

## Current Developments in Monofocal Intraocular Lens Technology

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### ABSTRACT

First intraocular lens (IOL) implantation was performed by Dr. Harold Ridley. This first IOL was completely different from the IOLs we use today. IOL technology is one of the fastest developing technologies in recent years in ophthalmology. Monofocal in the bag IOL is the most commonly used IOL according to American Society of Cataract and Refractive Surgery (ASCRS) surveys. In developing countries, use of this IOL are almost standart. There are many different monofocal IOL options on the market and determination of appropriate IOL must be individualized for each patient to reach perfect postoperative outcomes. The aim of this manuscript is to investigate different properties of IOLs on the market in light of evidence based medicine and to give hints about the individualization of the IOL selection. For this purpose, our manuscript emphasizes different properties of IOLs and does not refer any trademarks of IOLs.

**Key words:** Intraocular lens (IOL); Cataract, Lens technology

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### HISTORY

In 1949, English ophthalmologist Dr. Harold Ridley performed first successful intraocular lens (IOL) implantation. He presented this new surgical method in 1951 Meeting of American Academy of Ophthalmology (AAO) and reported results of first 8 operations in 1952<sup>[1]</sup>. In those days, many of ophthalmologists opposed to this method because many complications were seen such as unpredictable high postoperative refractive error, uveitis, glaucoma, corneal decompensation and permanent visual loss. Nevertheless, Dr. Ridley's new treatment method of cataract drew attention in various parts of United States and Europa. Nowadays, cataract extraction and IOL implantation is one of the most common surgeries across the world.

Original Ridley lens was designed for use in posterior chamber. Subsequent designed IOLs were implanted in anterior chamber because there were no modern operation microscopes in those days. IOL technology and implantation techniques developed with microsurgery techniques and equipments in parallel. Finally, modern IOLs were designed for use in anatomical localization of human crystalline lens.

### BIOMATERIAL AND MANUFACTURING TECHNIQUES

Perspex is a polymethylmethacrylate (PMMA) derivative and it was used as biomaterial in original Ridley lens. In today, IOLs are separated two main groups according to foldability of biomaterials. Unfoldable IOLs are made PMMA and foldable IOLs are made silicon, acrylic, hidrogel or collamer.

Acrylic biomaterial is the most commonly used optic material. Toxic monomers such as acrylate or methacrylate are transformed to nontoxic polymers such as phenyletilacrylate or polyethylmethacrylate using heat or ultraviolet (UV) electromagnetic

radiation. Physical strength of biomaterial depends on length of polymer chain. Biocompatibility of biomaterial depends on type of monomer. Tolerance of uveal tissue and lens capsule provide to keeping of the IOL in eye over years. Uveal biocompatibility is examined via presence of small round cell in anterior chamber and foreign body giant cell on surface of IOL. Capsular biocompatibility is examined via migration of lens epithelium on the posterior capsule and existence of capsular opacification<sup>[2]</sup>. Uveal biocompatibility and some optical properties of hydrophilic acrylic IOL are high<sup>[3,4]</sup>. Additionally, one study reported bacterial adhesion to surface of IOL is fewer in hydrophilic acrylic IOL than other IOLs<sup>[5]</sup>. But capsular biocompatibility of hydrophilic acrylic IOL is low. Capsular biocompatibility is very important because it effects long term visual outcomes negatively through posterior capsular opacification (PCO) and deformation of IOL surface<sup>[6]</sup>. For this reason, the most of the cataract surgeons use more common hydrophobic acrylic IOL than hydrophilic acrylic IOL if possible. New designed hybrid acrylic IOL combine advantages of two acrylic IOLs and provides higher uveal and capsular biocompatibility. Thus, this material yields better surgical outcomes via reducing postoperative anterior chamber cells and PCO rate<sup>[7]</sup>.

Heparin coating is a surface modification that enhances the uveal biocompatibility of IOL. Fewer aqueous flare are seen after implantation of heparin coated IOL<sup>[8]</sup>. Although heparin coated IOL increases the risk of PCO, this increase is not found statistically significant<sup>[9]</sup>. And this IOL can be used in patients with high-risk for postoperative intraocular inflammations.

