Premium IOLs Selection Criteria, Investigations IOl Models & Residual Correction : An Overview

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Abstract :

Cataract Surgery is the by far the 'most performed surgery' in the world. Now, more than ever before, the need for the ophthalmic surgeons to keep themselves abreast with the latest in refractive cataract surgery, is of utmost importance. Today, the patients demands are based on needs in tune with the modern gadgetaries and on knowledge about availability of different techniques and IOLs gathered from the internet. This article describes the selection criterias and the different advanced investigations necessary for extracting optimal results from premium IOL implantations. Whilst counselling is extremely important, pre operative examination of macula, optical biometry, wavefront aberrometry, corneal topography and dry eye evaluation are very crucial. Different IOL models are described in detail. Bifocal, Trifocal and Toric IOLs including Bifocal and Trifocal Toric, EDOF IOLs, marking for implantations and image guided operating systems add value to precision and perfection which affect the final visual outcome. Monetarily charging a premium and raising the expectation of the patient can only be met confidently if the surgeon is additionally well versed with the management of residual refractive error. It is equally important to know the future of premium IOLs so that we keep abreast with the latest in technology and then transfer it to the advantage of our patients.

Introduction:

Cataract surgery has seen the paradigm shift from being a restorative to now an established refractive procedure.

Technological innovation and specification in the intraocular lenses further evolved to improve the quality of the vision and life of the patient post-operatively. The use of Mono-focal intra–ocular lens has excellent distance visual outcome but the near and intermediate distance vision largely depends on additional spectacle corrections.

Toric IOLs, Multifocal and Accommodative IOLs are considered as premium IOLs. They are used mainly in patients having cataract with corneal astigmatism, presbyopia but without any other ocular comorbidities.

The most commonly used multifocal IOLs are the bifocal ones, which create two primary focal points, one for distance and one for near vision. The insufficient intermediate vision that these lenses offer has been one of their main drawbacks, especially due to the expanding needs of modern-day patients (e.g., use of electronic devices etc.). Trifocal IOLs were, thus, subsequently introduced, offering a third focal point for intermediate vision.

In an attempt to achieve good quality of vision at all distances, while avoiding undesirable photic phenomena, a new generation of IOL was introduced, the extended depth of focus (EDOF) IOLs.

Once you select your preferred procedures and technologies, you can determine patient suitability for any procedure and then decide which procedure or IOL you will use. Identifying a good patient for a premium IOL requires ample consultation time, during which you should make a reasonable assessment of personality type, quantify visual need and demand and determine the physical health of the eye.[1,2]

Patient Selection Criteria

The ideal patient is motivated to achieve spectacle independence for distance and near vision, understands the limitations of premium IOLs, and has realistic expectations. Patients should be informed about potential optical aberrations that could influence quality of vision. Some of these symptoms can later be improved through a process of neuroadaptation, but the patients must be aware of the possibility that these symptoms can permanently persist. Another important issue is

a possible second surgical intervention in the sense of bilateral premium IOL implantation, which could provide significantly better visual results in both multifocal and toric IOLs.[1,2,3] Different macular and optic nerve head diseases are associated with decreased contrast sensitivity.[1,4]

Astigmatism is an important preoperative factor, especially when considering that approximately 15%–20% of patients with cataracts have a preoperative corneal astigmatism of more than 1.25 diopter (D).[5,6] The presence of astigmatism in eyes with multifocal IOLs compromises all distance visual acuities, suggesting the need to correct astigmatism greater than 1.0 D. Furthermore, posterior corneal astigmatism should also be considered in surgical planning. Patients with irregular astigmatism are not good candidates for multifocal IOL due to questionable outcomes and refractive correction challenges. Limbal relaxing incisions or opposite clear corneal incisions can be performed during the surgery and laser refractive surgery can be used after the surgery in order to reduce astigmatism.[7,8,9] Regular astigmatism is most suitable for toric IOL implantation; however, irregular astigmatism in cases of keratoconus, or after keratoplasty, can also be successfully treated with toric IOL implantation. For patients with regular corneal astigmatism which require spectacle independence, toric multifocal IOLs should be discussed.

Any preexisting ocular comorbidities that could affect the vision are relative to absolute contraindications for premium IOL implantation. Therefore, a detailed preoperative ophthalmic examination is mandatory. Ocular pathologies, such as corneal pterygia and dystrophies and especially Fuchs endothelial dystrophy, should be carefully evaluated, taking into account the progressive nature of these diseases.[2,7] In young patients with amblyopia, functional improvement is possible with the use of premium IOL, but one should be careful because of uncertain postoperative refractive results. Several retinal diseases, such as retinitis pigmentosa and Statgart disease, are absolute contraindication for any premium IOL. In patients with uveitis, there is always a risk for early or late postoperative reactivation, and these patients should be avoided in premium IOL surgery. Patients with previous ocular surgeries should also be avoided in premium IOL surgery. Although not necessarily a contraindication, previous refractive ocular surgeries can induce significant amounts of higher order aberrations

that may preclude the use of premium IOLs, especially multifocal IOLs. Although the multifocal IOLs can be used as an aid for magnification in eyes with age-related macular degeneration (ARMD), the surgeon must be cautious as in multifocal IOLs there is a split between near and distance foci. In some cases, this could result in further contrast sensitivity reduction and even poorer vision than with monofocal IOLs. Additionally, macular diseases such as ARMD or diabetic maculopathy can progress after any cataract surgery. Care should be taken when considering for premium IOL implantation in patients with glaucoma or any optic nerve damage. Only glaucoma suspects and ocular hypertensive patients with no disk or visual field damage who have been stable for a longer period of time should be candidates for multifocal IOLs.

Patients with dry-eye syndrome and meibomian gland dysfunction are potentially extremely unsatisfied after cataract surgery, regardless of premium IOL type, due to tear-film abnormalities and subjective symptoms. These conditions should be treated aggressively before the surgery Premium IOL Decentration or rotation could lead to the reduction of premium IOL efficiency, resulting in significant visual disturbances. Therefore, ocular disorders with capsular instability (pseudoexfoliative syndrome or trauma induced zonulolysis) are absolute contraindications for multifocal and relative contraindication for toric IOL implantation. Mild zonular weakness is not strict contraindication for premium IOL implantation; however, adequate preoperative and preoperative assessment is essential.[2] In these eyes, implantation of capsular tension ring could provide stabilization of the capsular bag, and even contribute to better postoperative IOL centration. The function of the premium IOL is also dependent on postoperative pupil size and position, where patients with larger pupils may have more glare and haloes, but patients with small pupils may have difficulties in intraoperative IOL centration.[10], It is imperative therefore, all mentioned factors should be carefully considered before opting for premium IOL implantation.

