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Successful Premium Multifocal IOL Surgery: Key Issues and Pearls

Chen Xu

Abstract

Premium multifocal IOLs are a popular option for cataract or presbyopia patients today. Patients can achieve high levels of success and satisfaction after these advanced technology IOLs implantation. However, adequate preoperative clinical evaluation including patient selection, optical and anatomical examination is crucial to reach a success case. Based on the preoperative diagnosis including the corneal astigmatism, biometry measurement, IOL power calculation, presbyopia correcting IOLs' indications and contraindications should be assessed for IOL selection strategy. Surgical procedure should be technically optimized to achieve the best outcomes. Adequate management of both satisfied and unsatisfied patients will improve the benefit of current premium IOLs.

Keywords: premium IOL surgery, patient selection

1. Introduction

Premium multifocal intraocular lenses (IOLs) became more and more popular in modern cataract surgery after new millennium year [1, 2]. In tandem, the advances in ophthalmologic surgical approach such as femtosecond laser assisted cataract surgery (FLACS) [3], the improvement in biometry and IOL power calculation [4], the development of the intraocular lens techniques [5] led to successfully correct presbyopia, astigmatism and other refractive error through cataract or lens exchange surgery. These premium IOLs surgeries especially the presbyopia-correcting procedures can offer patients more visual and life quality without spectacle. But there are many key issues in the presbyopia-correcting procedure including proper patient selection, preoperative counseling, surgical planning and techniques which should be focused during perioperative stage.

2. Premium IOLs

Comparing with conventional IOL, premium IOLs can offer more and better visual function. But there are no standard criteria about premium IOL due to the continual evolution of the IOLs' technology. The aspherical IOL, blue light filter IOL, toric IOL had been defined as premium IOLs in the past decades. This chapter will highlight the presbyopia correcting IOLs as the premium IOLs in the following paragraph. The presbyopia correcting IOLs can be classified into three groups: accommodative IOLs, refractive or diffractive multifocal IOLs and extended depth of focus (EDOF) IOLs according to its optical design and physical properties.

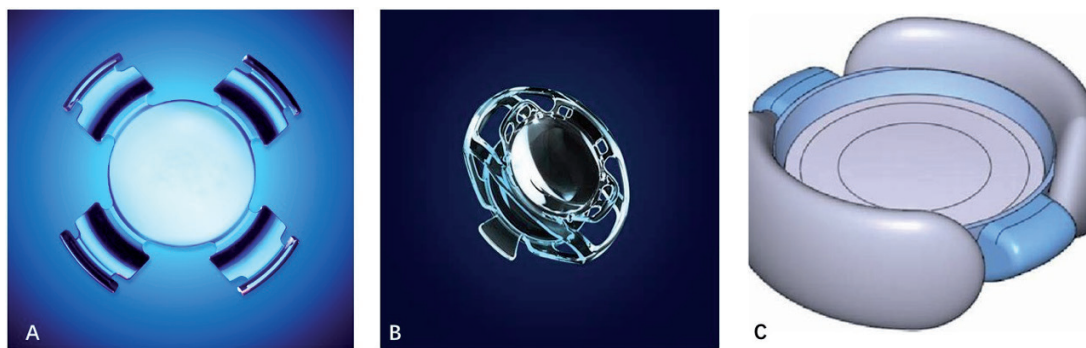


Figure 1. Accommodating intraocular lenses. (A): 1CU, HumanOptics; (B): Dual-optic synchrony IOL, AMO; (C): FluidVision accommodating IOL, PowerVision.

2.1 Accommodating intraocular lenses

Accommodative IOL are designated to produce a dynamic power with the change of IOL optic position, shape or refractive index by pseudoaccommodating and/or accommodating mechanisms with contraction of the ciliary muscle [6]. There are several accommodative IOLs design strategies: single-optic, dual-optic and deformable optic IOLs (**Figure 1**). Single-optic accommodative IOL (Crystalens, Bausch & Lomb; 1CU, Human Optics) possess the hinge design between the optic and the haptic to facilitate the anterior axial movement of effective lenses position with pressure of the capsule bag and vitreous during the accommodative stimulus. Previous studies demonstrated that 1 mm of optic movement is equivalent of 2 D of power change [7]. But the clinical studies had not demonstrated the consistent accommodation amplitude of the pseudoaccommodating IOL eyes especially in the long term follow up. Dual-optic Synchrony IOL (Abbott Medical Optics, AMO) utilize a positively powered biconvex front lens (+32D) connected to a negatively powered concave-convex lens. During the accommodative effort, the distance between the two optic elements increased that lead to increasing effective power of the overall lens [8]. The deformable optic design IOLs like FluidVision accommodating IOL (PowerVision) still underwent investigation in lab or clinical trial research. Though there are no contrast sensitivity loss or dysphotopsias issue, all these accommodative IOLs still have their limitations about the inability to consistently generate large amounts of accommodative power.

2.2 Multifocal IOL

There are two type multifocal IOLs according to optical design principle: refractive and diffractive IOLs (**Figure 2**).

Refractive multifocal IOLs based on the different dioptic power zone with the light ray's refraction principles. These zones provide various focal points, allowing for an improvement in distance, intermediate, and near vision. Though refractive multifocal IOL can afford good quality vision, the limitation of these symmetric multifocal lens (Array, Abbott Medical Optics; ReZoom, Abbott Medical Optics) are pupillary size and lens centration dependence. The asymmetric segmental refractive IOLs (Lentis Mplus, Oculentis) has been intended to reduce this problem and available for patients with low acceptance for dysphotopsia [9].

Diffractive multifocal IOLs rely on concentric diffractive surfaces on the optic portion of the lens, this causes constructive and destructive interference of optic wavefronts to provide two or three focality which led to bifocal or trifocal IOLs. A different approach about diffractive ring pattern, diffractive ring width and

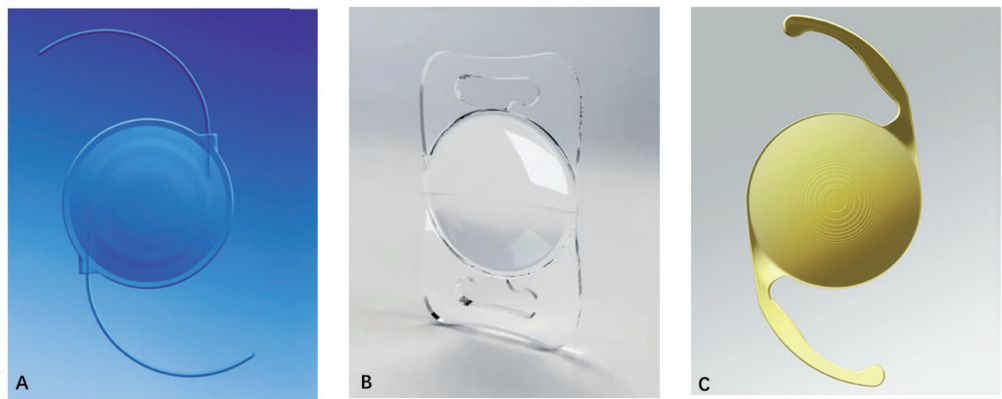


Figure 2.
Multifocal IOL. (A): Array IOL, AMO; (B): Lentis Mplus IOL, Oculentis; (C): ReSTOR IOL, Alcon.

step height by different manufactures introduces different add power and light distribution. Larger ring width provides less addition power and small ring width provides more addition power, while higher steps sends more light to distant focal point and lower step sends more lights to near focal point. The IOL (Restor, Alcon) with refractive-diffractive mix pattern and apodized steps which has concentric rings of decreasing height intends to influence light distribution between distant and near focal points on pupil size [10]. Multifocal IOLs are associated with higher rates of spectacle independence than monofocal IOLs, but are more frequently associated with dysphotopsias and decreased contrast sensitivity [2].

