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Optimising Vision: Extended Depth of Focus IOLs

The evolution in intraocular lens (IOL) technology has been rapid and exciting over the last 15 years. Extended Depth of Focus (EDoF) IOLs have removed some of the side effects associated with multifocal IOLs. They provide excellent visual quality and good contrast sensitivity with minimal night vision issues. Additionally, they achieve a significant degree of glasses independence.

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LEARNING OBJECTIVES

1. Understand the technology of Extended Depth of Focus (EDoF) intraocular lenses (IOLs),
2. Understand the place of EDoF IOLs in the cataract surgeons' arsenal,
3. Understand the benefits of EDoF IOLs,
4. Understand the limitations of EDoF IOLs, and
5. Understand the role of the optometrist in jointly managing cataract surgery patients with EDoF technology.

The introduction of multifocal IOL technology has ushered in a new era for patients who wish to improve their visual quality and achieve independence from glasses. However, one of the factors hampering the introduction of multifocality is the issue of progressive capsule fibrosis. This has inhibited the ability to create lenses that change shape to provide a range of focus. As a result, advances in technology have had to concentrate on the use of optics rather than movement to provide multiple focal points.

The side effects associated with providing multiple focal points are well documented. They include the induction of halos while night driving, and the experience of glare. One also has to accept the concept of optimal focal range sweet spots as, if one attempted to stretch the light energy across all focal points, the light energy would not be sufficient to see adequately at any focal point. As a result, patients wishing to achieve independence from glasses for both distance and near have had to accept these compromises, although they do improve significantly with ongoing neuroadaption.

Additionally, when splitting the light energy into multiple focal points, there is a reduction in contrast sensitivity stemming from both the division of the light energy coupled with the attrition derived from light scatter in the setting of diffractive optics. If there is some compromise in visual function from other ocular pathology, such as tear film instability, compromised corneal clarity from entities such as Fuchs Endothelial Dystrophy or retinal anomalies such as pre-macular fibrosis or retinal pigment epithelial change, the reduction in contrast sensitivity and flare off lights are regarded as an unacceptable compromise in visual quality.

This is the position where the evolution of Extended Depth of Focus (EDoF) IOLs have emerged. They represent a middle ground between monofocal IOLs that provide optimal distance vision and no visual side effects but no unaided near, and the multifocal platforms with excellent unaided near vision but the induction of halos and glare. The extension of a distant focal point to 60cm distance, while inducing minimal haloing and providing a contrast sensitivity akin to that of a monofocal IOL, has opened the door to a greater number of individuals to enjoy reduced spectacle dependence where multifocal IOLs would be either non desirable or inappropriate.

It is important to note however, that EDoF IOLs have their limitations. They are not an ideal refractive solution as the reading distance is slightly too far away for certain visual tasks, such as reading a book in bed, and the incidence of halos has certainly been described, although rarely in a debilitating manner.

Never the less, the EDoF platform is an excellent addition to the cataract surgeons' arsenal, allowing excellent visual quality with improved freedom from visual aids.

TECHNOLOGY

There are two current EDoF platforms with further companies set to join the field in the near future.