Counselling:

Counselling starts with comprehensive understanding of the technologies and techniques associated with a procedure, before they can educate the patient for it. IOL technology is ever-evolving, with new products entering the market on a regular basis. However, the multifocal lens design can result in a higher incidence of unwanted visual phenomena such as contrast sensitivity loss, glare and halos.[11,12]

The most important component of post-operative success with a premium IOL is preoperative counselling. As innovative as these new IOL options are, patients should be properly counselled that they aren't perfect—and may not be a perfect match for them. For starters, they will want to know a large out–of-pocket cost which is usually associated with premium IOLs. Be aware, large price tag may actually elevate their expectations, too. Implantation of multifocals without discernment or discretion may yield many disgruntled patients.

Patients who elect a presbyopia-correcting IOL must be motivated to be spectacle independent.

The conversation should include a careful evaluation of patient's needs, lifestyle and personality. Asking about lifestyle, work, and hobbies will give information about the types of visual tasks patient performs. Patients with unrealistic expectations or an overly critical personality are less likely to fare well with premium IOLs.

Counsellor should assess patient's refractive error, and current visual acuity should be considered. Hyperopes who have significant cataracts will gain the most from presbyopia–correcting IOLs, with uncorrected vision improvement at all distances. Mild myopes who rely on their near vision for specific tasks may have something to lose and could be dissatisfied with the result. About 35% to 40% of eyes undergoing cataract surgery have astigmatism equal to or more than 1.0D and about 20% have astigmatism greater than 1.5D[8-10] These patients should be counselled for toric trifocal after proper assessment.

Eyes with corneal conditions—such as keratoconus, anterior basement membrane dystrophy or corneal scars—are not good candidates for premium IOLs due to the risk of higher-order aberrations and irregular astigmatism.

Patients with a history of refractive surgery often prefer to maintain spectacle independence. A second refractive procedure can be offered as an enhancement if residual refractive error is significant after cataract surgery. Patients should be thoroughly educated on risks in these cases, though typically risks are lower than that of a lens exchange.

Counsellor should be aware, best way to avoid premium IOL pitfalls is by predicting and preventing them prior to surgery. However, even with careful planning, patients can end up dissatisfied. The most common cause of dissatisfaction in patients with multifocal implants is residual refractive error, followed by dry eye, glare and halos.[13,14]

It should be counselled preoperatively, any residual refractive error may be addressed with laser vision correction; however, it is vital to allow for adequate healing and stabilization of corneal topography prior to any refractive surgery. Refractive surprises may occur unpredictably, but are more likely in eyes with particularly short or long axial lengths, a history of previous refractive surgery or both. Surgical practices may include laser vision correction enhancement in their premium IOL packages in case of a "refractive surprise." Patients usually do well with premium IOLs once the residual refractive error is corrected.

In case of toric trifocal, if residual astigmatism is caused by rotation off the intended axis, the patient should be sent back to the Operation Theater and the lens should be rotated into the correct position within the first few weeks after surgery.

Neuroadaptation plays an important role in multifocal outcomes, especially positive dysphotopsia. No effective treatment for these symptoms is available. Four to 12% of cases in which bothersome glare, halos or starbursts are present are due to an IOL defect. These patients should be discouraged for Trifocal/ EDOF.

Investigations before Premium IOL implantation:

The expectations of a patient opting for premium IOL would definitely be more than those opting for routine IOLs. As clinicians, it is our duty to perform relevant investigations and then advise for the best suited Premium IOL for each patient. Following are the investigations to be advised in selection and planning of Premium IOLs.

Macula Oct:

There is growing evidence for the importance of more detailed evaluation of macula even with clinically normal appearance. Spectral Domain Optical Coherence Tomography (SD OCT) is non – invasive and sensitive test for evaluation of macular structure.

Studies conducted in patients undergoing cataract surgery with normally appearing macula have shown that routine use of OCT prior to cataract surgery can detect subtle macular disease, which may alter course of treatment or lead to modification of consent.

Moreira Neto et al. investigated 98 patients undergoing cataract surgery; they diagnosed preoperative maculopathies in 21.4% of the patients with SD-OCT, which was a larger percentage than that detected with binocular indirect ophthalmoscopy (11.2%). Similar results have been obtained from other studies.[15,16]

The most common macular conditions threatening vision encountered were epiretinal membrane (ERM) and myopia associated complications. Perimacular/foveal drusen, fovea plana, atrophy of retinal pigment epithelium are among the other conditions which can hamper the visual outcome. Patients having poor prognosis are not satisfied with the results. There are certain diseases which are progressive, for example the diagnosis of drusen identifies patients at risk for development of age related macular degeneration (ARMD) where Multifocal IOL will not be a good choice to advocate. Moreover, it also helps in preoperative counselling of these patients for necessary follow ups.

Hence, a routine use of OCT macula in Premium IOL cases can pick up these subtle macular disease which can be contraindication to the use of these IOLs.

Biometry:

This is the most essential tool for IOL power calculation prior to cataract surgery and also helps in selection of Premium IOLs.

Today we have shifted from Manual (Ultrasound) Biometry to Optical Biometry. In Manual Biometry, Keratometry readings are taken from manual or auto keratometer and entered in the A scan machine along with measurement of axial length and calculates the IOL power for the selected formula. Apart from being tedious and time consuming process, there are changes of human error and hence, getting inaccurate IOL power. It also has user bias based on skill of the operator. A wrong data entry can give a wrong IOL power especially in Toric IOLs. Optical biometry is comparatively faster, more accurate, non-invasive (non-contact), easy to operate and less chances of human error. A single machine measures all the parameters and calculates the IOL Power. Today, Ultrasound Biometry is mostly restricted to cases where optical biometry cannot be performed due to opaque optical media.

Advanced technologies related to optical biometry such as partial coherence interferometry (PCI), optical low-coherence reflectometry (OLCR), and swept-source optical coherence tomography (SS-OCT) have increased the precision of biometric measurements.[17,18] The accuracy of modern formulae depends upon their predictability of effective lens position (ELP). For the most part, this has been accomplished by increasing the number of variables—including preoperative anterior chamber depth (ACD), lens thickness (LT), corneal diameter (white to white, WTW), central corneal thickness (CCT), preoperative refraction, and age—as well as basic variables such as axial length (AL) and corneal power (K). It is advisable to take two readings on same or different machines for more accuracy and to avoid refractive surprises.

With the advancement in technology, it has been possible to make eyes absolutely emmetropic by putting IOL of exact power. This is possible because of new formulae evolving each day. In normal eyes (22-26 mm axial length), the formula of choice is SRK – T, while the Hoffer Q in short eyes (< 22 mm) and the SRK – T and Holladay 1 with Wang – Koch axial length modification in long eyes (>26 mm) is preferred. The advent of Barrett Universal II vergence formula has given a single formula that is applicable across wide range of axial length. It performs equally well in Asian population and has been found to be the most accurate formula in prediction of post-operative refraction in Indian eyes. The Hill–RBF and the Super Ladas formulae using artificial intelligence also hold the same promise.