2.3 Extended depth of focus IOLs

Extended depth of focus (EDOF) IOLs are a newer category of IOLs that aims to give an elongated focus of vision, that enhances depth of focus rather than introduces several foci. It can reduce photic phenomena, glare, and halos, which have been reported in traditional multifocal IOLs. Tecnis Symphony IOL (Abbott Medical Optics) was the first EDOF IOL approved in 2016 by the U.S. Food and Drug Administration (FDA) (**Figure 3**). Now, there are several EDOF IOLs had been released in the market which had combined with different techniques such as diffractive optical design, spherical aberration, chromatic aberration, pin-hole effect [11]. American Academy of Ophthalmology has provided consensus

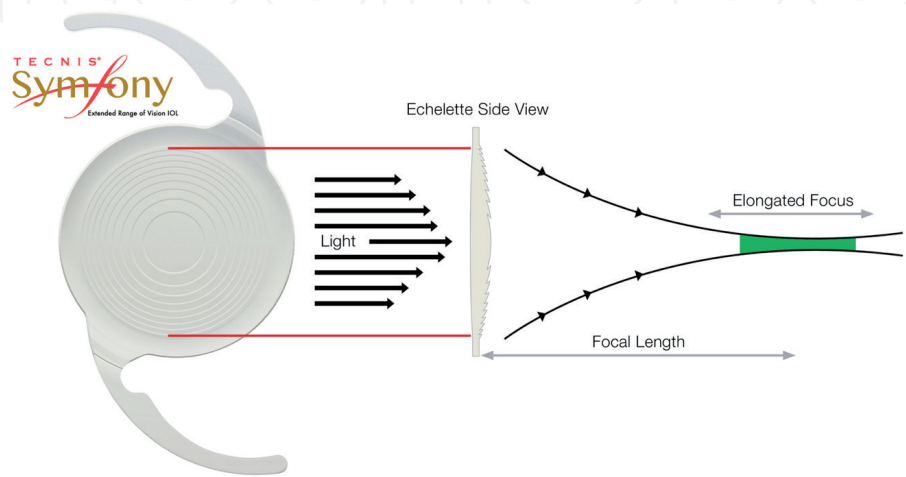


Figure 3.
EDOF IOLs: Symphony IOL.

Premium IOL	Principle	Optical design	Focality	Interm/ Near Add(D)
Crystalens (Bausch & Lomb)	Accommodative	Single-Optics	Accommodating	>0.4
1CU (Human Optics)	Accommodative	Single-Optics	Accommodating	1.36 ~ 2.25 [15]
Synchrony IOLs (AMO)	Accommodative	Duel-Optics	Accommodating	1
Array (AMO)	Refractive	Zonal, progressive	2	0/3.5
ReZoom (AMO)	Refractive	Zonal, progressive	2	0/3.5
Restor (+4,+3,+2.5) (Alcon)	Diffraction	Symmetric, Apodized	2	0/4.0 0/3.0 0/2.5
Tecnis ZKB, ZLB, ZMB (AMO)	Diffraction	Symmetric, Constant	2	0/2.75, 0/3.25, 0/4.0
AT Lisa 809MP (Zeiss)	Diffraction	Symmetric, Constant	2	0/3.75
SBL 2 and 3 (Lenstec INC)	Refractive	Asymmetric. Segmental	2	0/2, 0/3
Mplus Lentis MF 20/30(X) (Oculentis)	Refractive	Asymmetric. Segmental	2	0/2, 0/3
PanOptix AcrySof (Alcon)	Diffraction	Diffraction, Constant	3	2.17/3.25
AT Lisa Tri (Zeiss)	Diffraction	Diffraction, Zone	3	1.67/3.3
FineVision (PhysIOL)	Diffraction	Apodized Diffraction	3	1.75/3.5
Comfort Lentis MF 15 (Oculentis)	EDOF	Refractive	2	1.5/0
Symfony Tecnis (AMO)	EDOF	Diffraction, achromate	EDOF	1.75/0
Mini Well Ready (Sifi Meditec)	EDOF	Progressive, Spherical aberration	EDOF	0/3
IC-8 (AcuFocus)	EDOF	Masked, Pin-hole	EDOF	

Table 1.
Properties of popular premium intraocular lenses (IOLs) [10, 11].

statement for EDOF IOL. These should have an extended far focus area which reaches the intermediate distance, providing excellent intermediate vision. Depth of focus should be at least 0.5 D wider than monofocal IOL for distance visual acuity of 0.03 logMAR [12]. Nevertheless, in practice, EDOF lenses provide excellent intermediate vision, but inadequate quality of vision for near distance [13, 14] (**Table 1**).

3. Patients selection

Even the IOLs technique progress offers patients the possibility of spectacle independence, the selection of presbyopia correction candidates is the most important issue which can lead to a successful surgery [16]. The right patients are the cataract or presbyopia patients who seek an intraocular IOLs solution to spectacle

independence. The surgeon should understand patient's expectations about visual task. A detailed discussion should be held to explain the limitations of premium IOLs to patient, that can establish their realistic expectation [17].


The characteristics of lifestyle or work is also an important selection criterion for premium IOL procedure. Ophthalmologists choose the correct type multifocal IOLs depending on what they do or where they live. Different cultures expressed different visual requirement on lifestyle and work. There may be a lot of time-consuming on near work with the computer, tablet, mobile phone, and on near life with book reading in Asian people, while there are more of an outdoor life in western populations. Especially, Chinese text may be very small and intricate comparing to English character, and hence a full reading add is usually needed. Furthermore, Asian people are generally shorter figure and shorter arms which cause the shorter distance between the face and the book, the mobile phone and other materials. Low add multifocal IOLs or normal monovision strategies may not be able to cope with the demands of reading in Asian people. The near vision satisfaction will be gain better in western population than Asian people. When such near vision is a high priority, high add multifocal IOLs or full-range multifocal IOL is the better solution.

Age also plays an important role in patient selection. Several conditions become more prevalent with age, such as optic neuropathy, macular degeneration and ocular surface disease, that may compound the loss of contrast sensitivity seen in multifocal IOLs. The examination of ocular disease using OCT, visual field, visual electrophysiology will provide some information about the post-operative visual quality results. These age-related diseases will be discussion in below. Multifocal IOLs implantation in pediatric cataract case is the subject of much controversy [18]. Amblyopia is common in these patients especially in unilateral pediatric cataract patients, while multifocal IOLs will reduce the contrast sensitivity and exacerbate amblyopia. Another issue is the ongoing growing of the child resulting in the question of how to calculate the power of the implanted lens, because the target refractive status depend on the age of the patient and the visual demands. There are just a few publications on this subject, we also did not have any experiences of multifocal IOLs in children [19–21].