Figure 1. Abbott Symfony IOL

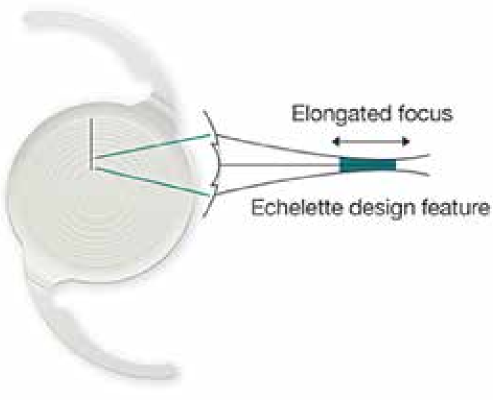
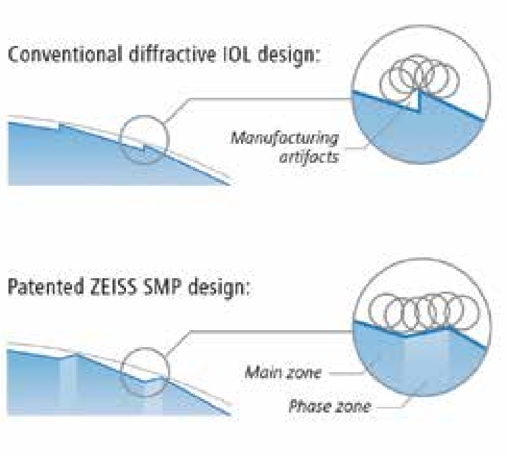


Figure 2. Zeiss AT LARA

Figure 3. Zeiss AT LARA with patented SMP design



The Abbott Symfony IOL was the first platform on the market. It has placed the diffractive optics on the posterior surface of the IOL and uses a proprietary echelette diffractive step.

More recently, the Symfony IOL has been joined by the Zeiss AT LARA. This IOL has the diffractive optics on the anterior surface and uses a patented Zeiss smooth microphase (SMP) design to minimise halos by smoothing the phase step of the diffractive ring.

Both platforms provide toric forms of the lens to compensate for pre-existing corneal astigmatism.

Extended Depth of Focus

In a similar manner, EDoF IOLs use diffractive optics to extend the range of focus for an IOL from infinity to around 60cm distance as a continuum. Diffractive optics use the principle of light as a wave hitting a fixed edge that then allows the wave to bend. A good way to visualise this is the principle of a wave hitting a headland and bending around to the beach. The diffractive rings are of a known height, and diametric distribution diverts a known proportion of light energy to alternative focal points.

Pure multifocal IOLs bring the near focal points fairly close, the near point being 40cm distant. Modern trifocal IOLs provide an additional intermediate computer distance focal point of either 60 or 80cm, depending on the specific IOL. Although there is a blend between these focal points, there is not a complete continuum –multifocal platforms have a flat spot for sharp vision such as reading text at around one meter distance.

"I have used these lenses in the setting of elite level players where a degradation of image quality at around the one meter mark engendered with traditional multifocal IOL technology… would have been detrimental to performance"

The EDoF IOLs use diffraction ring technology to stretch the distance focal point to a near focal point of around 60cm distance, superimposing the focal points to create a 'light bridge' effect that essentially provides a continuum of vision from infinity to 60cm without any appreciable drop off or flat spot in this range. Visual clarity does drop off closer than 60cm however, resulting in the necessity of reading glasses for visual tasks closer than 60cm.

Halos

The distinct focal points generated by multifocal IOLs that are presented to the retina simultaneously are responsible for the induction of halos. Halos are experienced as a ring like, 'spider web' of lights that form around bright sources of light directed straight at an individual, such as car headlights. When one focal point is sharp, the other is somewhat defocused and flared. The diffusion of light around the sharp focal point creates a haloing effect around oncoming headlights in tasks such as night driving and can induce a chandelier glow around general lighting.

By creating a smoother continuum of light distribution with EDoF IOLs, and bringing the near focal point closer to the distant one, the haloing effect is significantly diminished. The Symfony IOL in its published studies on launch, with large multicentre, multi-geographic trials, demonstrated very low spontaneous reports of halos. On average, across three separate trials, 90% of patients did not spontaneously report any halos at all and 7% described them as moderate. Reported

