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Modern management of presbyopia

PART 2: Contact lenses

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Presbyopia is a refractive error that originates from the eye having an insufficient ability to accommodate for near vision targets due to ageing[1]. Presbyopia is the final phase of a continuous loss of amplitude of accommodation. This decline begins before adulthood; however, it does not typically manifest in visual symptoms until the subjective amplitude of accommodation reduces to three to four dioptres around the age of 45[2].

After the age of 55, most patients are unable to sufficiently alter the refractive power of their eyes. It should be noted that patients will potentially have a pseudo-accommodative ability partly due to depth of focus effects produced by pupils that become progressively more miotic[2].

The current life expectancy within the UK is approximately 80 years of age. This means that phakic patients spend approximately half their life as a presbyope and more than 20 years with an insufficient ability to accommodate[2]. Patients who are presbyopic will likely use an optical appliance to assist them when viewing a near vision target.

This article aims to review the involutional changes that may occur as part of the normal process of ageing, and how presbyopia is managed using contact lenses.

AGE-RELATED OCULAR CHANGES

Ageing produces involutional changes, which typically lead to a decline of biological functions. Several involutional changes occur within the ocular surface and adnexa that have been reported in literature, including:

- A reduction in lacrimal output and alterations to the output composition[3]
- A reduction in number of functional meibomian glands and alterations to the lipid secretions[4]
- The development of conjunctivochalasis[5]
- A significant increase in the prevalence of ocular surface disease (dry eye)[6,7]

Pupil diameter has been shown to have an inversely proportional relationship with age. Pupil diameter at a luminance level of 220cd/m2 was found to be approximately 5.5mm in patients aged 20 to 29 years old, 4.5mm for patients aged 50-59 years, and 3.5mm for patients aged 70-79 years[8].

In a study conducted by Rico-del-Viejo *et al*, which investigated the effect of ageing on the ocular surface: a positive correlation was found between age and increased bulbar redness; increased corneal and conjunctival staining; a reduction in the functional performance of the meibomian glands; a reduction in the eyelid margin thickness, which is correlated with lid wiper epitheliopathy; an increase to eyelid laxity, which is linked to dry eye symptoms; a reduced tear meniscus height; and a decrease in tear secretion, which is associated with an increase in inflammatory markers[9].

Additionally, contact lens wear produces several involutional changes within the ocular surface and adnexa. Current literature suggests that contact lens wear is not associated with meibomian gland drop-out, however, there is data to suggest that the meibum of contact lens wearers has a 3˚ higher melting point compared to non-wearers[10]. Changes to the meibum composition may result in increased tear

osmolarity, increased tear evaporation rates and a reduction in tear film stability[11-13].

Higher order aberrations modestly increase as the eye ages, however, as presbyopia develops the natural compensatory mechanism produced by the crystalline lens is lost[14]. Ageing produces optical performance alterations due to the disruption of the compensatory effect between the anterior cornea and internal aberrations. This disruption results in an increase in high-order aberrations. Spherical aberration and horizontal coma typically increase in aging eyes[15].

Alterations to the tear film parameters have been shown to induce high order aberrations during dynamic aberrometry. These changes in high order aberrations are more significant in patients with tear film instability and ocular surface damage[16,17].

PHAKIC PATIENTS SPEND AROUND HALF THEIR LIFE AS A PRESBYOPE

METHODS OF PRESBYOPIC CORRECTION WITH CONTACT LENSES

Given the challenges that practitioners face in correcting presbyopia, it is prudent to explore the potential options that are available to patients.

Monovision

Monovision is a method in which contact lenses can be used to correct two focal lengths, typically distance and near vision. Full monovision is where the dominant eye is fitted with the distance correction and the non-dominant eye is fitted with the near vision correction.

Monovision is based on the principle of inter-ocular blur suppression (IBS). This means that the visual system can alternate suppression between the two eyes. In effect, if a patient is viewing a target in the distance, the near vision image is suppressed.

Estimates of successful outcomes when fitting new monovision wearers is approximately 60-70 per cent[18-20]. Stereopsis is negatively affected during monovision; however, it is not considered to be a significant cause of fitting failure[21]. The predictability of success is enhanced if the binocular visual acuity of the patient when wearing contact lenses is similar to that of the spectacle visual acuity, assuming there are no major reductions in stereopsis or contrast sensitivity[22].

Despite its proven effectiveness, the binocular rivalry and image suppression associated with this form of correction is likely to require a period of cortical adaption[23,24]. The use of soft toric lenses with monovision enables astigmatism to be corrected. Astigmatism that is equal to or greater than 0.75DC should be corrected, assuming that there is an improvement to the visual performance and that the power range and lens design is available to dispense.

Partial monovision

When a near vision addition exceeds +2.00DS, it may reduce the visual performance that the patient experiences. This is because as the reading add increases, the binocular stereoacuity will decrease. Factors such as low levels of illumination or optotypes that provide near-threshold stimuli (for example, the lowest line a patient can read during distance visual acuity assessment) also play a part in enhancing the negative effect of the increasing add. Partial monovision is where a practitioner will give the distance prescription to the dominant eye and a reduced near prescription to the non-dominant eye.