Image-guided Systems:

Image-guided systems are new technology. It is a surgeon's companion wherein it helps in surgical planning and execution. They also provide digital image guidance for toric IOL alignment without preoperative manual marking. The most common current surgical-guidance systems are the Alcon Verion Image-Guided System and the Zeiss Callisto Eye and Z align.[19,20] Another similar system is TrueVision 3-D (3 dimensional) Surgical System (TrueVision Systems, California).

These image-guided systems enables calculating the power of Premium IOLs (toric or multifocal IOL) using different formulas, selecting the optimum location of corneal and limbal incisions by providing an astigmatism planner, selecting the preferred diameter and centration of capsulorrhexis as well as IOL centration and position after the visual identification of the optical axis.

Amongst the image-guided systems, the Alcon VERION system has additional benefit of taking its own keratometric readings along with other biometric ocular parameters which include corneal radii, the magnitude of astigmatism, limbus position and diameter, WTW and pupillometry. It predicts the actual postoperative power in terms of sphere and cylinder. Other machines give it in terms of spherical equivalent which may be misleading. It is a reliable system for measurement of keratometry values and astigmatism. The keratometric power, magnitude and steep axis of astigmatism have no significant difference and there is good agreement among Verion, IOL Master 700 and Pentacam. It also captures a high resolution preoperative reference image of the eye which can be used to document the center of the undilated pupil, corneal reflex position or eccentricity of the visual axis, scleral vessels and iris structures. The VERION digital marker (VDM) located in the operating room allows the surgeon to see in real time a digital tracking overlay picture after the intraoperative registration. This system also corrects cyclotorsion by recognising scleral vessels and landmarks of the iris. The surgeon receives visual guidance for the important surgical steps like corneal incisions, capsulorhexis, IOL centration and IOL alignment of toric IOLs. Moreover, it calculates surgically induced astigmatism (SIA) and optimizes the constant of IOL in cases of post-operative follow up and repeated measurements taken by the system.[21-22]

The Zeiss Callisto Eye has similar functions where the keratometry and other biometric parameters are measured with the help of IOL Master 500 or 700. This system also provides markless alignment of toric IOLs.

TruePlan is a surgical planning application that collects and stores all diagnostic variables that are necessary for the creation of a customized surgical plan which is afterwards sent to the TrueGuide in the operating room. TruePlan can collect data from a variety of devices, such as i-Optics Cassini corneal LED topographer, OCULUS Keratograph 5M and OCULUS Pentacam AXL, as well as Haag-Streit Lenstar.

Aberrometry :

Wavefront aberrometry is helpful in screening of candidates for

multifocal IOL and for precision in Toric IOLs. As cataract surgery has become more of refractive surgery, we have to rule out other ocular co-morbidities to prevent patient dissatisfaction. One of the co-morbidities is aberration in optical system especially the higher order aberrations which produces visual disturbances even with a good visual acuity.

iTRACE is a ray tracing aberrometer combining wavefront aberrometry and placido based corneal topography. Hence, it is superior to other aberrometers in providing results individually for corneal and internal (lenticular) aberrations in addition to total aberrations.

It also helps in evaluating Angle Kappa which is angle between the visual axis and pupillary axis. High angle kappa is considered a contraindication for implantation of multifocal or extended range of vision IOLs as decentration of these premium lenses often result in poor post-operative visual outcomes. It also provides the measurement of 'Angle Alpha' which is measured at the nodal point of the eye. It is the difference between the center of limbus (optical center of cornea) and the visual axis. It is considered a confidence metric because knowing this number helps the surgeon predict how well the MFIOL will align optically with patient's visual axis.

The iTrace workstation incorporates an in-built Toric IOL planner, which calculates the IOL power and also provides axis of placement. Integrated Zaldivar toric calliper with toric calculator can be used to assess the accuracy of preoperative reference axis marking.

Intraoperative wave front aberrometry devices such as Optiwave Refractive Analysis (ORA) and Holos IntraOp perform a real time assessment of phakic, aphakic or pseudophakic refraction to provide feedback for toric IOL alignment. ORA is increasingly being used to estimate the toric IOL power and axis of placement based on the aphakic refraction, especially in post refractive surgery cases. It permits refinement of the axis by providing direction and magnitude of rotation required to achieve minimal residual astigmatism.

Corneal Topography And Tomography:

Routine biometry considers only the optical part of cornea which is central 3 mm. Hence a corneal topography is required to study the larger area of anterior surface of cornea and corneal tomography to study the entire cornea. Newer technologies such as slit-scanning videokeratoscope, Scheimpflug device, anterior segment OCT (AS-OCT) measures anterior and posterior corneal shapes. Topographic analysis eliminates pathological (Fruste) Keratoconus and irregular corneas. Pentacam based on Scheimpflug imaging allows quantifying the corneal irregularity (Total corneal irregular astigmatism), which will be at best lower than 0.300 m. Multifocal implantation is possible upto 0.500 m but contraindicated beyond. Similarly Toric IOLs are also not a good choice in irregular astigmatism. In contrast, Asymmetric but regular astigmatism gives excellent results.

Keratometric readings take into account only the anterior corneal surface. The posterior corneal surface has against-the-rule astigmatism pattern as compared to anterior corneal surface.[23,24] Therefore, in eyes with with-the-rule astigmatism, keratometric astigmatism overestimates total corneal astigmatism, whereas in eyes with against-the-rule astigmatism underestimates total corneal astigmatism.[23-25] This is explained by the fact that corneal thickness profile is not uniform. Hence, manifest astigmatism following Toric IOL implantation can be reduced by proper attention to both corneal surfaces. The complete evaluation of cornea helps in better planning and correction of astigmatism when we are considering Premium IOLs. It prevents unpleasant results and patient dissatisfaction.

Pupillometry :

Pupillometry is often overlooked, but is very important in IOL selection. It is measurement of size and reactivity of pupil. Pupil size affects vision with any IOL, but even more so with multifocal IOLs (MF IOLs). The post-operative visual disturbances are directly related to pupil size. Patients implanted with MF IOL often complain of light reflections or blurred rings which are basically ghost images. These ghost images worsen at night due to increase in pupillary size. Interaction with pupil size varies depending on various IOL brands. With multifocal IOLs, which limit their diffractive rings to the central zone of the optic like the Alcon ReSTOR with apodized refractive-diffractive design, reading vision is better with smaller pupils, while distance vision is better in dim lighting conditions, which may decrease night driving dysphotopsias. The AMO Tecnis multifocal IOL has diffractive rings through the entire optic, resulting in improved reading vision in low light situations when pupil sizes are larger. The key here is to select IOL for individual patient depending upon the size of the pupil, daily activities and desires of the patient.

It has been observed that a smaller pupillary size causes worse near vision. Hence, a limitation of 2 mm in photopic and 5 mm in scotopic will avoid any pupillary refractive disorder postoperatively.

