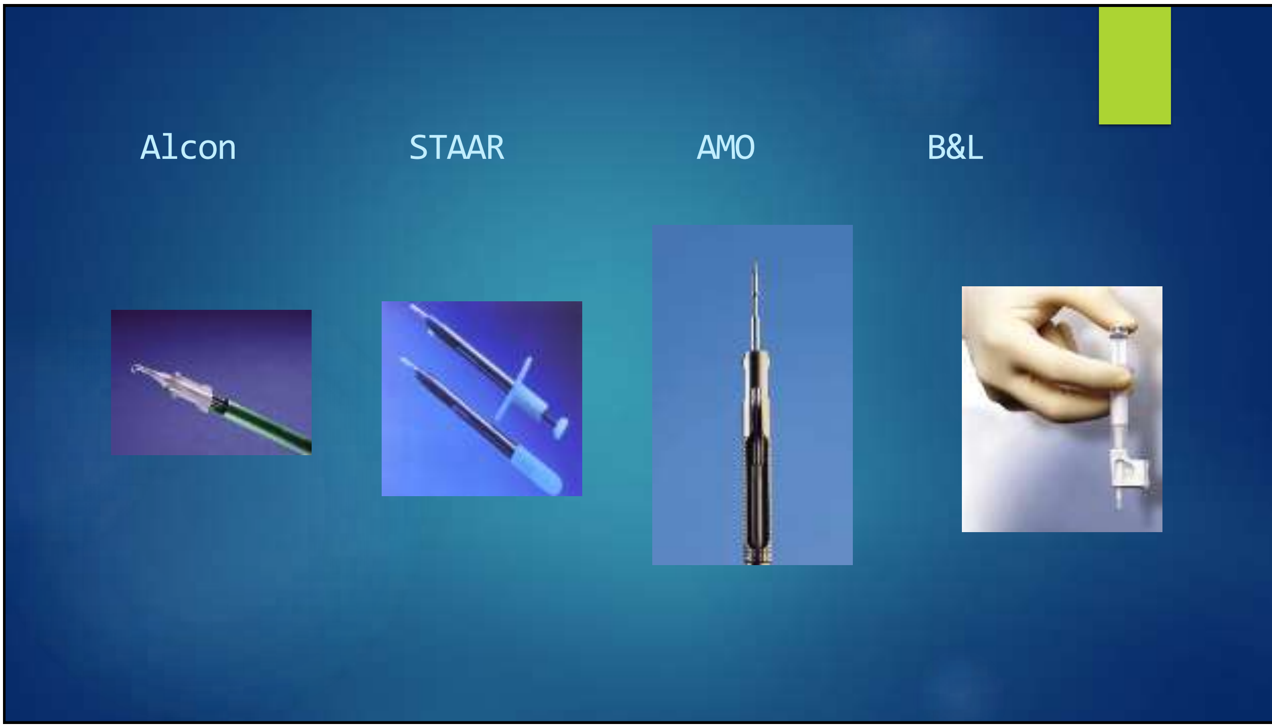
Stuck IOL:

IOL Injectors:

- Types:

❖ Screwing, considered by some slower, safer & more controlled

❖ Plunging or piston


Alcon
STAAR
AMO
B&L


Monarch D
OPHTEC
Injex

Advantages of injectors:

1. Smaller incision
2. Less traumatic to AC contents
3. Less IOL contamination, closed system
4. Less IOL damage
5. Need less space for IOL implantation , ie. phakic IOL and ICL

(Kohnen and Kasper, 2005)

Disadvantages of injectors:

- Loading techniques:
  Needs some skill, better done by the surgeon
- Improper movement may cause IOL damage
- Injecting techniques:
  Plunging injector threatens posterior capsule

(Shimizu, 2007)

Preloaded IOLs:

- Easier for the surgeon
- Saves time
- Less contamination
- Less trauma to IOL
- Proper loading

Difficulties with silicone IOLs:

- Low RI, thick implants, need wider incisions
- Rapid may be uncontrollable unfolding
- Slippery when wetted
- Causes capsular fibrosis
- Unsuitable in silicone filled eyes, adhere to implant

