The majority of patients undergoing cataract surgery in the UK receive monofocal intraocular lens (IOL) implants, necessitating the use of near vision corrections post-operatively. Recent years have seen the development of a range of IOLs that aim to overcome the problem of presbyopia; such IOLs may be multifocal or accommodating in design. This article will explore the key IOL options for presbyopia, along with their limitations, and consider factors relevant to eyecare practitioners managing these patients post-operatively.
Cataract surgery with intraocular lens (IOL) implantation has become a routine surgical procedure. Over 300,000 NHS cataract surgeries are performed each year and, in the vast majority of cases, surgery is performed under local anaesthesia. A foldable IOL is inserted into the empty capsular bag after liquefaction and aspiration of the opacified phakic lens. The IOL unfolds once inserted and haptics emanating from the optic stabilise the implant position; post-operatively, the capsule fibroses and contracts around the IOL. Conventional IOLs are monofocal in design, and with developments in cataract surgical techniques and pre-operative biometry, most patients can expect a near-emmetropic distance refraction post-operatively. A recently-published database study relating to 55,567 cataract procedures across 12 NHS trusts indicated that over 90% of cataract patients achieved monocular unaided distance visual acuity (VA) of 6/12 (0.3 logMAR) or better. Approximately 3-8% of patients implanted with monofocal IOLs will achieve good near vision (adequate for reading newspaper print) due to pseudoaccommodative effects including pupil miosis and increased depth-of-field; chromatic aberration; monochromatic higher order aberrations such as spherical aberration and coma; corneal multifocality; low myopia and against-the-rule myopic astigmatism. However, the majority of monofocal IOL recipients will require a near addition for everyday tasks. To alleviate the problem of presbyopia, a range of multifocal and accommodating IOL designs have been developed over the last three decades. Such implants are not available to NHS cataract patients unless as part of a clinical trial, or in exceptional circumstances, for example paediatric cataract, where funding may be applied for on an individual basis. Patients undergoing privately-funded cataract surgery or refractive lens exchange may opt for a multifocal or accommodating design in preference to a monofocal implant.

**Multifocal IOLs**

Multifocal IOLs (MIOLs) provide two or more fixed optical powers and therefore provide multiple co-existing retinal images, a concept known as simultaneous vision. For distance
viewing, a focused retinal image is formed by the regions of the IOL within the pupillary zone that contain the distance refractive correction; the image formed by the near-powered sections of the optic will be somewhat blurred. The co-existing images are sufficiently dissimilar for the brain to interpret them as separate, allowing the focused image to be selected and the blurred image suppressed. MIOLs have been in clinical use since the late 1980s and may be broadly classified into two categories: refractive and diffractive designs, with some implants incorporating both of these principles. A refractive IOL optic features distinct juxtaposed zones of different refractive power; these zones are typically arranged concentrically, although the relatively new Lentis MPlus IOLs (Oculentis GmbH; Figure 1) feature a sector-shaped near zone in the inferior region of the optic. The non-rotationally symmetric design of the Lentis MPlus means much of the optic acts as a monofocal IOL, and more light is directed to the distance focus than with conventional refractive IOLs. The design aims to improve contrast sensitivity and reduce photic phenomena including halo and glare, which are frequently experienced following MIOL implantation.

Diffractive MIOLs are based on the Huygens-Fresnel principle, where concentric rings on the optic surface generate separate distance and near foci with a proportion of incident light lost at higher orders of diffraction. Such implants have been shown in numerous published studies to result in good distance and near visual acuity outcomes, and reduced spectacle dependence compared to monofocal IOLs. Diffractive MIOLs have conventionally been bifocal in nature, although a new trifocal design (FineVision, PhysIOL) uses a combination of two diffractive profiles to split light to distance, intermediate and near foci. The trifocal design may reduce the need for spectacles for intermediate tasks, which is particularly relevant nowadays given that around two-thirds of retired persons regularly use a computer.

For existing monofocal pseudophakes who desire spectacle independence, the Sulcoflex supplementary IOL (Rayner Intraocular Lenses) is a relatively new option. Sulcoflex is designed to treat residual or unexpected refractive error following cataract surgery, without the need for risky explantation of the original IOL. It is the only IOL designed specifically for sulcus implantation, with the optic positioned anterior to the pseudophakic IOL. The multifocal Sulcoflex variant offers the advantage of being more easily reversible than in-the-bag IOLs in cases of non-tolerance; it can simply be removed through a 2.8mm surgical incision.

**Accommodating IOLs**

So-called accommodating intraocular lenses (AIOLs) aim to restore dynamic focus to the presbyopic eye. AIOLs fall into two main categories: single-optic and dual-optic devices, both of which are designed to be implanted into the capsular bag. AIOLs rely on the continued function of the ciliary muscle with advancing age and are designed to change their power in response to physiological changes occurring in the accommodative structures.