Dry Eye Evaluation:

The examination of ocular surface and tear film is often missed out in routine examinations. Managing dry eye in the perioperative period plays an important role in having good outcome. Most of the patients being operated for cataract surgery are elderly with pre-existing minimal dry eye which worsens after surgery. A simple corneal staining and tear film break up time during slit lamp examination can help in

diagnosis. Other investigations can be done when in doubt.

Dry eyes can also alter the keratometry and topographic readings used for IOL calculation. It can also produce false aberrations in aberrometry. Priming patients preoperatively about their dry eye level and explaining the steps taken to improve it before planning cataract surgery helps them better deal with the minimal increase in postoperative dryness. The dryness and ocular surface need to be treated so they are as normal as possible before investigations and surgery. These patients also need a closer follow-up postoperatively until the ocular surface stabilizes.

TORIC MONOFOCAL IOLS:

Toric intraocular lenses (IOLs) are the procedure of choice to correct corneal astigmatism of 1 D or more in cases undergoing cataract surgery.

Toric intraocular lenses (IOLs) were first introduced in 1992 by Shimizu et al. as 3-piece nonfoldable polymethyl methacrylate implants to be inserted through a 5.7 mm

incision. Technological advancements in terms of IOL material as well as design have resulted in better rotational stability and precise visual outcomes.

Patient Selection:

Ideal case selection is a prerequisite before surgery to ensure patient satisfaction as well as optimal outcomes. 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.

At present, standard toric IOLs are available in cylinder powers of 1.5 D to 6.0 D (1.03 D to 4.11 D at the corneal plane) and are intended to correct preexisting regular corneal astigmatism ranging from 0.75 D to 4.75 D. Extended series and customized toric IOLs to correct higher cylinder powers are also available. 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).

Marking Techniques:

Accurate alignment of toric IOL is a prerequisite to achieve successful outcomes. Various methods have been described to place the preoperative reference and axis marks and may be broadly categorized as manual methods, iris fingerprinting techniques, image-guided systems, and intraoperative aberrometry-based methods.

Manual techniques

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 reference marks are commonly placed in the 3'o, 6'o, and 9'o clock positions to improve predictability. The marking may be performed with a skin-marking pen, or with the help of various devices such as a thin slit-beam, weighted thread, pendulum marker or Nuijts-Solomon bubble marker. This is followed by the intraoperative alignment of these reference marks to the degree gauge on a fixation ring, and the target axis is then marked with a corneal meridian marker.

A change in patient position from sitting to supine may induce significant cyclotorsion, and up to 28° of cyclotorsion has been observed in 68% cases. Hence, the patient should be sitting erect with the back resting against a wall and a straight-ahead gaze while marking the reference axis to avoid inadvertent errors. The cornea should be dry, and adequate topical anesthesia should be administered to improve patient comfort during marking.

The three-step marking method is fairly accurate, and a mean error of 2.4° ± 0.8° has been observed during axis marking with a bubble marker, with a total error of 4.9° ± 2.1° in toric IOL alignment. Both bubble marker and pendulum marker are easy and reproducible techniques with fairly accurate results. A comparative evaluation of four different marking techniques including coaxial slit beam, bubble marker, pendular marker, and tonometer marker observed minimum rotational deviation with the pendular marker and least vertical misalignment with the slit lamp marking technique. The least accurate results were observed with the tonometer marker, whereas the other three methods provided fairly accurate results. Slit-lamp assisted pendular marker has been observed to give more accurate results than using a horizontal slit-beam alone or a direct nonpendular marker.

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 intersurgeon variability may be observed in the accuracy of marking.

Osher ThermoDot Marker (Beaver-Visitec International, BVI, Waltham, Mass.) has been developed to eliminate the ink-associated problems in reference axis marking. It employs a bipolar cautery to create an ink-free, precise reference mark during surgery. Anterior stromal puncture using a 26-gauge bent needle stained with sterile blue ink has been described for reference axis marking, to obtain precise reference marks with no smudging.

Functional outcomes

A UDVA of 20/40 or better is achieved in 70%–100% of cases undergoing toric IOL implantation. Spectacle– independence

for distance vision has been reported in 60%–97% of patients with toric IOLs.

Lower degree of mean residual astigmatism is observed with toric IOLs as compared to nontoric IOL's with or without limbal relaxing incisions. Residual astigmatism may result from preoperative measurement errors, marking errors, posterior corneal astigmatism, ELP, and postoperative IOL rotation. A randomized control trial observed residual astigmatism of 1.0D or less in 88% cases and 0.5D or less in 53% cases undergoing toric IOL implantation.

IOL rotation may be observed as early as 1 h after surgery, and a majority of rotations occur within the initial 10 days. Early IOL rotation likely results from incomplete OVD removal, whereas late postoperative rotation, is influenced by the IOL architecture, design, and axial length. The axis of IOL implantation is associated with postoperative rotation, and an increased incidence of rotation has been observed in cases with vertical axis of IOL implantation (with-the-rule astigmatism). Capsulorhexis extension or inadequate IOL coverage also contribute to postoperative rotation.

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.

BIFOCAL AND BIFOCAL TORIC IOLS

The idea of multifocal IOL was first conceived by Hoffer in 1983 while the first bifocal IOL was implanted by Dr. John Pierce in 1986. Since then a large variety of multifocal IOLs have been developed.

Bifocal IOLs effectively utilizes mainly three principles to enhance the quality of vision as shown in many clinical studies

Table 1 : Multifocal IOLs

Manufactures/ Brand name	Type of Optic	Optic diameter (mm)	IOL materials	Add at IOL plane (D)	Light distribution
ReZOOM (AMO)	Refractive	6 mm	UV blocking Hydrophobic acrylic	+ 3.0 D	Pupil dependent
ReSTOR (ALCON)	Apodized anterior	6mm	UV blocking Hydrophobic	+ 3.0 D, + 2.5 D	Pupil dependent
	Diffractive surface refractive base		acrylic		
Tecnis MF (AMO)	Posterior diffractive surface	6mm	Hydrophobic acrylic	+4.0 D +3.25 D +2.75 D	41% for distance 41 % for near
AT LISA 809 (Carl Zeiss)	Posterior diffractive surface	6mm	Hydrophilic acrylic 25% with hydrophobic	+3.75 D	35% near 65% distance
Acridiff (Care group)	Apodized refractive Diffractive	6mm	UV blocking Hydrophobic acrylic	+3.25 D	Pupil independent
ACRIVA REVIOL (VSY biotechnology)	Refractive-diffractive	6mm	Hydrophobic acrylic	+3.75 D	Pupil independent
Eyecryl Actv (Biotech)	Refractive-diffractive	6mm	UV blocking Hydrophobic acrylic	+3.75 D +3.0 D	Pupil independent

namely

A. Multizonal Refractive [26,27] –use concentric or annular ring–shaped zones of varying dioptric powers on the anterior surface.

B. Diffractive [27,28] –basically have concentric microscopic steps on the posterior surface of lens utilizing Huygens-Frsnel principles.