Patients' current visual acuity and refractive error and 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 have transparent crystalline lens may be dissatisfied with the result, because they often rely on their near vision for specific tasks and may have something to lose postoperatively.

Before choosing the presbyopia correcting IOLs, the surgeon should spend a lot of time in counseling with patients to access the personality, occupation and lifestyle of patients. In some clinics, a questionnaire is also helpful for evaluating patient's needs and ranking patient's personality from "easygoing" to "perfectionist" (**Figure 4**). It is important to rule out those patients who have unreasonable expectations about perfect visual needs or who have anxiety, doubt, nervousness characteristics. Those patients are more likely to be dissatisfied with presbyopia correcting IOLs. A visual behavior monitor that patients can wear on their spectacles to track their visual behavior and environment, now provides a lifestyle match index to help ophthalmologist convert that data into useful clinical information to select the best IOL for a given patient [22].

Some patients who need the specific vision requirement in their daily work and life also should be excluded out of the candidate, such as airline pilots, truck drivers, taxi drivers and anyone whose job requires activity at night or low-light conditions. The patients who often mention halos and glare disturb their jobs also should



PREOP: Phacoquest (Catquest + Navq) - SPEED II OSD

EN

* Do you find that your sight at present in some way causes you difficulty in your everyday life?

Yes, very great difficulty	Yes, great difficulty	Yes, some difficulty	No, no difficulty	Cannot decide
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* Are you satisfied or dissatisfied with your sight at present?

Very dissatisfied	Fairly dissatisfied	Fairly satisfied	Very satisfied	Cannot decide
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<p>Do you have difficulty with the following activities because of your sight? # so, to what extent? In each row place just one tick in the box which you think best corresponds to your situation.</p>	Yes, very great difficulty	Yes, great difficulty	Yes, some difficulty	No, no difficulty	Cannot decide
Reading text in newspapers(3)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Recognising the faces of people you meet(4)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Seeing the prices of goods when shopping(5)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Seeing to walk on uneven surfaces, e.g. cobblestones(6)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Seeing to do handicrafts, woodwork etc.(7)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Reading subtitles on TV(8)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Seeing to engage in an activity/hobby that you are interested in(9)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

<p>How much difficulty do you have</p>	Extreme difficulty	Moderate difficulty	A little difficulty	No difficulty	N/A or steps for non-visu reasons
Reading small print, such as newspaper articles, items on a menu, telephone directories(1)(2)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Reading labels/instructions/ ingredients) pipes such as on medicine bottles, food packages(1)(1)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Reading your post/ mail, such as, electric bill, greeting cards, bank statements, letters from friends & family(1)(2)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Writing and reading your own writing, such as: greeting cards, notes, letters, filling in forms, checks, signing your name? (1)(3)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Seeing the display & keyboard on a computer or calculator(1)(4)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Seeing the display & keyboard on a mobile or fixed telephone(1)(5)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Seeing objects close to you and engaging in your hobbies, such as: playing card games, gardening, seeing photographs(1)(6)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Seeing objects close to you in poor or dim light(1)(7)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Maintaining focus for prolonged near work(1)(8)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Conducting near work(1)(9)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Figure 4.
Preoperative questionnaire (courtesy of dr. Takashi).

be rule out of the candidates. The diffractive or refractive multifocal IOLs will increased the photic phenomena in dim environment, while the accommodation IOL or monovision based on the monofocal IOLs should be better choice.

4. Preoperative ocular evaluation

The detailed preoperative examination of clinical ophthalmologic conditions should be done to help patients achieve good results because a successful presbyopia correcting solution often based on a healthy eye. Choosing the right presbyopia correcting IOLs should be considered for biometry, keratometry, topography and pupil reactivity and other eye comorbidities.

4.1 Corneal astigmatism

It is important to correct astigmatism in the premium IOLs surgery. The post-operative astigmatism should be less than 0.75D in the eye which bifocal or trifocal IOL had been implanted. Over 1.5 diopter postoperative astigmatism is one of main reasons for patient's dissatisfaction following surgery. The larger amounts of post-operative astigmatism will cause decreasing visual function of multifocal IOLs, increasing some optical phenomena [23].

The keratometry, autorefractometry and corneal topography/tomography are the helpful preoperative diagnostic devices to evaluate patients with astigmatism to select the astigmatism correction option—limbal relaxing incisions (LRI) or toric presbyopia correcting IOLs. The corneal topography provides more detailed useful information on the regularity of the corneal astigmatism than conventional keratometry or optical biometry (IOLMaster, Lenstar). Tomography devices like Pentacam address the posterior corneal astigmatism or total corneal astigmatism which deliver to more accuracy correcting astigmatism in multifocal IOLs cases (**Figure 5**). Another important issue in management of corneal astigmatism is surgical induced astigmatism which results from flattening in the meridian of the incision and steepening 90° away. The surgeon should evaluate his surgical induced astigmatism (SIA) via standard astigmatic vector analysis or online calculator [24].

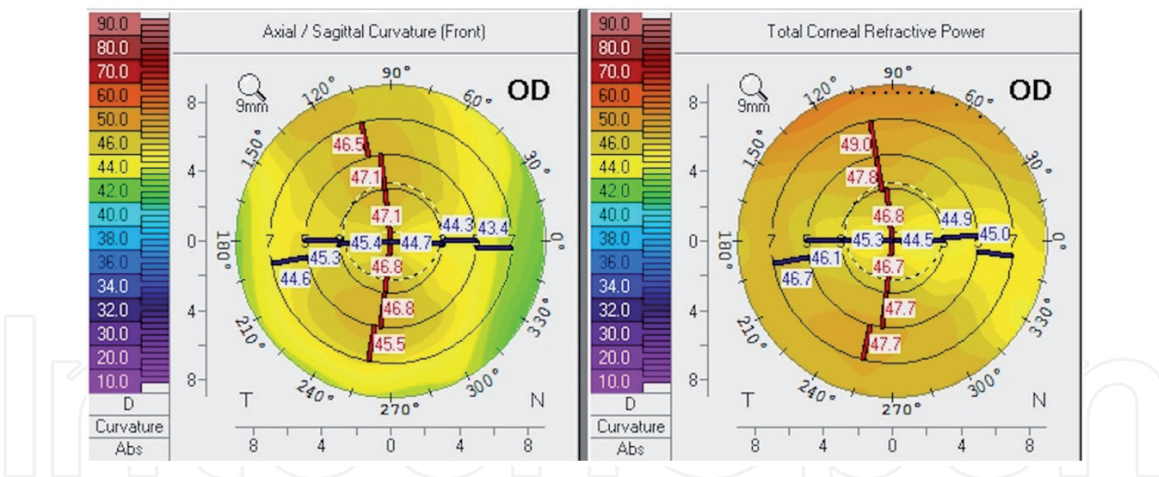


Figure 5.
 Regular corneal astigmatism and total corneal astigmatism.