Figure 4. Monofocal IOL

Figure 5. Multifocal IOL

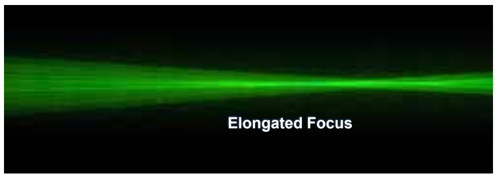


Figure 6. EDOF IOL

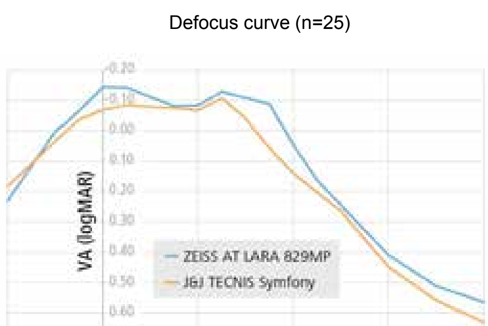


Figure 7. An ocular defocus curve for the AMO Symfony and Zeiss AT LARA EDOF IOLs. It demonstrates the extended depth of focus allowing comfortable unaided reading equivalent to a 2 diopter add for near vision unaided.

levels of halos for the Zeiss AT LARA IOL are at a similar level.

Correcting Chromatic Aberration
Visible light has a spectrum of wavelengths. Red light is a longer wavelength, being 625 to 740nm. Blue is 445 to 520nm. The physics of optics dictates shorter wavelengths are bent by a curved surface such as the cornea to a greater degree than a long wavelength. As a result there is actually a spread of the focal point across the visible light spectrum.

Monofocal and standard multifocal IOLs perpetuate this chromatic aberration, resulting in a reduced contrast sensitivity due to an extended focal point. This effect is accentuated in multifocal IOL technology due to the multiple focal points presented simultaneously.

EDoF IOLs reverse the diffractive ring chromatic aberration (Figure 8a,b,c). The red focal point is closer to the IOL compared to the blue, the opposite to that encountered in a typical IOL (Figure 9). Therefore the spread of the focal point due to the different wavelengths encountered in the visible light spectrum is minimised or eliminated. This allows for enhanced contrast sensitivity that compensates for the inevitable reduction in contrast sensitivity encountered by providing multifocality. The enhancement of contrast sensitivity in EDoF IOLs brings them close to that encountered in monofocal IOLs. This results in good vision in low lighting conditions, a reduced impact from optical side effects such as halos and glare, and extends the application of multifocal IOL technology to patients who may previously have been deemed unsuitable. This would include lifestyle factors such as those who frequently drive at night, or have ophthalmic conditions that can, in their own right, increase light scatter such as tear film instability, corneal guttate, or subtle epi-retinal membranes.