C. Hybrid IOLs –(using both principles)

Principle of Apodisation (gradual reduction in height of diffractive steps from centre to periphery) has been utilized as further refinement in some multifocal IOL.

There are two focal points created along the optical axis to provide good uncorrected distance and near vision as well as functional intermediate vision using the concept of

simultaneous vision but at the same time reduced effective light energy reaching each focal plane often lead to loss of contrast sensitivity and the superimposition of multiple images on the retina results into unacceptable halos and glare. These visual disturbances are main causes for dissatisfaction in the patients using these lenses. However, these dysphotopsia have been observed to reduce after the bilateral implantation because of bilateral summation effect and more importantly by neuroadaptation mechanism after the gap of some time.

Bifocal IOLs have evolved from various modification and designing principle right from rigid PMMA platform to foldable silicone to acrylic. Bifocal IOLs in the current scenario mostly utilizes fully diffractive (Tecnis/acrilisa) or apodized diffractive and refractive (Acrysof Restor) with aspheric lenses.

On comparative evaluation, Diffractive multifocal IOL performed better than the refractive multifocal IOL in uncorrected near visual acuity (UNVA), reading acuity, reading speed, smallest print size, spectacle independence, halo, and glare rate.

Cochrane review and meta-analysis both demonstrated higher rates of spectacle independence with multifocal IOL compared to monovision strategy using monofocal IOL.[29,30] However, subjective visual disturbances including glare and haloes were both more common and bothersome in patients receiving multifocal IOLs compared to monovision.

Compared to multifocal IOLs, monofocal IOLs are not considered to cause reduction in contrast sensitivity, and thus may be a better choice in patients suffering from glaucoma, macular degeneration, or other diseases causing reduced contrast sensitivity.

Although, satisfactory outcome in terms of spectacle independence for distance and near vision have been reported in patients using bifocal IOLs but the newer advent of EDOF lenses and Trifocal IOLs have demonstrated superior results in terms of unadded intermediate VA.[31,32]

But as per few literature, Mix-and-match implantation of diffractive multifocal IOLs with different add power provides an excellent wide range of vision, as well as high levels of visual quality and patient satisfaction.[33,34]

So, to conclude, Conventional bifocal IOL is still preferred in patients who demand good near vision, do not drive, cannot afford trifocal IOL/ EDOF IOL and have bifocal IOL in another eye. Preferred addition is +4 D in nondominant eye and +3.25 D in dominant eye.

TRIFOCAL AND TRIFOCAL TORIC IOLS

Introduction:

The quest for Spectacle independence has created innovation to Trifocal and Trifocal Toric IOLs from Multifocal bifocals and its toric versions.

Table 2 : Trifocal IOLs

Specification	Biotech Optiflex Trio	Zeiss AT LISA tri	Fine Vision Physiol	Alcon Panoptics	Acriva^{UD} Trinova
Optic	Diffractive Refractive Aspheric Trifocal	Trifocal + Bifocal Combination	Trifocal Convolution	Quadrifocal– Enlightened IOL Technology	Trifocal Sinusoidal Vision Technology, Foldable, Single Piece, Aspheric,
Light Yield	88.30%	85.70%	85%	88%	92%
Light Distribution in Day light (Pupil size- 2.0- 2.5 mm)	40% Far, 30% Int 30% Near	40% Far, 35% Int, 25% Near	50% Far, 30% Int, 20% Near	60% Far, 20% Int, 20% Near	41% Far –30% Int, 29% Near
Light Distribution in Dim light (Pupil size- 5.0- 6.0 mm)	51% Far, 23% Int, 26% Near	60% Far, 10% Int, 30% Near	70% Far, 6% Int, 24% Near	70% Far, 15% Int, 15%Near	45% Far 25% Int, 30% near
Intermediate and Near Addition (IOL Plane)	3.50D – 1.85D	3.33D – 1.66D	3.50D – 1.75D	3.25D – 2.17D	3.00D–1.50D
Theoretical Reading Distance	38 cm –72 cm	36 cm –72 cm	34 cm –68 cm	35 cm –55 cm	38cm– 80cm
Material	Hydrophobic Natural Yellow	Hydrophilic acrylic with hydrophobic surface	Hydrophilic acrylic	Hydrophobic	Achromatic, Hydrophobic Surface, UV, Violet, and Blue Filter

Diopter Range	7.0 D –30.0 D	0.0D – 32.0D	10.0D – 35.0D	10.0D – 32.0D	0–32 D
Total Number of Rings	12	28	20	15	12 ridges
Diffractive zone Diameter	4.0	4.34	5.1	4.5	
Size of center Ring (9 mm)	1.12	1.06	1.16	1.15	
Angulation	0	0	5	0	

Different types of trifocal IOLs with different haptic and optical designs are currently available, all attempting to offer excellent vision at far, intermediate, and near distances while providing a low incidence of photic phenomena and high patient satisfaction in contrast to Refractive or Diffractive Multifocal IOLs. The main disadvantage of refractive multifocal IOLs is their pupil dependence and the loss of energy is the main disadvantage of diffractive IOLs.

As Dr. Piovella said, "The trifocal IOL has fewer rings on the optic surface, which reduces the potential for visual disturbances that can be difficult to manage in demanding patients. In addition, it is independent of pupil diameter up to 4.5 mm. Therefore, it provides good quality vision in younger patients who tend to have a larger scotopic pupil."

Theoretical simulations carried out by Holladay et al. demonstrated that aspheric lenses may undergo a decentration of up to 0.4 mm and a tilt of up to 7° before they start to show a lower performance than their spherical counterpart. Piers et al.'s10 studies revealed an even higher tolerance to malposition, the resulting threshold values being 0.8 mm of decentration and 10° of tilt. Central Continuous Curvillinear Capsulorhexis is most important factor in IOL centration postoperatively. IOL decentration and rotation following its implantation, can be due to different factors, such as IOP, haptic pressure upon the capsular bag and the remainder of viscoelastic material, capsular bag size, or the lenses' design and material.

Trifocals and Trifocal torics are being accepted with good patient satisfaction in different studies. Patient requirement and habits are important consideration before considering particular types. Most trifocals provide good near, distance vision and variable intermediate vision. Taller people may get different models than shorter people considering their specific requirements. Good pre-operative chair time is important for optimum results. Also, many trifocals are new and will require further careful evaluation to establish their utility.

Table 1 Comparison of the three types of IOLs in terms of quality of vision at different distances, reading performance, contrast sensitivity, and optical phenomena

Type of IOL	Distance vision	Intermediate vision	Near vision	Reading performance	Contrast sensitivity	Optical phenomena
Bifocal IOLs	+++	+	+++	+++	+++	+++
Trifocal IOLs	+++	+++	+++	+++	++	++
EDOF IOLs	+++	+++(+)*	++	+++	+++	++

A (+) sign indicates performance of the IOL in terms of vision, reading performance and contrast sensitivity. The more (+) signs indicate higher performance. In case of optical phenomena more (+) signs indicate higher frequency of optical phenomena. *, EDOF IOLs outperform trifocal IOLs in terms of intermediate vision under mesopic conditions, but they exhibit similar results under photopic conditions. EDOF, extended depth of focus; IOL, intraocular lens.