(Buratto, 1998)

Postop. Complications of foldable IOLs:

- Decentration or dislocation, specially silicone, after YAG laser

(Agustin and Miller, 2000)

- Asymmetric rhexis, irregular adhesion to capsular leaves, shrink capsular bag causing decentration. Specially with MF and T IOLs

(Assia etal, 1995)

- Precipitates:
  - Most common first generation silicone (more than PMMA)
  - Second generation silicone, more biocompatible

(Vasavada and Singh, 1998)

PCO:

- ✓ Most common after first generation silicone
- ✓ Less after hydrophilic acrylic
- ✓ Less after second generation silicone

(Hollick et al, 1998)

- ✓ Least after acrylic IOL, adhering to PC and having square edge.

(Oner et al, 2000 and Samuelson et al, 2000)

IOL opacification:

- Hydrogel comprises large family of polymers
- Certain hydrogels promote calcification when immersed in solutions containing calcium and phosphate

- Grading of IOL opacification (mostly acrylate IOL):

- Grade 1: Forceps marks
- Grade 2: Mild generalized opacification, clear visualization
- Grade 3: Moderate generalized opacification, no details
- Grade 4: Advanced opacification, no visibility

(Milanskas, 1992 and Kochand Heit, 1992)

➢ Visual problems(Photic phenomena):

- Dysphotopsia:
- Positive:

  Edge glare, arcs, haloes (at point light sources)

  Surface reflections due to increased RI and flat implant surface .

  Acrylic IOL with posterior square and anterior round edge alleviate dysphotopsia.

- Negative dysphotopsia :

  Darkness or shadow usually in the temporal field

(Davidson, 2000)

Premium IOLs:

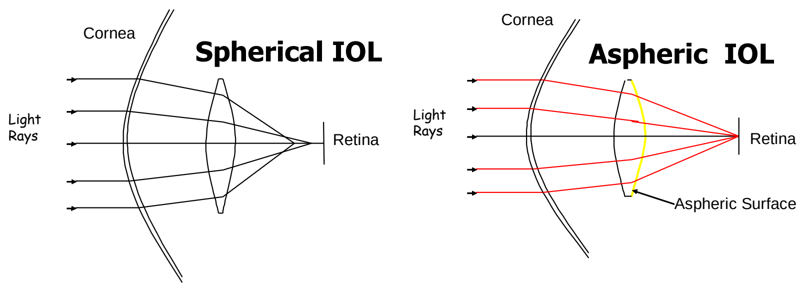
- Aspheric
- Multifocal
- Toric
- Accommodative
- Trifocal
- Extended range of vision
- Phakic

Aspheric IOLs (Wavefront technology):

- In the human eye, the cornea has +ve spherical aberration
- Crystalline lens has –ve spherical aberration neutralizing it
- Aging lens loses this ability causing dimin. quality of functional vision
- Aspheric IOL with prolate surface has –ve spherical aberration
- In contrast , spheric IOL has +ve spherical aberration, adding to that of the cornea

(Packer, 2006)

Spherical Aberration Corrected IOL



But:

- Advantages of aspheric IOL diminish with decentration
- These should be avoided if anatomical decentration may be encountered

(Dietze and Cox, 2007)

- **Toric IOLs:**

Corneal astigmatism in cataract patients:

- 1 D : in 50% *(Vitale et al, 2008)*
- 1.5 D or more : in 15-30% *(Hoffer, 1980 and Warlo,2005)*
- More than 2 D : in 8% *(Hoffman and Hutz, 2010)*

- 2.5 D or more : 4.6 % *(Ferrer – Blasco et al, 2008)*
- 3 D or more : 2 % *(Khan and Muhtaseb, 2011)*
- Postop. corneal astigmatism of 0.75 D or more, causes reduced vision and halos *(Nichamin, 2006)*

- Phaco eliminates *lenticular astigmatism*.
- To eliminate *corneal astigmatism*, surgeon must determine:

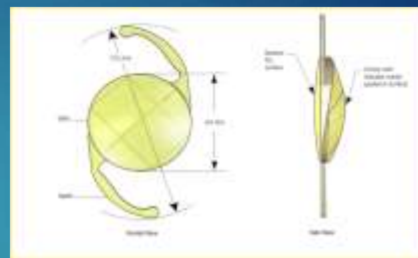
its *amount* and *meridian,* and

surgically induced astigmatism (SIA).