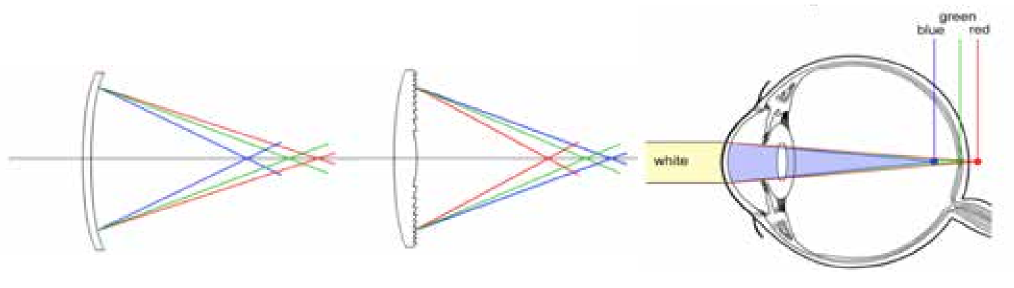


Figure 8a. Cornea b. EDoF IOL c. Resultant focal point on the fovea

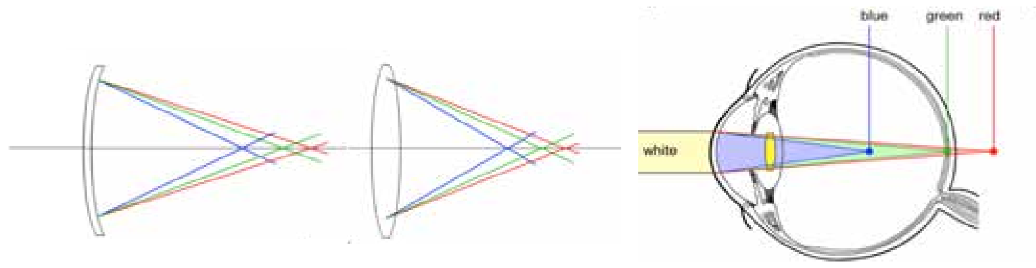


Figure 9a. Cornea b. Typical IOL c. Resultant focal point on the fovea

BENEFIT
EDoF IOLs have a significant benefit to patients who are undergoing either cataract surgery or proceeding with refractive lens exchange.

The continuum of vision from infinity to a 60cm distance provides a very useful range of vision. Sharp vision in the distance is of course provided, which is a necessity with any IOL selection. Visual tasks, such as reading the dashboard of a car while driving, are easily performed. The 60cm near focal range is ideal for patients who use computers extensively. This extends to both

> "Patients should be co-managed with their optometrist to ensure the required reading glasses are provided in the early post-operative period, once refractive stability is achieved"

desktop computers that are commonly used at an 80cm range, and to laptops and tablet computers that are more commonly used at 60cm. In the modern era, both laptop and desktop computers are commonly used, and allowing a patient to smoothly transfer from one to the other without the necessity for position adjustment is very useful. The 60cm focal range is ideal for those who read a newspaper or for papers that are read when placed on a desk.

The expanded and continuous focal range has also proved to be very useful for those involved in certain sports. Squash and tennis require the ability to fixate rapidly on a small moving target that travels from distance to an impact point of around one meter. Clear, immediate focus throughout this range is critical for optimal performance. I have used these lenses in the setting of elite level players where a degradation of image quality at around the one meter mark engendered with traditional multifocal IOL technology, with its ocular defocus curve dropping at this point, would have been detrimental to performance. The improvement noted after the implantation of EDoF IOLs was reported to be significant and impressive.

EDoF IOLs are also very useful for patients who perform frequent tasks in relatively low lighting scenarios. Patients who drive frequently at night have reported being comfortable and confident with driving. The halos are generally reported too insufficient to compromise driving. Neuroadaption, encountered in all multifocal IOLs, is generally rapid and profound.

I have found that patients who work in fields where colour appreciation is critical, such as designers and photographers, generally report an appreciation in the vividness of colour stemming from the correction of chromatic aberration. Enhanced contrast sensitivity also facilitates accurate tonal differentiation.

People who demand a large range of focus, such as builders, also appreciate the continuous extended focal range of EDoF IOLs. Accurate depth perception preserved with the binocularity provided by the IOLs, coupled with the ability to see near in any direction, as opposed to the direction specific near provided by multifocal glasses, is very useful for this cohort.

LIMITATIONS

The near focal point at around 60cm is the principle limitation of the EDoF class of lens. Although it has minimal side effects, including reduced halos and glare, as a purely refractive IOL selection it is inadequate to provide the majority of patients with sharp close vision.

I have had a significant number of patients that could read N4 with this class of IOL however it certainly is not a given. If a patient presents seeking good close vision unaided – at around 40cm distance – this class of lens will not be consistent enough to provide a reliable outcome. Patients are counselled that it is likely that there are certain visual tasks that will require reading glasses, such as reading a book in bed at night or removing a splinter.

Additionally, although the EDoF IOLs are designed to have a fairly minimal degree of haloing, they certainly can induce them. The awareness of this, and the impact on activities such as night driving, is unpredictable and varies in severity. It would be extremely uncommon for this to result in vision at night that is unacceptable to the point of requiring an IOL explant, however it certainly should still be discussed in detail.