Small amounts of regular astigmatism can be corrected with manual LRI or femtosecond laser LRI, the later method achieved a higher correction and lower postoperative cylinder than manual LRI patients [25]. LRI correction is determined by Abbott Medical Optics' LRI calculator (<http://www.lricalculator.com>).

The toric presbyopia correcting IOLs is more predictable treatment than LRI, providing good uncorrected vision at distance and either intermediate or near, depending on the built-in add [26, 27]. The toric IOL can be calculated with online program provided by the IOL manufacturer. Most of online calculators had taken into consideration anterior corneal astigmatism, posterior corneal astigmatism and SIA, and choosing IOL toricity by using the total corneal refractive power or in-built nomogram. Some new technologies had been developed to improve toric multifocal IOLs solution flow to achieve the better outcome, including intraoperative wavefront aberrometry (ORA system, Alcon), Image Guided System like Verion(Alcon), Callisto Eye (Carl Zeiss Meditec).

Corneal with irregular astigmatism is contraindicator for multifocal IOLs. Irregular astigmatism often caused by previous corneal infection disease, trauma, dystrophies, pterygium or severe dry eye. In these conditions, poor higher-order root-mean square (HO RMS) corneal wavefront error over a 6-mm zone will present in Pentacam or other aberrometry. If this value exceeds $0.50 \mu\text{m}$, the patient will have a high risk of halos and glare with a multifocal IOL (**Figure 6**).

4.2 Keratoconus

Cataract surgery in keratoconic eyes is not uncommon issue which need to be addressed. Proper IOL selection must be individualized for each keratoconic patient to achieve an optimal outcome. Even for monofocal IOLs implantation, IOLs power calculation is a challenging issue due to the abnormalities of both anterior and posterior corneal surface [28]. Some studies have shown promising results about toric IOL in nonprogress keratoconic patients, while in progress cases the combined procedures including intracorneal ring segment (ICRS), cross linking and toric IOL is preferred [29, 30].

But multifocal IOLs should be avoided because the loss of contrast sensitivity associated with multifocal lenses will be magnified by the corneal irregularity. Previous corneal surgical history like pterygium, PKP is an important etiology for irregular astigmatism. IOL solution in these cases is similar to the keratoconus cases.

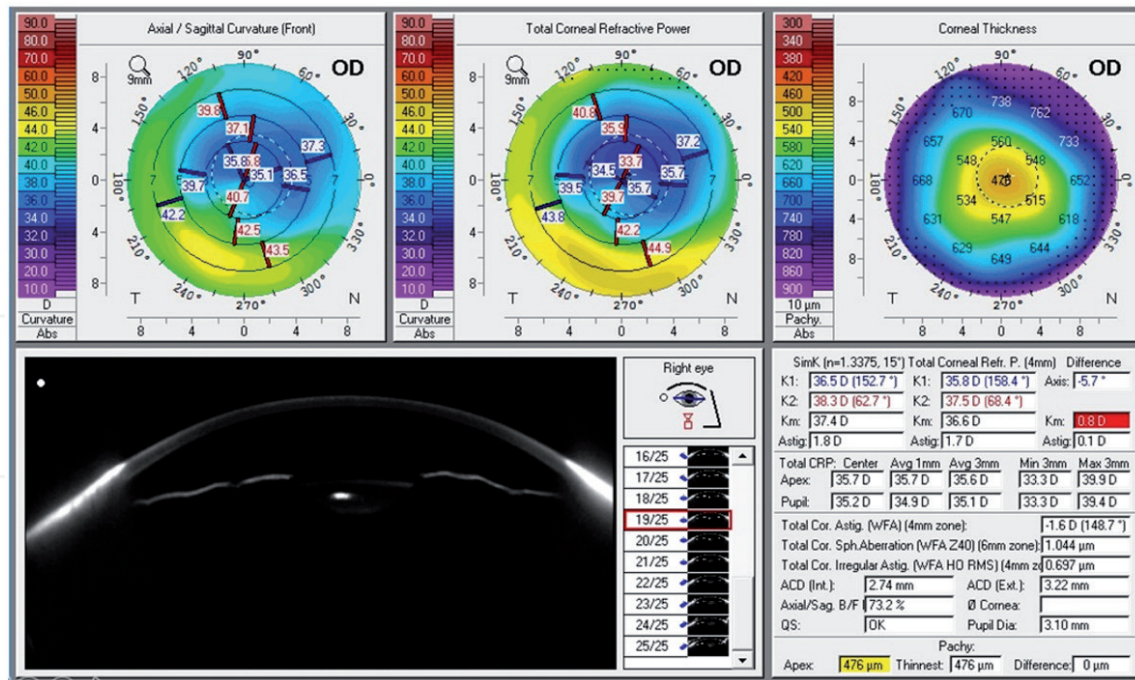


Figure 6.

Corneal irregular astigmatism with history of corneal refractive surgery. HO RMS is 0.679 μm , over 0.50 μm .

4.3 Previous corneal refractive surgery

Patients who have undergone myopic or hyperopic LASIK/PRK/RK tend to select the premium IOLs with higher expectations regarding the refractive outcome. But intraocular lens power calculation for these patients is challenging because it is difficult to calculate the true corneal power. The optical quality of cornea is another factor to consider for IOL selection. The high order aberration is increased after the laser myopic corneal which led to decrease the visual result of multifocal IOLs and increase the photophobia like halo, glare [31]. If cornea high order aberration is higher than 1 μm especially it caused by corneal irregularities, the presence of irregular astigmatism/coma, a decentered/uneven treatment bed, the patient should not be considered as good candidate for multifocal IOL implantation [5].

The post-myopic LASIK patients who had previous treatment was less than -6 D, ablation bed was fairly well centered with no or little irregular astigmatism and did not experience problems with night vision can be considered to use presbyopia correcting IOLs. [32] Some surgeon preferred EDOF IOLs (Symfony, Johnson and Johnson Vision) in these patients, because its larger size central optic and higher light transmission provides an enhanced contrast sensitivity as compared with other refractive or diffractive multifocal IOLs [33, 34]. If monovision was already created with LASIK or PRK, and monovision is probably a much better way to go.

In the patients who had underwent the hyperopia laser correction have increased negative spherical aberration and are best suited for aberration-free multifocal IOLs or IOLs with positive spherical aberration. The accommodating IOL was recommended by some surgeon if multifocal IOLs and EDOF IOLs were intolerant by the significant corneal coma.

A monofocal IOL is often the best choice in patients with previous RK who often had irregular corneal or increased corneal aberration. Now, pinhole IOLs (Xtrafocus, Morcher GmbH) is an effective presbyopia correcting solution for irregular astigmatism RK patients. It can correct of postoperative residual refraction and provide an elongated depth of focus [35].

4.4 Ocular surface disease (OSD)

Understanding the patient's ocular surface is of critical importance because ocular surface pathologic features can lead to false corneal power, induced astigmatism and unstable bad visual acuity.