The manufacturing process of IOL consists of the following steps briefly: Copolymerization, castpolymerization, optical forming and coupling of pieces (this step is not necessary if IOL is one-piece). Optical forming is performed via molding or lathe cut after the processing of biomaterial. Mold damage is high in molding technique and it causes producing damaged IOL. So, lathe cut technique is more cost effective and more commonly used than molding technique.

## MECHANICAL PROPERTIES

The variation in optic and total diameter of IOL is limited. In animal study, IOLs with 6 mm and 7 mm optic diameters implanted in the pig eyes, were compared. Pig eyes implanted IOL with 7 mm optic, need less pressure at the scleral indentation for visualization of peripheral retina in vitrectomy<sup>[10]</sup>. While larger optical size is advantageous in visualisation of peripheral retina, it is disadvantageous in terms of folding and implantation through small incision. Optic diameter of IOLs is almost standart due to this limitation. When total diameters are compared, average rotation and stabilization are similar in IOLs with 12 mm and 13 mm total diameters<sup>[11]</sup>. This parameter does not seem very important in IOL selection.

There are various haptic designs on the market such as plate haptic, C haptic, modified C haptic, J haptic, quadripod haptic and more. A study comparing various haptic types reported that double C haptic contacts the lens capsule at 4 points. Double C haptic design maintains anteroposterior and rotational stability of IOL<sup>[12]</sup>. In postoperative 3rd month, the average rotation of IOL was found as 1.85 degrees in this haptic design<sup>[13]</sup>.

Planar and angular haptics are another differentiation in haptic design. There can be 5, 10 or more degrees in optic haptic junction of IOL with angular haptic. IOL deformation is less in planar haptics while anterior capsule opacification is less in angular haptics<sup>[14]</sup>. PCO and IOL decentralization occur equally in both of planar and angular haptics<sup>[15]</sup>.

In theoretic, toric IOL can correct very high degree astigmatism such as 30 diopters but cylindrical power of toric IOL on the market are limited. Cylindrical power is important factor for the rotational stabilization of IOL. High degree cylindrical power causes rotational instability and increased postoperative refractive error after cataract surgery. In this reason, postoperative refractive predictability of surgery reduces after implantation of high degree toric IOL<sup>[16,17]</sup>. Postoperative positional stabilization of high degree toric IOL needs to be improved.

Intraocular lenses can be implanted via manual or preloaded cartridge. The use of the preloaded cartridge spreads more and more. Preloaded cartridge shortens the duration of surgery, reduces the lens contamination and deformation<sup>[18]</sup>. It can be expected the use of manual cartridge going to vanish in the coming years.

Another factor that effects mechanical properties of IOLs is dioptic power. Atomic force microscopy technology has the ability to quantatively analyze surface properties with nanometere spatial resolution, relevant to the interaction between biomaterials and biologic tissues. According to quantitative results of atomic force microscopy, most of the surface roughness parameters are statistically significant different in IOLs with different dioptic powers such as 10D, 20D or 30D from a single manufacturer. However, factors other than dioptic power can also effect surface roughness and it is not fully known whether small dioptic differences effect these parameters. Therefore, further research is needed on this topic. In summary, according to our knowledge, although the relation of IOL dioptic power and surface roughness does not directly effect the IOL selection, it should be known<sup>[19]</sup>.

## IMAGE QUALITY

After cataract surgery, PCO is one of the most important causes of visual loss. Migration and proliferation of residual lens epithelial cells lead PCO. 360 degree square edge design blocks mechanically the epithelial cell migration and proliferation. Thus, PCO rate is reduced<sup>[20]</sup>. 360 degree square edge design and uninterrupted capsule-IOL contact are as important as use of hydrophobic acrylic biomaterial in terms of PCO<sup>[21]</sup>. 360 degree square edge design reduces PCO rate but it can cause the stray-light effect. The stray-light effect and ghost image occur due to light reflections within the IOL. These negative effects can be reduced via frosted edge design<sup>[22]</sup>. So, undesirable light reflections are blocked while IOL is optically clear.

All of IOLs on the market block UV electromagnetic radiations. Additionally, some IOLs contain blue and yellow filters to protect retina from phototoxicity. Thus, the light permeability of IOL is approximated to the young human natural lens. But one study shows that blue light is necessary for scotopic vision in night and melatonin suppression in day<sup>[23]</sup>. So, benefits of these filters are controversial and further research is needed. At least, we know that color filter coated lenses do not negatively effects postoperative visual acuity and contrast sensitivity<sup>[24]</sup>.