Single-optic AIOL designs have been used most extensively to date, and are based on the passive-shift principle where ciliary muscle contraction initiates an anterior axial movement of the IOL optic, increasing the eye’s refractive power. Exact mechanisms of action vary between manufacturers, with Tetraflex (Lenstec Inc.) and CrystaLens (Figure 2; Bausch & Lomb) designed to move anteriorly increasing the eye’s refractive power.

The potential accommodative amplitude of passive-shift IOLs is dependent upon the power of the implant (and therefore the patient’s refractive error). McLeod and colleagues proposed a simple formula to approximate the power change occurring with anterior axial shift of an AIOL optic: $\Delta Dc = (Dm/13) \times \Delta s$ (Equation 1) where $\Delta Dc$ is the change in the eye’s dioptic power, $Dm$ is the power (D) of the AIOL, and $\Delta s$ is the change in lens position (mm). For an AIOL with a fairly typical power of +20D, Equation 1 indicates that 0.65mm of anterior movement is required to generate 1.0D of accommodation. In myopic eyes, requiring lower powered implants, considerably more axial movement would be required. High-precision biometric techniques such as partial coherence interferometry and ultrasound biomicroscopy have been employed to measure axial optic movements occurring with AIOLs. Natural viewing of a near stimulus results in low levels of anterior movement of the optic, for instance 0.01mm to a maximum of 0.33mm, although pharmacological stimulation of accommodation, using topical pilocarpine, can induce up to 0.8mm of axial displacement.

It is clear that the anterior axial shifts associated with single-optic AIOLs are insufficient to provide adequate near function to presbyopic eyes. However, several published studies have reported reasonable intermediate and/or near vision outcomes with these implants, along with excellent distance vision results. It has been hypothesised that some of the near vision benefits of single optic AIOLs may be due to lens flexure during accommodative effort, which may impact on the eye’s optical aberrations, increasing depth of focus. Some recent AIOL designs incorporate additional features to aid near vision, for example, the CrystaLens AO features aspheric optic surfaces with zero spherical aberration and is also designed to arch and steepen with accommodative effort to increase the eye’s dioptic power. To further optimise near

*Figure 3* The Synchrony dual optic AIOL. During ciliary muscle contraction, the anterior optic is designed to move anteriorly, increasing the eye’s refractive power.
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Figure 4 The Sarfarazi dual optic AIOL features an elliptical shape to conform to that of the capsule.

vision outcomes, refractive targets for AIOL implantation are frequently slightly myopic, for example -0.12 to -0.50D.21

Dual optic AIOL designs have been developed to overcome the dependence of potential accommodative amplitude on refractive error (and optic power), which limits single optic AIOLs. Dual optic devices consist of a highly positive-powered (for instance +32D) and mobile anterior optic, connected to a stationary negatively-powered posterior optic. The power of the posterior optic is dependent upon the refractive error of the patient. As the anterior optic is more powerful than a single-optic AIOL, its forward shift generates a greater increase in refractive power. Dual optic devices occupy the whole capsular bag, with aqueous filling the interoptic space. During ciliary muscle contraction, when a reduction in capsular tension occurs, the anterior optic moves anteriorly and the interoptic separation increases.

The Synchrony (Abbott Medical Optics) has CE approval for use in Europe and is the most widely used dual optic AIOL to date. The new SynchronyVU features an aspheric central zone on the anterior optic to mimic the increase in negative spherical aberration occurring during natural accommodation; this aspect of the design relies on near vision pupil miosis. A further dual optic AIOL was developed by FM Sarfarazi (Shenasa Medical LLC), and features an elliptical design to conform to the natural shape of the capsule. Bausch & Lomb acquired the rights to develop and produce the Sarfarazi in 2003, and in vivo use in the rhesus monkey demonstrated a potential for 7.0-9.0D of pharmacoologically-induced accommodation, although there are no published reports of human use.26

Based on the differences in mechanisms of action, dual optic AIOLs should provide higher amplitudes of accommodation, and improved near vision performance compared to single optic designs. A comparative study of visual outcomes with a single optic AIOL (Crystalens HD; n=27 eyes) and a dual optic device (Synchrony; n=26 eyes) was published by Alió and colleagues in 2012.27 As might be expected, both IOLs demonstrated excellent distance vision results at six months post-operatively. Defocus curve testing was employed to assess near vision abilities. The technique involves measuring distance vision acuity (VA) while the distance-corrected patient views a letter chart through a series of positive- and negatively-powered spherical defocus lenses (equivalent to viewing at different distances). Results can be plotted on a two-dimensional graph (Figure 5). Eyes with good levels of accommodation (or pseudoaccommodation) will demonstrate excellent VA across a range of levels of negative defocus. As can be seen in Figure 5, the near vision potential was limited with both AIOLs, with a steep drop-off in VA as negative lens defocus increased, although the Synchrony group demonstrated significantly better median acuity at the -3.00D and -3.50D levels of defocus. Furthermore, no differences between the groups in terms of reading acuity or reading speed were observed. These data represent one of the first comparative studies of single- versus dual-optic AIOLs and indicate that both types of implant provide similar limitations in near vision outcomes.