Preoperative dry eye will lead to post-operative refractive surprise, blur vision and foreign body sensation, excessive tearing, and photophobia that makes patients unhappy [36]. Surgeon and assistant should address the OSD issue as part of preoperative discussion to management the patient expectation.

The most common OSD is meibomian gland dysfunction and dry eye. A thorough evaluation of the lids and lashes, testing for lacrimal gland function and tear film should be included in preoperative examination. A symptoms questionnaire also helps to capture OSD before surgery.

The treatment is based on severity and subtype of OSD. Steroid and preservative-free lubrication can be used for improving the corneal surface. Other therapy included moisture chamber glass, punctal occlusion, and oral omega fatty acid supplements. If the ocular surface condition is not improved after advanced therapies, the multifocal IOLs is not recommended due to significantly high and persistent postoperative OSD symptoms [37]. The low tear breakup time, increased meibomian gland dropout will increase the high order aberration leading to decrease the visual quality after the premium IOLs implantation [16].

Besides OSD, there are some corneal disease inducing irregular astigmatism will affect the premium IOLs section, such as addressing anterior basement membrane dystrophy (ABMD), epithelial basement membrane dystrophy, Salzmann nodular degeneration (SND). Appropriate management of these corneal abnormalities should be performed before cataract surgery in order to gain the reliable corneal keratometry and other ocular biometry parameter.

4.5 Pupil size, angle kappa and angle alpha

Pupil size, shape and centration also have a significant influence on presbyopic IOL surgery. In diffractive multifocal IOLs, the difference of diffractive step height determined the different light energy distribution in far, intermediate and near distance. Light energy distribution of the multifocal IOLs (MIOLs) varies with different aperture. For apodized diffractive IOLs, the near reading will become difficulty due to light energy goes more to distance in dim illumination. It suggested eyes implanted with multifocal IOLs should have a photopic pupil size of 3.5 mm or less and mesopic pupil size of 5 mm or less [38]. The average pupil size of photopic and mesopic are correlated with contrast sensitivity defocus curve [38]. The photophobia phenomenon like glare and halo also more complained in the large pupil patients. For the asymmetric refractive multifocal IOLs, the pupil size is an important parameter which had a significant negative subjective impact for outcomes [39].

Angle kappa (K) is defined as the angular difference between the visual axis and the pupillary axis while angle alpha refers to the angular distance between the visual axis and the optical axis. Though postoperative far, intermediate, and near vision is not affected by angle K which does not include the fixation point, large angle K might play a role in the decentration of multifocal intraocular lenses (IOLs), potentially resulting in the incident of glare and halo increasing which led to patient satisfaction with multifocal IOLs [40–43]. A well-centered lens in the visual axis is vital for proper functioning of presbyopic IOLs. Chord between the pupil centration and visual axis is the value to be evaluated for IOL location. It was suggested that a MIOL is unacceptable for use if the k value is greater than half of the diameter of

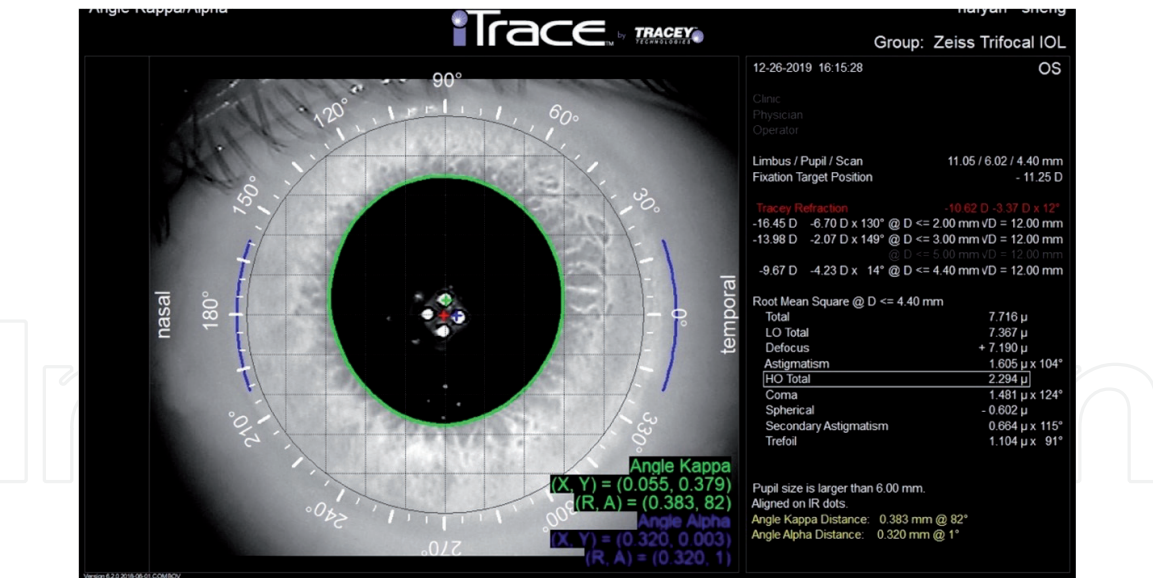


Figure 7.
Pupil size, angle kappa and angle alpha.

the central optical zone. The limitation of k value is different according to the different multifocal IOLs—ReSTOR(Alcon) 0.4 mm, Tecnis multifocal IOL (Abbott Medical Optics) 0.5 mm, FineVision POD F IOL(PhysIOL) 0.6 mm [44].

Angle alpha is defined by the radial distance between the center of the limbus and the visual axis, which was found to predict the tilt of the IOL in respect to the visual axis. Wang had demonstrated that angle alpha was relatively stable whereas angle kappa changes from pre- to postoperative situation [45]. Angle alpha seems to be a better predictor for photic phenomena and patient satisfaction with multifocal IOLs [46]. But there still was different aspects on the predictive capacity of angle α on the outcome with multifocal IOLs. Piracha had concluded the angle alpha distance is larger than 0.5 mm, the eye is not suitable for multifocal IOL implantation [47], while Fu found there was no statistically significant correlation between angle alpha and the objective visual quality parameters [41] (**Figure 7**).

4.6 Glaucoma

Glaucoma patients often presented with the visual field damage, contrast sensitivity loss, small pupils and capsular and zonular issues, to affect vision outcomes must be taken into account when choosing a premium IOL.

Previous generation multifocal IOLs (Restor, Alcon; ReZoom, Abbott Medical Optics) were reported to significantly reduce the contrast sensitivity, especially in refractive multifocal IOL implantation. New advanced technology multifocal IOL or EDOF IOLs seem to mitigate the loss of contrast sensitivity [48]. And multifocal IOL also affect the visual field test and oct scan in the glaucoma patients' follow-up.

But because of a lack of scientific evidence in the form of large trials on the impact of multifocal IOLs in glaucoma, decisions regarding the implantation in a glaucoma patient should be tailored according to the patient's motivation and the rate of glaucoma progression. The patient who is glaucoma suspect, ocular hypertensive, early stage with controlled and stable visual field damage is the candidate for diffractive multifocal IOLs and EDOF IOLs. The patients with severe, advanced, progressive glaucoma, or with high risk of pupil or zonular changes like chronic miotics, pseudoexfoliation, pigment dispersion will not benefit of multifocality [49].