Optical density and chromatic aberration of IOL are related to refractive index and Abbe value respectively. Higher refractive index and Abbe value increase the image quality. Glistening is another effective factor on the image quality in medium or long term. Glistening is fluid filled microvacuoles that form within the IOL optic (especially hydrophobic acrylic IOL) when the IOL is in aqueous environment<sup>[25]</sup>. New glistening free hydrophobic acrylic IOL that contains different polymer combination and was packaged in solution was recently introduced<sup>[26]</sup>.

Refractive power of IOL is same in all over the surface of IOL in spherical optical design. This design causes an increase in spherical and chromatic aberration while reducing visual acuity and contrast sensitivity<sup>[27]</sup>. Additionally, photic phenomena such as glare and halo occur more commonly in spherical optic than aspheric optic<sup>[28]</sup>. Aspheric optic makes overrefraction in periphery of IOL and decreases spherical and chromatic aberrations. For these reasons, IOL with aspherical optical design is used more frequently than IOL with spherical optical design. Additionally, asphericity value of aspheric IOL should be known. The asphericity value of aspheric IOL on the market is not same and they range from 0 to -0.27. Different asphericity values are used to compensate the positive aberration of cornea. This aberration is different in each patient and it can be detected with preoperative detailed examination. By the use of aspherical IOL with appropriate asphericity value, contrast sensitivity is increased, spherical and high order aberrations are decreased and postoperative visual outcomes can be perfected<sup>[29]</sup>.

Phacoemulsification is a milestone in cataract surgery. 3.2 mm or 2.8 mm incision sizes were used in recent years and 2.0 mm or smaller incision sizes are used in currently. Many of IOLs on the market can be implanted through small incision sizes. Smaller incision in cataract surgery and use of these new IOLs provide faster wound healing, less surgical induced astigmatism and better uncorrected visual acuity. There are significant differences even between 2.0 mm and 1.8 mm incision sizes in terms of these parameters<sup>[30]</sup>. In future, new IOLs that can be implanted through smaller incision, will increase satisfaction of patients in postoperative period.

## CONCLUSION

Intraocular lens technology is the fastest developing and most studying technology in ophthalmology. There are too many IOLs have different properties on the market in today. For perfect postoperative outcomes, surgical equipments and techniques should not be standart, they must be customized. And surgeon should determine the appropriate IOL for each patient in light of evidence based medicine.

Hydrophobic or hybrid acrylic biomaterial and 360 degree square-edge design decrease PCO rate<sup>[2,7,20]</sup>. Frosted edge design blocks the light reflection within IOL and provides better vision when use square edge IOLs<sup>[22]</sup>. Smaller incision and IOL with better foldability should be used for perfect postoperative outcomes<sup>[30]</sup>. High refractive indeks, high Abbe value, glistening free and aspheric optical design upgrade the image quality<sup>[26-28]</sup>. Preloaded cartridge is very important factor that reduces peroperative and postoperative complication rates<sup>[18]</sup>.

Heparin coated IOL can reduce the postoperative intraocular inflammation<sup>[8]</sup>. The use of this IOL should be considered in high risk patient group especially pediatric population.

If there is capsule contraction syndrome in fellow eye, the use of IOL with angular haptic should be considered to prevent anterior capsule opacification<sup>[14]</sup>.

In normally, blue or yellow light filters on IOL surface are not necessary<sup>[23]</sup>. Chromophore added IOL can be implanted in patients with retinal degeneration to protect retina from phototoxicity. However further research is needed in this regard.

If necessary toric IOL can be implanted but postoperative positional stabilization of toric IOL is low<sup>[16,17]</sup>. For astigmatic correction, cataract surgery should be combined with other techniques such as limbal relaxation incision, so cylindrical power of IOL should be reduced. Additionally, double C haptic design provides stable IOL

position in these patients.

Large optic diameter is advantageous for peripheral retinal examination<sup>[10]</sup>. Peripheral retinal examination is more important in patients with diabetes mellitus or degenerative myopia than others. IOLs with larger optic diameter should be preferred in these patients if it is possible.

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