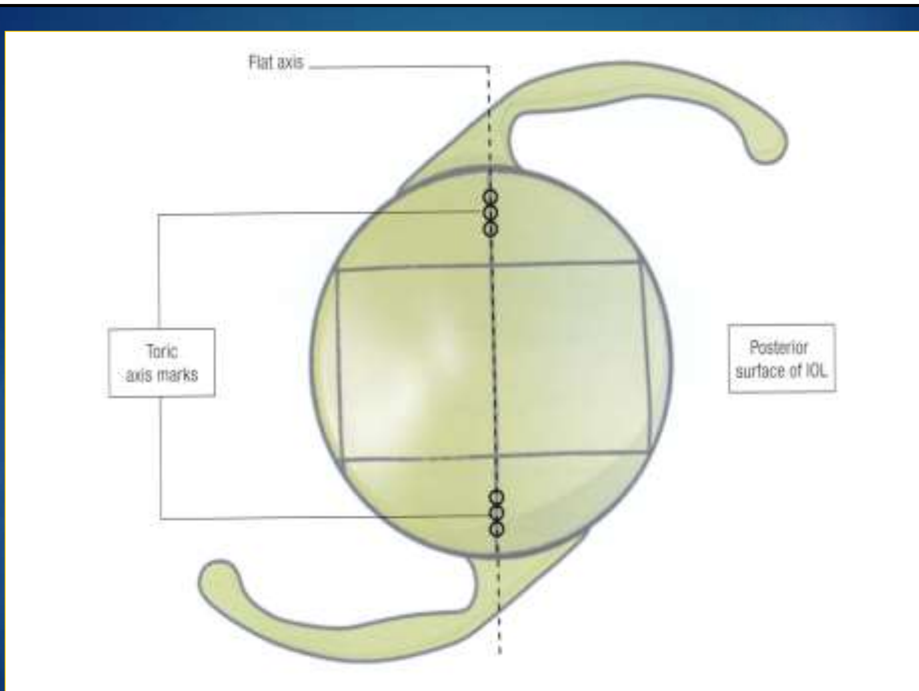
Staar Toric IOL:

- Single piece
- Plate haptic
- Foldable silicone
- Biconvex 6 mm optic
- Spherocylindrical anterior surface
- Anterior fenestration at end of each haptic
- Cylindrical powers of 2D or 3.5D

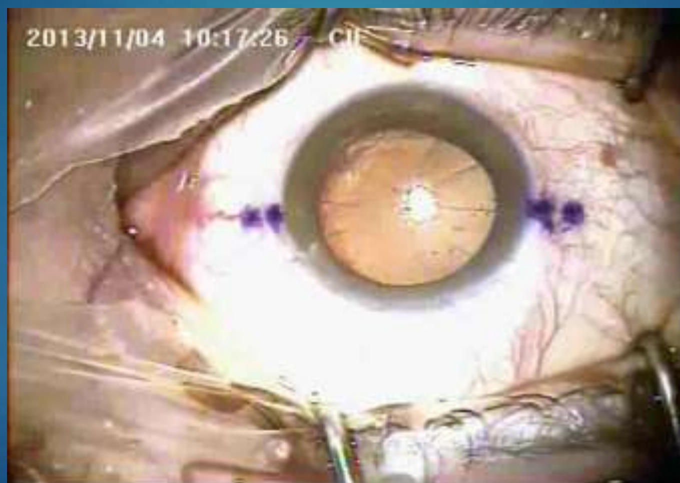
Acrysof Toric IOL



- Hydrophobic acrylic
- Single piece with modified L haptics
- Posterior toric surface
- 6 mm optic, 13 mm overall diameter

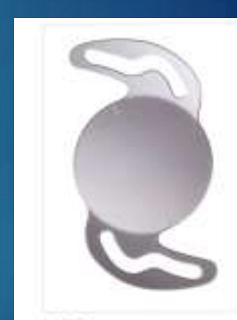


Video: Phaco, T-IOL:



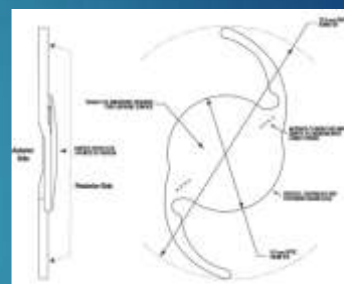
Rayner T-Flex Toric IOL:

- One piece hydrophylic acrylic
- Aspheric
- Two sizes:
  - -6.25 mm optic, overall diam 12.5 mm
  - -5.75 mm optic, overall diam 12 mm
- Square edge



Tecnis Toric IOL:

- One - piece
- Hydrophobic acrylic
- Aspheric
- Posterior toric surface
- Overall diameter 13 mm
- Correction up to 6 D astigmatism



- Main disadvantage of TIOL postop. rotation causing defect in astigmatic correction
- Misaligned T-IOL is recognized in early postop. days and should be repositioned before permanent fibrosis in the capsule

(Sun et al., 2000)

IOLs Treating Presbyopia:

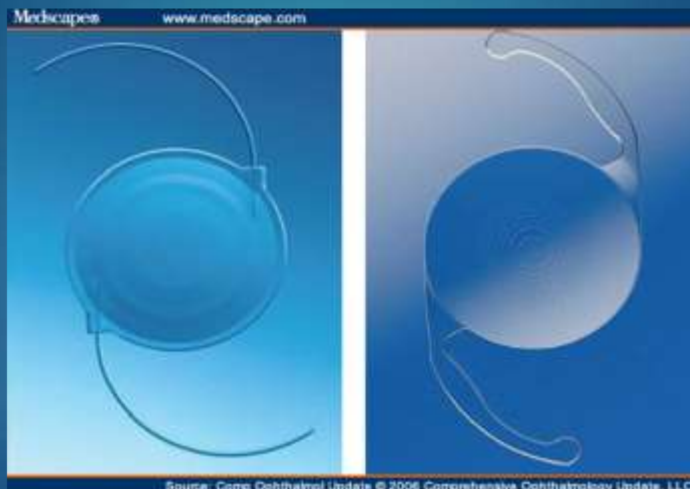
- Multifocal
- Accommodating
- Trifocal
- Extended range of vision

Multi focal IOLs:

Restor : appodized diffractive
Tecnis: diffractive
Rezoom: refractive
Array: refractive

Product Specifications
13.0 mm
6.0 mm
Model Number:
Optic Diameter: 6.0 mm
Optic Type: Apodized diffractive optic
Diffractive Power: +4.0 diopters of add power at the lens plane, equal to approximately +3.2 diopters of additional power at the spectacle plane
Haptic Angulation: 0 degrees (planar)
Haptic Configuration: Modified L (STABLEFORCE®)
A-Constant:
Refractive Index:
Diopter Range: +10.0 through +30.0 diopter (0.5 diopter increments)
Filtration: UV and blue light