4.7 Retinal disease

It is a controversial topic of premium IOLs application in retinal disease patients because there are varying degrees of macular lesion, ranging from drusen without visual damage to the late stages of atrophic AMD. Multifocal IOLs are strictly not recommend in retinitis pigmentosa and Stargardt's disease, while diabetic retinopathy, age-related macular degeneration, and epiretinal membranes are relative contraindications [50]. Beside the different character of retinal diseases, the progression is an important issue to consider for premium IOLs solution [17].

For the mild or stable disease, multifocal IOLs is option for patient with careful and thoroughly consent about the prognosis including the issue of lower contrast sensitivity and long-term results with the disease progressing. Many studies had demonstrated the contrast sensitivity decreased in multifocal IOLs. Due to loss of contrast sensitivity at lower spatial frequencies is also presented even in mild forms of AMD, the EDOF IOLs is preferred in these cases. Multifocal IOLs generally are disadvised for patients with severe AMD because pre-existing pathologic features are a contraindication.

The presence of an epiretinal membrane (ERM) can lead to more unpredictability with the spherical power of the IOL selection and its refractive outcome. Multifocal IOLs in ERM patients will face to the loss of contrast sensitivity, increased risk for postoperative cystoid macular edema [51].

There are few studies addressing the multifocal IOLs and retinal disease, which report a significant improvement in visual-related outcomes than the monofocal implantation. Nevertheless, more research is needed to address the aforementioned concerns and to optimize the use of MIOLs in eyes with retinal disease.

5. Ocular biometry and IOL power calculation

Accurate measurements are critical for determining the correct power of a premium IOL before it is implanted during cataract surgery. The emmetropia is key factor of a successful refractive lens exchange to gain spectacle independence. Attaining this goal requires eliminating astigmatism and achieving a precise post-operative plano refraction within ± 0.25 D.

Ocular biometry involves anatomical measurements of the eye, including the axial length (AL), keratometry, anterior chamber depth (ACD), lens thickness (LT), horizontal white to white (HWTW) which are the parameters for IOL power calculation [52].

Even the ultrasound biometry is still used in some difficult cases such as brunescant cataract, white cataract and severe subcapsular cataract. A hyperopic surprise often appeared in high myopic patients by using ultrasound biometry, because A-scan measured the deepest part of the staphyloma while macula was on the edge of the staphyloma which led to false longer axial length.

With IOLMaster (Zeiss) introduced in 1999, optical biometry technique provide a directly measurement from the macula to the corneal vertex. It becomes golden standard as it is highly accurate, easy to perform, non-invasive and comfortable for the patient. The accuracy of optical biometry, and in particular the IOLMaster 500 (Zeiss) and Lenstar 900 (Haag-Streit), have been extensively confirmed across a wide range of scientific studies [53, 54]. New generational optical biometry IOLMaster 700 (Zeiss) has integrate swept source optical coherence tomography to measure axial length. It allows for penetration of dense cataracts, determination of lens thickness (not available on the prior generations of IOLmaster), and visualization of the foveal pit to both ensure alignment of the image and possibly detect

pathology like epiretinal membrane or cystoid macular edema which is influenced the premium IOLs power calculation [55].

Besides the accuracy biometry, the IOL power calculation formula choice also is critical for premium IOLs surgery. Though the third and newer generation formula can get accuracy refractive result in normal axis length and keratometry eyes, attention must be paid to the long axial length eye as well as the abnormal corneal power cases [56]. New IOL power calculation formula like Barrett, Hill-RBF and Olsen will achieve more precision and accuracy in longer and short axial length eyes [57].

The IOL power calculation in post corneal refractive surgery eyes always is a challenge issue. Whether corneal radical keratotomy or PRK/LASIK always change the corneal shape of in different ways. Errors in evaluation of the correct corneal power and errors in estimating the effective lens position with the classical thin-lens formulas lead to underestimate the IOL power and hyperopic postoperative refractive surprise. Many adjustment methods had been developed to estimate the true corneal keratometric data such as Haigis-L formula, Shammas no-history formula [58]. The new device like schiempflug or swept source OCT which can directly measure the anterior/posterior/total corneal power to obtain more accuracy results [59]. Modern IOL formulas, such as the Barrett True-K and ascrs.org web-based IOL power calculator can provide greater refractive predictability [60].

Cataract surgeon must personalize his IOL constants for premium lenses. Although the design of the IOL is the primary factor in the constant, variations in surgical technique such as the placement of the IOL, the location and design of the incision, and differences in biometry and technicians also affect the personalized lens constant. Preoperative biometric data and post-operative refractive error of 20 to 40 cases should be collected in order to personalize lens constant [52]. This process is the only way to achieve superior results with these IOLs and accuracy to within ± 0.25 D for 95 percent of patients. Personalizing the lens constant is critical to eliminating the systematic variations that make excellent results and happy patients the rule with multifocal lenses.

6. Advanced technology IOL selection strategy

When the patient and ocular conditions had been fully evaluated, the surgeon can match the right advanced technology IOL to the right patients that can ensure positive outcomes. Here we present a premium IOLs decision flowchart based on the detail recommendations mentioned above.

- Patients selection:
 - A strong desire to be independent with spectacle for near, intermediate, far distance
 - A positive attitude and leading an active life, not a perfectionist
 - A job not to require activity at night or low-light condition
- Ocular Feature Checklist
 - Preoperative visual acuity and refractive error
 - i. Hyperopic, high myopia and plano presbyopia are good candidates for presbyopia correcting IOL surgery.

- ii. Mild myopia with presbyopia patients are typically accustomed to removing their glasses at near, so it is important to set proper expectations
- iii. Thorough education and careful counsel are needed for mild myopic patients before presbyopia correcting IOLs surgery.
- Corneal conditions
 - i. Dry eye or OSD evaluation and management
 - ii. Corneal astigmatism or aberration measurement by using multi-device
 - iii. Address the posterior surface corneal astigmatism
 - iv. Consider surgical induced astigmatism
- Pupil size and centration
 - i. photopic pupil size of 3.5 mm or less and mesopic pupil size of 5 mm or less
 - ii. angle Kappa greater than half of the diameter of the central optical zone
- Comorbidities
 - i. Post-corneal refractive surgery
 - ii. Glaucoma
 - iii. Retinal disease
- Biometry measurement and IOL calculation
 - 1. Optical biometry is recommended, which included partial coherence interferometry (PCI) IOLMaster 500, optical low coherence reflectometry Lenstar 900 and SWEPT source OCT IOLMaster 700
 - 2. 3rd and new generation formula: [61]
 - Haigis, Hoffer Q, Holladay 1 and 2 and SRK/T.
 - Barrett Universal II formula
 - Emmetropia Verifying Optical (EVO), Kane, Næser 2, Olsen, the Panacea, Pearl DGS, Radial Basis Function (RBF), T2 and VRF formulas
 - 3. Special attention to post-refractive surgery IOL calculation issue
- IOLs solutions