EXTENDED DEPTH OF FOCUS (EDOF) INTRAOCULAR LENS:

The basic principle behind EDOF IOLs is to create a single elongated focal point to enhance the depth of focus or range of vision. A proprietary diffractive echelette design is used in EDOF IOLs and forms a step structure. The height, spacing, and profile of the echelettes are optimized to achieve constructive interference of light from different lens zones, thus producing a novel light diffraction pattern. In addition, proprietary achromatic technology and negative spherical aberration correction improve the image quality. With technological advancement, EDOF IOLs showed good visual outcomes with less contrast reduction and fewer photic

phenomena commonly associated with multifocal IOLs. However, according to some studies, EDOF lenses worked less efficiently for near vision than did trifocal IOLs. Currently, several types of EDOF IOLs are commercially available, including the Tecnis Symfony (Johnson and Johnson Vision), Mini WELL (Sifi Medtech), IC-8 (AcuFocus Inc) and Wichterle Intraocular Lens-Continuous Focus (Medicem). Until 2018, the Tecnis Symfony was the only United States Food and Drug Administration (FDA)-approved EDOF lens.

Quality of Intermediate and Near Vision

Trifocal lenses were developed to improve the quality of intermediate vision through the incorporation of a third focal point that was missing in bifocal IOLs. Several studies have investigated whether implantation of trifocal IOLs held its promise to improve intermediate vision compared to bifocal IOLs. Liu et al. in his study concluded that after a follow-up period of 3 months, there is no statistical difference ($P>0.05$) for near and distance vision in bifocal and trifocal IOLs. On the other hand, the uncorrected intermediate visual acuity (UIVA) measured at 80 cm was significantly better in the trifocal IOL group compared to the bifocal IOL group ($P<0.01$).

EDOF IOLs, also referred to as extended range of vision (ERV), have the ability to create a continuum of foci through the implementation of spherical aberration and the presence of optically active transitional zones. Consequently, an extended area of focus is created, enhancing the quality of intermediate vision. The Tecnis Symfony (Abbott Medical Optics, Inc., Abbott Park, IL, USA) was the first EDOF-labeled IOL approved by the U.S. Food and Drug Administration in 2016.

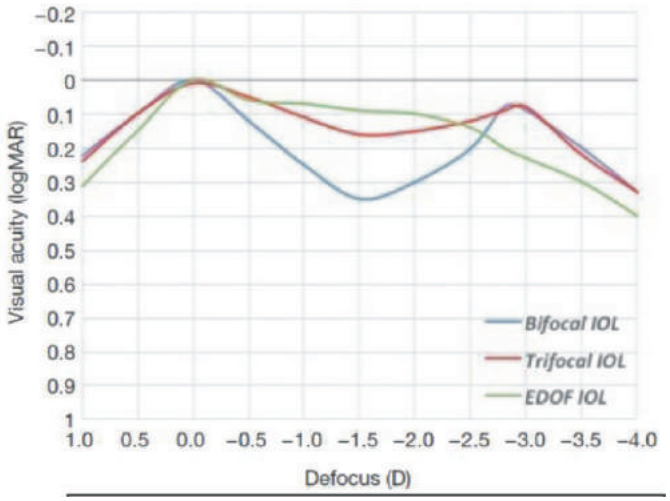
EDOF lenses exhibit similar results in terms of distance vision when compared to trifocal or bifocal IOLs. Several studies reported no statistically significant difference between the EDOF lens and the trifocal lenses in either monocular ($P=0.717$) or binocular ($P=0.837$) uncorrected distance vision.

The performance of trifocal and EDOF lenses appears to be similar also in the context of intermediate vision. Cochener et al. reported the absence of a statistically significant difference between the two groups of lenses, with a tendency for better outcomes with the EDOF IOL, when targeted for emmetropia. In the prospective study by Mencucci et al., implantation of the EDOF lens resulted in better outcomes in terms of intermediate vision under mesopic conditions. However, in photopic conditions, there was no statistically significant difference in uncorrected intermediate vision outcomes between the EDOF and the trifocal IOLs. Thus, it seems that the illumination settings may play a crucial role in the performance of each IOL type when intermediate vision is concerned.

Both EDOF and trifocal IOLs achieve spectacle independence for intermediate and distance vision. In terms of near vision, several studies shows that trifocal IOLs are superior to EDOF IOLs. In fact, Mencucci et al. showed a higher usage of spectacles for near vision in patients who were implanted an EDOF IOL, compared to those who were implanted a trifocal one. However, the level of post-operative satisfaction was the same for both patient groups.

The Defocus Curve

The evaluation of the defocus curve is of great importance as it offers the practitioner and the patient information about the



Graphic representation of the defocus cures for the three types of IOLs.

expected visual performance of the IOL over the entire distance spectrum. The position of the peaks in the defocus curve is related to the main focal points of the IOLs, hence these curves express the performance and optical imaging of each IOL as a result of its individual design. Typically, the bifocal IOLs are associated with a V-shape defocus curve pattern with the highest visual acuity at 0.00 D, resulting in better performance at distance vision, a second peak between −2.00 and −2.50 D and a sharp gap for intermediate vision.

Shen et al. conducted a metanalysis and concluded that the trifocal IOLs achieve a better result at defocus of −1.50 to −0.50 D and present a significantly better intermediate vision when compared to bifocal IOLs.

EDOF IOLs produce a smooth, uninterrupted, and dome-shape like defocus curve, which provides good quality intermediate vision and tapers off at reading distance. Thus, EDOF IOLs provide better vision at −1.00 and −1.50 D defocus compared to bifocal IOLs and worse near vision than trifocal IOLs at −2.00 to −4.00 D defocus (i.e., between 50 and 25 cm).

The multifocal and EDOF IOL performance has also been shown to depend on pupil size. Since pupil size may affect

everyday tasks such as driving at night or viewing in sunlight. EDOF IOLs provided the best vision at 2 mm pupil diameter. Trifocal IOLs showcased better pupil independence than both bifocal and EDOF IOLs.

Contrast Sensitivity

Post-operative contrast sensitivity is regarded as a good surrogate marker of visual function. Cochener et al. had described the theoretical superiority of EDOF over the trifocal IOLs in terms of contrast sensitivity due to the compensation of chromatic and spherical aberrations by the EDOF IOL design. Mencucci et al. confirmed this hypothesis and demonstrated that the EDOF is associated with enhanced contrast sensitivity, under both photopic and mesopic conditions, when compared to the trifocals.

When the comparison involves an EDOF and a bifocal lens, there is absolutely no statistical difference in terms of contrast sensitivity.