Array - Restor



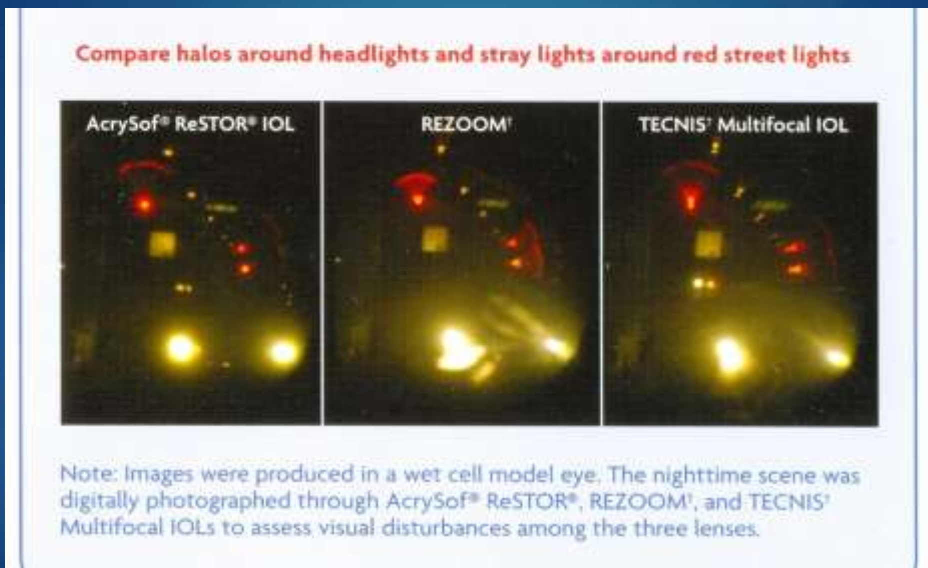
- Refractive pattern provides 5 concentric zones for near and distance powers (Rezoom)
- Diffractive pattern creates 2 major focal points, 4 diopters apart (Tecnis)
- Appodized diffractive IOL has hybrid diffractive/refractive optic with central 3.6 mm of concentric diffractive steps. The periphery is identical to the monofocal acrylic Acrysof, (Restor) .

(Carones, 2005 and Lehman, 2005)

- Multifocal IOLs improve near vision without major adverse effects on distance vision.
- Quality of life has been reported to be better than with monofocal IOLs concerning spectacle independence.
- Satisfaction level for *intermediate vision* is *lower* than near and distance vision.

Limitations of multifocal IOLs:

- ✓ Halos, glare and diminished contrast sensitivity especially in dim light have been reported
  (Packer, 2006)
- ✓ Dimin. contrast sensitivity is explained by the division of light in the image to 2 or more focal points
  (Alfonso et al., 2007)
- ✓ Driving at night is a limitation because of glare.
- ✓ Higher incidence of PCO than with monofocals
  (Vignolo et al., 2007)



Talk to patient: Tell him/her:

- The goal is functional vision with less dependence on spectacles not necessarily perfect vision
- Halos and glare and reading in dim light

(Schallhorn, 2016)

▪ Accommodating IOLs:

- Differ from monofocal in haptic design
- Haptics are flexible to move optical portion slightly forward upon ciliary muscle contraction.

- Same distance vision as MF IOL
- Better intermediate vision
- Higher incidence of PCO

(Ang, 2016)

- **Akkolens IOL** , 2 overlapping progressive lenses,
- Spring like haptics allow moving perpendicular to optic axis

Trifocal IOLs:

- Recent trifocal 100% diffractive technology
- Provide 3 useful focal distances
- Biocompatible hydrophilic copolymer
- 25% water content
- Reduces corneal spherical abberrations

(Alfonso et al, 2007 and Alio et al, 2011)

- With MF-IOLs, one image is in focus while the out-of-focus image is suppressed (simultaneous vision)
- This causes halos

(Cochener, 2016)

- Corrects limitations of traditional MF IOLs:
  - Photic phenomena
  - Poor intermediate vision

(Sheppard et al, 2013 and Mojzis, 2014)

- 68% of patients did not perceive photic phenomena disabling, improved with time due to neuroadaptation

(Law et al, 2014)

Extended range of vision IOL:

- UV filtering hydrophobic acrylic
- Biconvex
- Wavefront-desighned anterior aspheric surface
- Posterior achromatic diffractive surface
- Although it has diffractive gratings, it creates only one image on the retina

(Caceres, 2016)

- This technology uses achromatic diffractive echelette design that corrects corneal chromatic aberration

- This enhances contrast sensitivity and provides extended range of vision

- Most pseudophakic chromatic aberrations arise from chromatic dispertion of IOL rather from cornea or ocular media

- Ocular chromatic aberration causes blur and reduced contrast

- Correction of this, using achromatic IOL improves optical quality

(Cochener, 2016)

IOL advancements:

- Acriva lens, combines trifocal features with extended depth of focus

- Sapphire Auto focal lens, remotely programmed by physician to adjust IOL power .

  Liquid crystal optic automatically changes optical power with changing pupil size

Thank You