Monofocal aspheric IOLs is most common IOLs in modern phacoemulsification surgery which can neutralize the residual corneal spherical aberration and improve contrast sensitivity especially in dim light condition. For the patients with

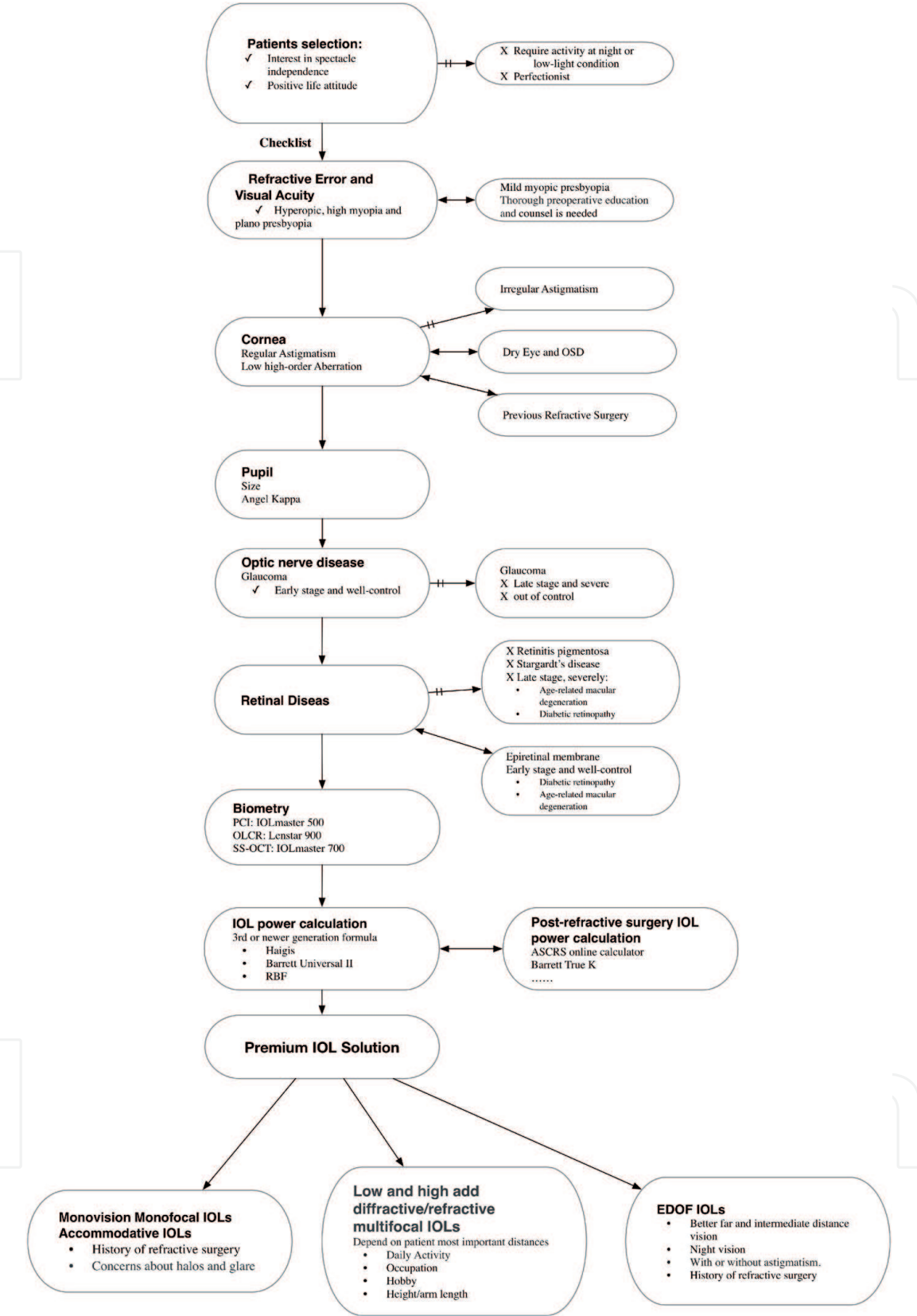


Figure 8.
Flow chart for advanced technology IOL selection.

previous corneal myopic or hyperopic correction procedure or with high concern about halo, glare and night vision, the choice of aspherical IOLs should be tailored basing on the high aberration. Monofocal aspheric IOLs can be used for monovision that is a simple solution for presbyopia correcting. It provides monofocal quality of vision, and many patients have been satisfied with this option. However, some patients have reported reduced depth perception, a feeling of imbalance, and

limited intermediate vision. There are some modified strategies as mini-monovision or micro monovision which the non-dominant eye targeted for -0.75 to -1.25 D (mini-monovision) or around -0.50 D (micro-monovision) of myopia to increase visual function at near and intermediate distance [62]. But monovision design may cause some potential problems such as loss of depth perception [63, 64]. A soft contact lens trial is a good predictor for simulating monovision solution, but due to cataract patients often being with worse vision, it is not always indicative of actual visual performance after cataract surgery.

Accommodating IOL is designed for allowing the IOL to move anteriorly or posteriorly, depending on the accommodative forces of the eye. It has the better contrast sensitivity and low photophobia than multifocal IOLs. However, most patients cannot achieve sufficient accommodation for functional near vision and might require reading glasses.

Multifocal IOLs by using refractive or/and diffractive optics is most popular presbyopia correcting IOLs solution in recent years. These type IOLs provide the high patient satisfaction and a better chance of spectacle independence in the refractive lens exchange procedure. Near addition powers are different in different multifocal IOLs, which is often from 1.5D to 4.0D. The higher add can offer a better near vision, but easy led to adverse effects such as dysphotopsia and a reduction in contrast sensitivity. In some aged patients, it will cost several months to neuroadapt of the multifoci images in the retina. To decide which near add power is right for a given patient, the surgeon must evaluate subjective factors (occupations, hobbies, expectations, concern about night vision) and objective factors (preoperative visual acuity and refraction error, height/arm length).

Extended depth of focus (EDOF) IOLs are a set of intraocular lenses that extend vision instead of offering discrete close, intermediate, or distance vision. These IOLs based on diffractive, pin-hole or aberration technique, while minimizing the quality of vision compromises and night vision symptoms that are associated with multifocal lenses. The EDOF IOLs are more tolerance higher levels of cylinder error, especially for higher amounts of astigmatism in the range of 0.75D to more than 1.0D. Due to EDOF IOLs delivers less spectacle independence than trifocal IOLs, mini-monovision is common strategy with EDOF IOLs implantation. It set the nondominant eye's target at -0.75 D, which relates to an extension of the depth of focus, giving the patient the ability to read at a distance of about 45- to 50 cm, thus optimizing their potential for spectacle independence [50]. EDOF IOLs also can be considered for patients who had history of corneal refractive surgery [34] (Figure 8).

7. Surgical techniques

Success in cataract surgery with premium IOLs lies in performing every step precisely and predictably. The surgeon team should check the patient's information, the surgical device and material availability.