Multifocal and EDoF IOLs are contraindicated in patients with significant concurrent ocular pathology. Obviously significant retinal pathology such as age-related macular degeneration of either wet or dry form, chronic macular oedema in conditions such as central or branch retinal vein occlusion, and diabetic maculopathy or significant epi-retinal membranes are a contraindication. In these conditions, 100% of the incoming light energy should be dedicated to a single focal point to avoid any further compromise in an eye with impaired visual function.

Similarly, significant corneal pathology demonstrates a contraindication to their use. Keratoconus and keratoectasia create too complex an optical system to allow for good quality vision with any diffractive optics. These corneas already demonstrate corneal multi-focality and are best corrected with either monofocal or restricted aperture IOLs.

Corneas that are causing visual degradation, due to Fuchs Endothelial Dystrophy either in the early decompensation stage or at the point of requiring intervention such as Descemets membrane endothelial keratoplasty (DMEK), should receive monofocal IOLs. Independence from glasses is a less important consideration when refractive outcomes are somewhat less predictable.

> "Patients with EDoF IOLs implanted have excellent visual quality and good contrast sensitivity with minimal night vision issues, while still being able to achieve a significant degree of glasses independence"

INCORPORATION OF EDOF IOLS INTO REFRACTIVE PRACTICE

Patient Selection

The critical consideration in entertaining the use of any multifocal or EDoF IOL is the general health of the eye. Careful evaluation of the eye is paramount. Obvious absolute contraindications have first to be eliminated. These include the aforementioned corneal and retinal conditions that compromise visual function.

Relative contraindications also need to be considered. Significant meibomian gland dysfunction destabilises the tear film, and the reduction in the tear film break up time is a major cause of dissatisfaction with the visual quality with EDoF IOLs. These patients should be treated comprehensively for meibomian gland dysfunction pre-operatively. Should control of the condition be difficult to achieve, it may be prudent to consider either delaying cataract surgery until they are symptomatically controlled or consider using a monofocal IOL.

The presence of mild or well controlled glaucoma is not a contraindication to their use, however advanced nerve fibre layer loss or lack of control of glaucomatous progression would indicate a monofocal IOL and is the correct choice.

Obviously the patient's visual goals must also be considered and respected. If there is no desire to achieve independence from glasses for reading, then I cannot see the rationale in using any EDoF or multifocal IOL implant. Any side effect, even if fairly minimal in IOL platforms such as EDoF lenses, is unacceptable if the visual goal of reducing spectacle independence is not important to the patient.

If the eye is suitable and the patient is motivated, then a careful discussion of the patient's visual requirements is imperative. Firstly, it is important to determine where the majority of the patient's near visual tasks occur. Questions regarding the use of computers, frequency and distance of preferred reading and other near visual tasks should be determined. It can be useful to actually measure the working distances the patient wishes to achieve to ensure their visual goals will be met. A discussion of activities such as night driving is important and the concept of halos needs to be elaborated upon.

If a patient wishes to achieve reading and computer vision without glasses, and can function comfortably at 60cm near working distance, they are ideal candidates for EDoF IOL technology. The reduced haloing effect, together with the excellent neuro-adaption to them that is generally encountered, make them an excellent IOL choice in achieving high patient satisfaction.

The EDoF IOL's forgiving nature, with regard to the potential necessity for refractive optimisation following IOL implantation using strategies such as LASIK, is another benefit. Traditional multifocal IOLs are far more demanding regarding subtle degrees of residual refractive error, which has reduced their adoption by the general ophthalmic community. An EDoF IOL is better able to tolerate mild residual astigmatism and is a more predictable choice for a surgeon who does not have ready access to refractive surgery strategies.

OPTOMETRIC INVOLVEMENT

The EDoF class of IOL dovetails well into joint management of cataract patients with optometrists. Reduced halos and optimal contrast sensitivity mean high patient satisfaction and less complaints in the practices of both ophthalmologists and optometrists.