Managing presbyopia-correcting IOLs in optometric practice

Although the devices described in this article are relatively recent additions to the ophthalmologist’s armoury, they continue to gain popularity and are, therefore, seen more frequently in general ophthalmic practice. Clearly, if the examining optometrist has not seen the patient previously, it is beyond his or her control as to which patients are the most suitable for MIOL or AIOL implantation. Indeed, the techniques adopted by ophthalmologists preoperatively to select patients are currently very subjective. Often, the most successful postoperative patients are those who perceive their uncorrected near/reading vision to be essential rather than an option or bonus offered by the new lens designs. Consequently, it is important that optometrists are aware of these multifocal devices and the potential post-operative optical side effects.

Here, rather than considering each IOL design in turn, we outline the problems that may arise with a patient presenting for a postoperative eye examination, and how these symptoms can be managed. It is worth noting that patients may continue to be symptomatic until both eyes have been implanted. The optometrist should be aware and advise the patient that the full synergistic benefit of the IOLs may not be experienced until the fellow eye is treated. On rare occasions, some patients may require implant removal for severe symptoms. In these cases, a good dialogue with the local ophthalmologist is critical.

Photic phenomena: halos and glare

Although spectacle independence is achieved more often with multifocal than monofocal...
IOLs, unwanted photic phenomena, particularly halos, are more prevalent in patients with MIOls and are the primary reason for patient dissatisfaction. Moreover, refractive MIOLs appear to be associated with more photic phenomena than diffractive MIOLs. With MIOLs, one or more focal points will not be conjugate with the retina at any given time. Depending on the patient’s ability to adapt to blur, these out of focus image planes often lead to a reduction in contrast sensitivity and the appearance of halos and disability glare. In an attempt to minimise these symptoms, many MIOL designs incorporate an aspheric surface to maximise contrast sensitivity and visual function.

Dysphotopsia (often referred to as ‘halos’) frequently occurs with MIOLs, but often reduces as the visual system adapts to the phenomenon over time. If seen soon after surgery (within two months), the examining optometrist may need to counsel the patient and explain that their symptoms should reduce with time. If the patient remains symptomatic and neuroadaptation does not occur, ophthalmologists may use weak concentrations of miotic drugs (that is pilocarpine) to decrease pupil size and reduce the appearance of halos and glare. Ultimately, some patients may require IOL exchange, but this is rare and increases the risk of complications such as cystoid macular oedema.

Halos and glare are particularly apparent in low illumination as the pupil dilates. In this situation, the optometrist should be able to manage the patient aware of the risks associated with driving at night. When driving is essential, patients could be advised to use the car’s internal dome light to minimise symptoms. However, the best advice would be for the patient to refrain from driving if the symptoms were hindering visual performance.

**Figure 5**: Median defocus curve for 27 eyes implanted with Crystalens (Group A) and 26 eyes implanted with Synchrony (Group B). Error bars represent range of visual acuity (VA) values. Reproduced with permission from Elsevier.

**Distance/near blur**
As with multifocal contact lenses, postoperative distance blur is often resolved by carefully checking the patient’s residual refractive error, paying particular attention to any uncorrected cylinder induced during surgery. Some reports suggest that wavefront-guided keratorefractive surgery may also be an option to ameliorate higher-order aberrations. Patients may also perceive near blur, despite being fitted with devices designed to address this issue. One possible explanation for postoperative blur at near is the change in working distance, from that adopted with the pre-operative near vision correction. Here, the optometrist should take time to redefine the patient’s optimum near point and their new range of clear vision.

Optometrists may also have to manage their patient’s expectations following AIOL implantation. Although designed to change optic position or shape within the eye upon contraction of the ciliary muscle, current versions of these lenses have received mixed reviews in the literature. Although some near function may be restored, many patients will require a near vision prescription to support near tasks. It may be beneficial to provide the patient with accommodation training, although the use of such techniques requires further investigation. One benefit of AIOLs is that the optical zone is monofocal in nature; while patients may have limited accommodation, they will also not have multifocal image planes which, as we have seen, can induce other unwanted symptoms.

Finally, presbyopia correcting IOLs are, by their very nature, often implanted in an eye with co-morbidities (for example dry eye). These associated ocular conditions frequently exacerbate the presenting symptoms following IOL implantation. It is important, therefore, that optometrists are aware of these and manage the conditions accordingly.

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