Surgeons must pay attention to preexisting or surgically induced astigmatism, because it can have a huge impact on visual outcomes with a multifocal IOL. The magnitude of astigmatism and axis should be checked by more than two device such as topography, IOLMaster, Lenstar and so on. For less than 1.0D astigmatism, the incision at steep axis is the better approach. When preoperative astigmatism is up to 1.5 diopter, the limbal relaxing incisions (LRIs) can be considerable [65]. At higher levels of astigmatism than 1.5D, the best solution is toric multifocal IOLs [66]. Whether LRI or toric IOLs, the corneal limbal mark should be made before surgery. Many manual method or device had been developed, and computerized automated axis marking system also can be chosen [67].

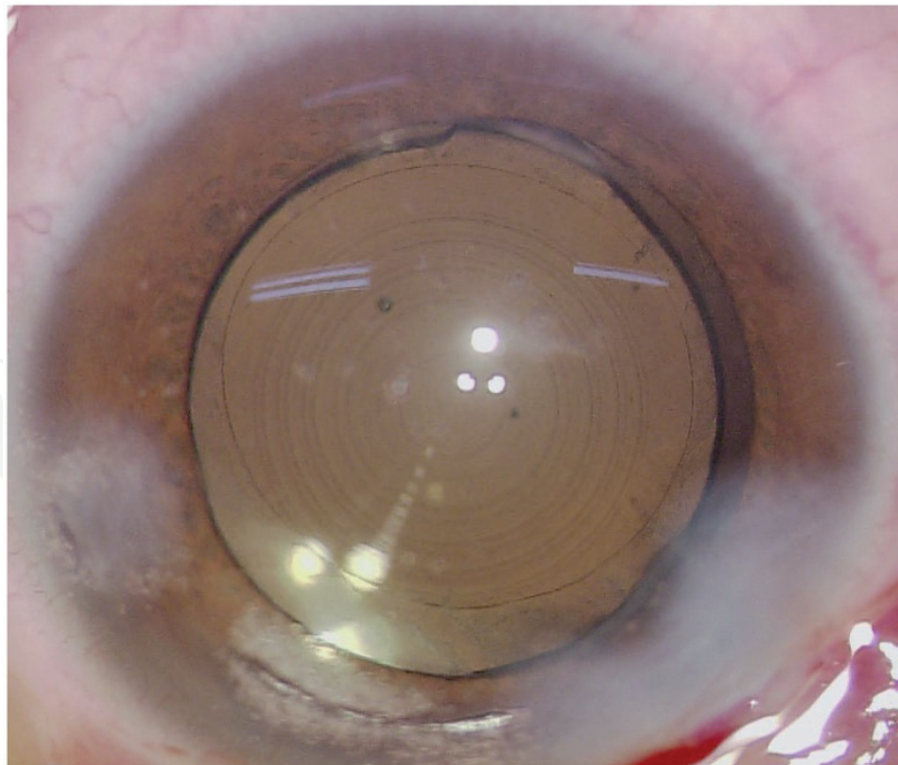


Figure 9.
Trifocal IOL (Panoptix, Alcon) implantation with 5.0 mm FLACS capsulotomy.

A 5.0–5.5 mm perfectly round and centered capsulorhexis is preferred for premium IOLs surgery. The right size capsulorhexis will completely cover the optic of IOLs, let the lens center over the visual axis to get the best visual results. The capsulorhexis size depends on the different IOLs design. The precise size will be customized when femtosecond laser is available, which led to less intraocular aberration postoperatively [68, 69] (**Figure 9**).

The Healon or other viscous ophthalmic viscoelastic device (OVD) can protect the endothelium cells during the procedure. It also can flat the anterior capsule to make capsulorhexis more controlled. The OVD should be removed completely when surgery finished to prevent intraocular pressure from increasing. If the toric multifocal IOLs used, the OVD should be totally removed behind lens to avoid the accident rotation after surgery [67].

8. Management of dissatisfied patients

Even with fully preoperative examination, careful patient's selection and precisely uneventful surgery, there are always some unhappy patients with their postoperative outcomes.

The main complaints associated with presbyopia correctiong IOLs include blurred vision, photic phenomenon. Blurred vision may be present at near, intermediate, and far distances, or specific distance. It was attributed to refractive error or residual astigmatism, posterior capsule opacification, dry eye, or coexisting ocular disease. It was also caused by loss of contrast sensitivity.

The premium IOLs very affected by small residual ametropias. Surgeon must carefully calculate IOL power by using advanced biometry formulas, customize constant according to previous experience. Any astigmatism greater than 0.75 D in a blur vision patient should be treated. The most common intervention to management of residual refractive error is spectacles or contact lens. Bioptics refractive

enhancement can be performed in spherical or cylinder error patients, while IOL exchange or piggyback solution also can be used in case of important defect or if the previous solutions are not possible [17].

Another common cause of blur vision after multifocal lens implantation is ocular surface disease. The symptoms can be resolved by treating with lubricating artificial tears, punctal plugs, warm compress and vectored thermal pulsation treatments.

Patients with multifocal IOLs appear more sensitive to posterior capsule opacity than with monofocal IOLs. If posterior capsule opacification is suspected to be the cause of visual disturbance, and symptoms have been worsening since surgery, the surgeon should consider Nd:YAG laser capsulotomy. If there is any chance that a lens exchange may be done, YAG capsulotomy should be delayed, as an open posterior capsule makes the exchange more difficult.

Photoc phenomena can consist of glare, halos, and dysphotopsias. It also caused by IOL decentration, dry eye, posterior capsule opacification, or multifocal IOL design. During the procedure, carefully management should be taken including capsule tension ring implantation, centration of the IOLs relative to the visual axis, polishing the anterior and posterior capsule. Most case of photoc phenomena will be tolerance or disappear by the time. After the reason of dry eye and PCO had be excluded, the night-time dysphotopsia and decreasing of contrast sensitivity are due to intrinsic properties of multifocal IOL. The most effective aid in managing these problems is neuroadaptation which is highly dependent on the individual and often need time to adapt. If a patient is still bothered by these problems more than three months after surgery, or if their quality of life is significantly affected, an IOL exchange for a monofocal IOL is almost always an alternative [50].

Proper management of the unhappy premium IOL patient requires time, patience, and familiarity with different medical and surgical options and techniques. The most important things are extensive preoperative patient education and avoiding the inadequate patient. Careful patient selection and clear communication regarding realistic expectations are the keys to success with premium IOLs.

9. Summary

Premium multifocal IOLs are a popular option for cataract or presbyopia patients today. Patients can achieve high levels of success and satisfaction from these IOLs. However, adequate preoperative clinical evaluation including patient selection, optical and anatomical examination is crucial to reach a success case. Based on the preoperative diagnosis including the corneal astigmatism, biometry measurement, IOL power calculation, presbyopia correcting IOLs' indications and contraindications should be assessment for IOL selection strategy. Surgical procedure should be technically optimized to achieve the best outcomes. Adequate management of both satisfied and unsatisfied patients will improve the benefit of current premium IOLs.

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