Reading Performance

Mencucci et al. compared the reading skills of patients who were implanted the trifocal IOLs and the EDOF IOL under both photopic and mesopic conditions. No statistically significant differences were found in the reading performance among the patient groups (P>0.05). The authors proposed that although trifocal lenses exhibited better outcomes for near vision, the enhanced contrast sensitivity of the EDOF lens possibly compensates for the worse near vision with this type of lens, thus leading to similar reading performances.

Optical Phenomena

The design of multifocal IOLs is based on the division of light into different foci. Although the addition of new focal points has improved intermediate vision, the focused image is always overlaid by one (bifocal) or two (trifocal) secondary out-offocus images, coming from the added foci of the IOL. Thus, an important aspect of multifocal or EDOF IOL implantation is the occurrence of undesired optical phenomena, which may compromise quality of vision. Optical phenomena include Graphic representation of the defocus cures for the three types of IOLs. halos, flashes, starbursts, glare and shadows. Due to their subjective nature, a quantitative assessment of these phenomena is difficult to illustrate. Evaluation of optical phenomena varies across different studies, which makes valid comparisons of different IOLs almost impossible.

Multiple studies have reported no statistically significant difference in the optical phenomena of various multifocal IOLs, with the visual disturbance that patients experience being none or mild. Halos seem to be more common than glares, especially in larger pupillary diameters (i.e., 4.5 mm). The frequency of all the optical phenomena decreases as time goes by, likely due to neural adaptation.

Comparisons between EDOF and trifocal IOLs showed no difference in the dysphotopic phenomena in the two groups. Less than 1% of patients experienced symptoms and of those who did, very few reported disturbances in their everyday life. Savini et al. compared EDOF and bifocal IOLs and found that Halo size and intensity were more prominent in patients with bifocal IOLs while EDOF IOLs seemed to induce fewer night halos.

Conclusions:

Over the past few years newer IOL technology has transformed the cataract surgery and raised the patient expectations of excellent distance, intermediate and near vision. The choice of IOL should depend on each patient's needs according to their work and daily habits (e.g., use of computers, electronic devices etc.). The main IOL types that have been developed include bifocal, trifocal and EDOF IOLs. In general, trifocal IOLs enhance intermediate vision in comparison to bifocal IOLs, due to the addition of a third focal point, while maintaining good distance and near vision. The EDOF lenses provide better contrast sensitivity and decrease spectacle dependence for distance and intermediate vision. EDOF IOLs are also being associated with less visual disturbances than bifocal IOLs. However, EDOF lenses are inferior to the trifocal ones in terms of near vision, though this difference does not seem to alter patient satisfaction levels.

Management of residual refractive error after cataract surgery

Introduction:

Postoperative residual refractive error after cataract surgery in the modern day ophthalmology is a cause of concern and disrepute and should be dealt with judiciously with an individualised approach for every specific patient scenario. Residual error can be broadly categorised into myopia, hyperopia and astigmatism. This article discusses enhancement strategies which consist of two general categories: corneal ablative procedures, and exchange, addition, or manipulation of IOLs .

Even in the hands of the most experienced and meticulous surgeon, refractive surprises can occur due to myriad factors which includes preoperative fallacious biometry, intraoperative improper IOL positioning , manufacturing deficiencies. Emmetropia (spherical equivalent – 0.5 to + 0.5 D and <1.0 D astigmatism) is the target refraction in most cataract cases. A "physiological" astigmatism of up to 1.0 D either with or against the rule may be useful to increase the depth of focus thus increasing the quality of vision in daily life. Astigmatism of up to 1.0 D may also be considered as a physiological measure to reduce uncorrected presbyopia for eyes with intact retina and

optic nerve.

Counselling of the patient, treatment of dry eyes and prescription of appropriate glasses or contact lens takes care of the majority of post operative residual refractive errors.

Next important step is to Identify the cause of refractive surprise

1. A formal subjective refraction is essential as auto–refraction is prone to error.
2. A thorough dilated examination is necessary to identify surgical causes such as tight corneal sutures , placement of the IOL in the sulcus or subluxation. Look for a distended capsular bag due to retained viscoelastic that can cause a myopic shift. The presence of corneal pathology such as corneal scarring or oedema can influence the refractive outcome. Post-operative cystoid macular oedema can cause a hyperopic shift.
3. Review the refractive history as well as the biometry, the IOL selection process and the surgical records. Wrong patient biometry, transcription errors, selecting the lens from the ACIOL column, incorrect A-constant or incorrect formula can all lead to insertion of the wrong IOL
4. Check the axial length by repeating the biometry which might not have been done accurately prior to surgery due to a dense cataract. Ultrasound measurements are prone to error as contact with the cornea may compress the eye and lead to underestimation of axial length.
5. Check for abnormal keratometry. The presence of high Ks or astigmatism can indicate pre-existing undiagnosed keratoconus. Previous refractive surgery is not always volunteered by the patient. LASIK flaps can be hard to detect and absent in previous LASEK/PRK.
6. If there has been no error, the refractive surprise can be attributed to effective lens position and a similar error is likely to occur in the fellow eye.

Surgical options for correction of refractive error following cataract surgery:

Lens-based procedures -

Lens based procedures are preferable in some situations and have certain advantages If there is a large postoperative refractive surprise, lens based procedures are more effective in reducing high degrees of spherical error. The original cataract wound can be reopened and the IOL implanted soon after the initial surgery (IOL exchange). There is no need for special settings such as those required for laser refractive surgery.If the lens to be removed is foldable it can be cut and removed through a small incision (Figure 1) The piggyback technique involves the implantation of two IOLs in the posterior chamber of the same eye or one in the bag and one in the ciliary sulcus. It is easier than exchanging the original IOL as sometimes the original IOL is strongly adherent to the capsular bag and its removal may cause rupture of the capsular bag and zonular damage, which may lead to cyclodialysis, retinal tears and macular edema. Another advantage of a piggyback IOL is its reversibility.

Many different types of piggyback lenses have been used. The Add-On variety, with its large optic size and rounded anterior optic edge design reduced iris trauma. Sulcoflex variety placed in the ciliary sulcus is also a safe and predictable option. Sulcoflex multifocal piggyback IOL can be used to tackle hyperopic -presbyopic surprise in a high myopia patient.

In case of residual astigmatism after toric IOL implantation which could be due to total corneal astigmatism estimation error, Toric IOL calculator error, Surgically induced astigmatism or rotational error. it is assumed that a magnitude of 3.5% hypo correction occurs per each 1° of misalignment of the lens, and at 45° of rotation its influence is neutralized, and above 45° additional astigmatism is induced. Realignment of the toric IOL is needed in 0.65%–3.3% cases, with more than 10° of rotation from the target axis. The UDVA is significantly worse in misaligned multifocal toric IOLs as compared to monofocal toric lenses.

