Evolution of Intraocular Lenses

1Bharti Ahuja MS, FMRF, 2Tarun Arora MD

1. Sankara Nethralaya, Chennai
2. Dr. R.P. Centre for Ophthalmic Sciences, All India Institute of Medical Sciences, New Delhi

The advent of phacoemulsification and microsurgical techniques has revolutionized the era of cataract surgery. This evolution has gone through various generations (Table 1). It has been more than one half of a century since the first lens was implanted in 1949.

An English ophthalmologist, Sir Harold Ridley (Figure 1) is credited with the first successful modern intraocular lens implantation on November 29, 1949 at St Thomas hospital in London. He performed extra capsular cataract surgery (Figure 2) on a 42-year-old woman. He observed that polymethyl methacrylate (PMMA) fragments from airplane cockpit windshields were well tolerated in the anterior segment of eyes of Royal Air force pilots injured during World War II. His original implanted IOL was a biconvex PMMA disc of diameter 8.35 mm, weighing 112 mg and a power of +24D. Though the postoperative result was a -21 diopter overcorrection but still it was a giant leap for cataract surgery. However this lens design was abandoned soon due to associated risks of inferior decentration, posterior dislocation, uveitis and glaucoma.

Table 1: The generations of intraocular lenses

<table>
<thead>
<tr>
<th>Generation</th>
<th>Date</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>1949-1954</td>
<td>Original RIDLEY posterior chamber lens</td>
</tr>
<tr>
<td>II</td>
<td>1952-1962</td>
<td>Early anterior chamber lenses</td>
</tr>
<tr>
<td>III</td>
<td>1953-1975</td>
<td>Iris supported lenses</td>
</tr>
<tr>
<td>IV</td>
<td>1963-1990</td>
<td>Intermediate anterior chamber lenses</td>
</tr>
<tr>
<td>V</td>
<td>1975-1990</td>
<td>Improved posterior chamber lenses</td>
</tr>
<tr>
<td>VI</td>
<td>1990 to 2000</td>
<td>Modern capsular posterior chamber and modern anterior chamber lenses</td>
</tr>
<tr>
<td>VII</td>
<td>2000 to present</td>
<td>Premium IOLs, aspheric optics, extended ranges, multifocal, accommodative, phakic IOLs</td>
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</table>

Figure 1: Sir Harold Ridley
The next generation of IOL implantation shifted focus to anterior chamber (AC) placement of lenses. Barron first implanted convexo-concave anterior chamber intraocular lenses (ACIOL) made of PMMA with steep anterior curve and short radius of curvature. As the lens touched the endothelium and had poor outcomes, he changed the lens design to one of plano-convex.

Strampelli, Choyce, Danheim and Barraquer subsequently provided various designs (Figure 3). Because of Strampelli’s early success and Choyce’s later modifications of his original design, Strampelli has been credited with originating the modern ACIOLs. However corneal decompensation (pseudophakic bullous keratopathy) and uveitis-glaucoma-hyphema (UGH) syndrome were observed with many subsequent AC lens designs. Many modifications of haptic loop configuration and lens vaulting characteristics led to a reasonable predictable lens design of ACIOL provided by Choyce and later by Charles Kelman.

The third generation belonged to the Iris supported/fixated lenses that were advocated by Cornelius Binkhorst (Figure 4) in The Netherlands. He coined the term ‘pseudophakia’ in 1959 to indicate the presence of an IOL. His first lens was a four loop, iris-clip IOL design that was later modified to two-loopiridocapsular IOL. Dislocation, pupillary deformity, pupillary erosion, iris atrophy with transillumination defects, pigment dispersion, uveitis, corneal edema and hemorrhage resulted due to chronic rubbing or chaffing of the iris by IOL loops or haptics. These were more with metal loop and multiple looped lenses. These required a larger limbal incision for insertion as these all were biplanar with the optic placed in front of pupil. Binkhorst later changed the biconvex lenses to simple convexo-plano lenses. Several reports subsequently established the optical superiority of these lenses over biconvex lenses.

Fourth generation lenses showed markedly improved lens design and manufacturing techniques. Lenses were made of rigid and flexible material, open loop, one-piece PMMA designs such as the three and four point fixation Kelman IOls. Disadvantages such as the close proximity of haptics/loops to delicate tissues such as the trabecular meshwork, corneal endothelium, angle recess and anterior iris surface
and difficulty encountered in IOL sizing particularly with rigid lens designs however persisted.

Next generation showed a revolution in IOL design and a return to posterior chamber as a choice for IOL implantation. First uniplanar posterior chamber lens implanted by John Pearce of England was a rigid one piece PMMA tripod design, two inferior feet implanted in the capsular bag and the superior foot in front of the anterior capsule and sutured to the iris. Since 1977, Shearing, Simcoe, Arnott modified lens designs and largest number of IOL styles available today are flexible open loop designs (J-loop, modified J-loop, C-loopor modified C – loop). One obvious major advantage with posterior chamber intraocular lenses (PCIOL) was their position behind the iris, away from the delicate structures of the anterior segment. Open loop flexible, one piece all PMMA posterior chamber designs with posterior convex or biconvex optics appeared to be a protective factor for minimizing posterior capsular opacification. In 1980s it became evident that PCIOL should be implanted in the bag to eliminate all contact with uveal tissue.

The next era marked a marriage between IOL design and improved surgical techniques into extra capsular surgery and the IOLs were fabricated from both rigid and soft biomaterials. With the development of surgical techniques that allow secure in the bag implantation, rigid PMMA and foldable IOLs also evolved to work well. These can be inserted through incisions as small as 5.5-6 mm in length. The ideal diameter for a one-piece IOL design is 12-12.5mm that allows it to fit perfectly into the capsular bag (measures about 10.5 mm in diameter). A foldable IOL is made of a soft material that can be folded and implanted through a 2.8 to 3.5 mm incision. Materials used were poly HEMA, hydrogel and polydimethylsiloxane.

The current generation of IOLs continued to evolve each year. Routine monofocal IOLs till this era were not able to compensate for presbyopia and astigmatism. Here came the role of premium IOLs. IOLs were designed to achieve a normal vision for all range of distances as to satisfy patient expectations and lifestyle. A better term is “lifestyle IOL” as they improve the lifestyle and quality of life for patients. These consist of aspheric monofocal, toric, multifocal, multifocal-toric and accommodative lenses.

Future has in store a range of different IOL technologies. One of the example is Smart IOL by Medennium (Irvine, CA). A thermodynamic hydrophobic acrylic IOL, designed to completely fill the capsular bag but is convertible at room temperature to a thin rod, which can be injected through a very small incision. Under the influence of body temperature, it reconstitutes to its initial size, shape and imprinted diopteric power. This would fill the capsular bag but become adherent to it (hydrophobic acrylic), which becomes covered with fibronectin. It would result in large amplitudes of accommodation as of minute changes in the shape of lens because of high refractive index.

Concept of SUPER IOL has been thought of for future generations. An IOL of accommodative/multifocal and toric variety made up of single piece acrylic, preloaded and where vital centration is required whose power can be changed with time.

**Suggested Reading**

1. Parson’s diseases of the Eye 21st edition
2. Implants in ophthalmology AIOS, CME series (No.15)
5. Foldable Intraocular lenses 1993 -Robert G. Martin, James P. Gills, Donald R. Sanders