> "I have been delighted with the surgical outcomes I have achieved with EDoF lenses. Refractive accuracy is the same as with standard monofocal IOLs"

I always counsel patients having EDoF IOL implants that they will require reading glasses for close near visual tasks – the reinforcement of realistic expectations regarding unaided near vision is critical. Patients should be co-managed with their optometrist to ensure the required reading glasses are provided in the early post-operative period, once refractive stability is achieved.

SURGICAL CONSIDERATIONS

Refractive targeting for IOL power selection is generally subtly on the myopic side. An EDoF IOL comfortably accepts a minimal degree of myopia residual post-operatively without significant degradation in distance vision quality. It is possible to aim for a mini-monovision approach with a slight myopic bias in the non-dominant eye without encountering a significant degree of distance vision attrition, as would be encountered with a monodical IOL due to the expanded focal range.

Although I generally use the same IOL in fellow eyes to allow for optimal binocular summation, some surgeons have certainly achieved effective outcomes with a mix and match approach. In this scenario, an EDoF IOL is placed in the dominant eye and a traditional multifocal in the non-dominant eye. The rationale is to minimise the awareness of halos by taking advantage of ocular dominance and covering the one meter visual flat spot engendered with a traditional multifocal IOL implant while still providing reading capability up to 40cm distance in the non-dominant eye. This approach would naturally engender more halo awareness than an EDoF implanted into either eye.

All EDoF IOLs can be implanted through a 2.2mm corneal incision and no modification of standard cataract surgery technique needs to be made. Careful toric alignment is as important as with any cataract surgery procedure.

RESULTS

I have been delighted with the surgical outcomes I have achieved with EDoF lenses. Refractive accuracy is the same as with standard monofocal IOLs. Reading vision has been generally good with 81% of patients achieving N8 unaided vision and 100% N10 at three months post-operatively. Reading distance does vary somewhat from 40 to 70cm distance.

In the recent clinical trial I have been involved with, of the toric form of the Zeiss AT LARA, the average reading distance was 49cm. No patient required glasses for computer use, however 40% would be using glasses for close near visual tasks (around 40cm). Out of all EDoF IOLs I have implanted, just two patients have requested an IOL exchange for a traditional multifocal IOL implant to optimise their uncorrected near vision. No patients have requested an IOL exchange for issues such as compromised night driving due to halos.

CONCLUSION

The introduction of the EDoF class of IOL is an exciting advance in cataract and refractive surgery. It is always important to tailor an approach to the specific requirements of an individual.

There exists a gap between monofocal IOLs that provide an absence of optical side effects but complete dependence on near glasses, and the excellent reading vision with increased night visual side effects encountered with multifocal platforms.

Although EDoF IOLs do not completely achieve all the strengths of either a monofocal or multifocal approach, neither do they share the weaknesses of either. I often regard the EDoF class as that with the broadest range and least compromise.

Patients with EDoF IOLs implanted have excellent visual quality and good contrast sensitivity with minimal night vision issues while still being able to achieve a significant degree of glasses independence.

Dr James Genge is the founder and medical director of Freedom Eye Laser and Northern Beaches Eye Surgery. His practice is in Dee Why, Sydney.

Dr Genge trained at Sydney Eye Hospital and subsequently undertook a Fellowship in corneal, cataract and refractive surgery at Moorfields Eye Hospital in London.

A cataract, refractive and corneal subspecialist, he has extensive experience with all aspects of refractive and cataract surgery. He implanted the first Symfony EDoF IOL in Australia and is one of two surgeons in Australia performing the trial of the toric form of the Zeiss AT LARA toric EDoF IOL.

Dr Genge performs Contura Vision Topographic linked LASIK with the Alcon Refractive Suite. He performs lamellar corneal transplant surgery, including Descemet's membrane endothelial keratoplasty (DMEK) and deep anterior lamellar keratoplasty (DALK).

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