The calculation of the ideal IOL axis is performed using ray tracing aberrometry (iTrace) or according to Berdahl & Hardten formula (astigmatismfix.com), which considers the characteristics of the IOL implanted, the axis on which it is positioned, and the residual manifest refraction..Using this technique the IOL can be redialled to the desired axis in the early postoperative period, preferably the first week.In a study by Oshika et al., 6431 eyes are implanted with toric IOLs, and realignment was performed in 0.653% of cases .

Its not recommended to exchange a monofocal IOL with a Toric IOL in case of post operative high astigmatism as a surprise because its difficult to predict the induced astigmatism in the process of wound enlargement. In such condition, corneal ablation is recommended. Femtosecond laser-assisted intrastromal keratotomies may also be attempted to correct residual astigmatism.

Corneal ablative procedures:

Laser refractive surgery avoids additional intraocular surgical procedures, provides better accuracy than IOL exchange or piggyback lens techniques especially for cylinder outcomes and gives higher predictability of results. LASIK /PRK seems a safe option even in post YAG capsulotomy patients. Additional optic enhancements can be done in future once LASIK flap has been done.

LASIK enhancement is more effective and predictable after monofocal IOL implantation as compared to a multifocal IOL. Wavefront-guided treatments with iris registration may provide better outcomes than conventional LASIK.

LASIK enhancement for refractive surprise after cataract surgery has few limitations .In large refractive error, thin corneas, corneal opacities and dry corneas, corneal ablative procedures cannot be carried out. Pre-existing cataract incisions also create problems during flap creation sometimes.

CONCLUSION:

The best method to tackle postoperative refractive surprise is to prevent it by following strict preoperative protocols. Once it happens, LASIK/PRK is a better and safer alternative to IOL manipulation techniques except in high errors and suspicious corneas.

Future of Premium IOLs

In this world that is in a constant state of technological evolution the quest is to give our patients access to future improvements in lens design. At some point in the future, we will likely solve the puzzle of accommodation.

Adjustable and exchangeable lenses are within the realm of possibility for the future of IOLs. We can look forward to some innovative technology.

Examples of Adjustable Lens Technologies

Three New IOL Related Technologies on the Horizon.

1) Ring less multifocal IOL

First step towards that direction has been made with the new Eyhance IOL from Johnson and Johnson. It provides definite advantage in terms of reducing glare and haloes – which is one of the main problem with multifocal IOLs.

2) Postoperative Refractive Adjustment

Postoperative Refractive Adjustment is a post-op laser treatment where the surgeon is able to alter the diopter size of an already implanted IOL using a femtosecond laser and an optical focusing system. The laser doesn't change the thickness or shape of the IOL, however, it changes the hydrophilicity of the lens. So far it's been tested on Acrylic lenses from all the major manufacturers and has had great accuracy in achieving the desired change in diopter. If this system is approved for public use in the future, it would dramatically change the game, eliminating the needs for explanting IOLs with miscalculated diopters. As the patient ages, there is potential for an annual adjustment of the IOL's diopter for the best possible vision from that IOL. Something to think about!

RxLAL. RxSight (formerly Calhoun Vision) right now has the only FDA-approved technology that allows non invasive alteration of lens power. The labeling of the company's Light Adjustable Lens (RxLAL) is for correction of up to 2.00 D of postoperative sphere and/or -0.75 to – 2.00 D of residual postoperative refractive cylinder. According to FDA data, patients achieved 20/20 visual acuity at 6 months at a rate twice as high as patients receiving standard IOLs.

Perfect Lens.

Another company, Perfect Lens, is approaching noninvasive adjustment of IOL power through a different mechanism. The company's developers have found a way to alter the power of a hydrophobic IOL through a technology called phase wrapping. In this process, a femtosecond laser applies a pattern of spots to the lens, thus creating a lens within the lens, using Fresnel optics. The laser energy changes the relative hydrophilicity of the acrylic lens, thereby changing the refractive index. The technology can theoretically be used with any hydrophobic acrylic lens, and it has been shown to create highly accurate power changes of up to 3.60 D. It can correct sphere and cylinder and even create or reverse multifocality. The desired characteristics could be written onto the lens postoperatively.

Merck is developing yet another technology, dubbed LicriEye, for postoperative lens power adjustment. This technology is based on a proprietary reactive mesogen material called Licrivue. Mesogens are compounds that display properties similar to those of liquid crystals. The material is flexible and has been used in other applications such as in LCD and OLED displays to help improve the optical quality of images. The mesogens can be altered postoperatively using non invasive methods.

3) Small-aperture IOL

AcuFocus has now created a monofocal intraocular lens (IC-8) that uses the "pinhole effect" principle to alleviate distortion and expand depth-of-field in an IOL implant. The basic principle is similar to the KAMRA corneal inlay in which only allows central, focused light to reach the retina, removing the blur caused by peripheral defocused light. The results (in theory) would mean the highest quality of vision over the broadest continuous range of any premium IOL currently available. This essentially means that this technology could compete directly with the multifocal market, providing a high-quality dynamic range of focus in a monodical lens.

4) The Omega Gemini Capsule

The Omega Gemini Capsule is essentially an artificial capsule that is implanted into the eye in order to create a

stable environment to house other ophthalmic technologies such as IOL implanted, medication delivery, and augmented reality technology. The Gemini Capsule props the capsule open, is 3 dimensional and creates artificial "walls" within the capsules, enforcing the stability of the

implantable space. Omega's future hope is that Gemini will provide the ability to house implantable technology (in addition to IOLs) for the future, things like augmented reality devices.

There are two modular IOL technologies now in development, the Harmoni Modular IOL (ClarVista Medical) and the Precisight (InfiniteVision Optics). Both ClarVista and InfiniteVision have created multicomponent IOL designs that consist of a base plate with haptics that accepts proprietary exchangeable optics. The optics can be removed while the baseplate and haptics remain in place. This will make the process of exchanging or upgrading IOLs easier to recommend in the event of a refractive surprise, multifocal intolerance, or the emergence of a technology upgrade.

Conclusion The future is coming. Perhaps it is already here. We must do everything in our power to leverage the collective creativity of physicians, engineers, and materials scientists to continue moving the needle. The human lens is a work of wonder, and we need better designs to mimic its natural functions as well as less invasive ways of correcting refractive misses.

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Patients have varied and Nuanced perspectives on Surgical Glaucoma Management

Investigators interviewed patients with moderate to severe open-angle glaucoma to understand their priorities and treatment preferences. The concerns of the 28 surgery-naïve participants were relatively similar to patients with milder glaucoma. They were apprehensive about the impact of glaucoma on their vision-dependent daily activities, the avoidance of visual symptoms and reduction of treatment burden. Patients also expressed anxiety about their visual prognosis and contemplated their tolerance for surgical treatment. Based on these findings, the authors urge researchers to expand glaucoma trial outcomes to include functional patient-centered outcomes. *Ophthalmology Glaucoma, September 2020*