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Enhanced monovision

Enhanced monovision is where a practitioner will fit one eye with a multifocal lens and the other eye with a single vision lens. The rationale for this approach is that it may improve binocular summation and provide stereoacuity to a monovision wearer who is experiencing blur as their reading addition increases. The most common approach is to fit the dominant eye with a single vision lens and the non-dominant eye with a multifocal lens.

Modified monovision

Modified monovision can be achieved in several ways, for example, using different add powers, such as fitting a low add multifocal to the dominant eye and fitting a medium to high add in the non-dominant eye. Another way of achieving modified monovision is fitting a centre distance multifocal in the dominant eye and fitting a centre near in the non-dominant eye. The practitioner is using different lens designs for each eye to improve the vision at one focal length at the expense of another.

Reversed monovision

Reversed monovision is where a practitioner fits the dominant eye with the near vision correction and the non-dominant eye with the distance correction. This offers the patient the potential to achieve a higher performance from their near vision. This form of monovision is likely to have a negative impact on the distance visual acuity, thus driving status and occupational vision needs would need to be confirmed.

Bifocal contact lenses

British Standards BS EN ISO 18369-1:2017 states that bifocal contact lenses are defined as a contact lens having two optic zones usually for distance and near-vision correction[25]. Modern bifocal contact lenses are only available as rigid gas permeable (RGP) materials. Bifocal contact lenses can be manufactured using different surface geometry designs including, alternating, concentric and diffractive, though the latter is not currently a commercially available design.

Concentric bifocal designs are a type of simultaneous image contact lens. These contact lens designs have a primary viewing zone in the centre of the lens, and a secondary viewing zone in the periphery of the lens. Concentric bifocal lenses are available as centre-distance or centre-near. These lenses can be classed as biconcentric[26].

Alternating bifocal designs (***Figure 1***), also known as translating designs, work on the principle that the eye's typical primary gaze position for a given task will encourage viewing through the appropriate area of the lens. For example, as the eye looks downward towards a near vision target.

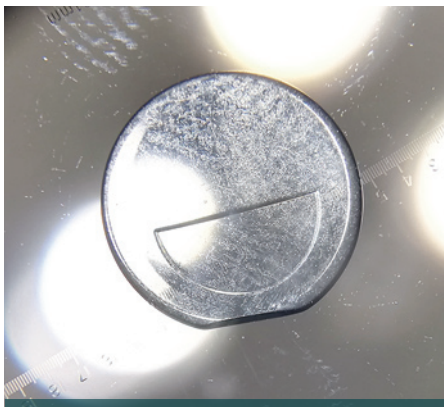

FIGURE 1: ***Alternating bifocal contact lens***

FIGURE 2: ***Diffractive bifocal contact lens***

Diffractive bifocal contact lenses (***Figure 2***) are historical designs of bifocal contact lenses that uses refraction to correct distance vision, and a combination of refractive and diffractive optics to correct near vision. The back surface of the lens utilises a diffractive 'zone plate', which effectively splits incident light passing through the lens into two focal points – typically distance and near.

Multifocal contact lenses

British Standards BS EN ISO 18369-1:2017 defines multifocal contact lenses as: "a contact lens designed to provide two or more zones of different corrective powers"[25]. Multifocal lens options have proliferated significantly in recent years[27] – and are available in a variety of lens types and modalities[26].

Simultaneous designs

An aspheric lens surface incorporates a rotationally symmetric surface design, which introduces spherical aberrations. This surface design produces progressive graduation in refractive power from the geometric centre of the lens to the periphery of the lens. Centre-distance lenses introduce positive spherical aberrations in the periphery of the lens. Centre-near lenses introduce negative spherical aberrations in the periphery of the lens[14].

Simultaneous design multifocal contact lenses result in multiple retinal images being presented at the retina simultaneously, the in-focus and out-of-focus images. Patients are likely to require a period of cortical adaption (where the correct visual input is selected by the brain with the out-of-focus image being supressed) of up to 15 days[28] to adjust to the power profile of these lens designs. It is not unusual to encounter complaints of 'ghosting' and 'blur', particularly in dark conditions when pupil diameter increases[29,30].

There are three categories of simultaneous image contact lens designs:

- **Aspheric multifocal contact lenses** ***(Table 1 - page 4)***
- **Annular design multifocal contact Lenses** ***(Table 2 - page 4)***
- **Extended depth of focus (EDOF) multifocal contact lenses** ***(Table 3 - page 4)***

Simultaneous vision multifocal contact lenses have the potential to offer patients an acceptable level of visual acuity, however, some patients' subjective response to their overall vision performance may be sub-optimal due to dysphotopsias, such as 'ghosting'[34], 'haloes'[35] and various other description of glare perception that do not alleviate over time due to cortical adaption.

Decentration of a simultaneous vision multifocal contact lens is more likely to induce unwanted aberrations. It is therefore argued that good centration of

a multifocal is highly important. As the lens design becomes more complex, for example the lens design has a higher magnitude of spherical aberrations, there is greater likelihood that this will have visual implications to the patient[26].

Theoretical modelling suggests that EDOF lenses are less susceptible to the issues related to ocular aberrations, pupil size and decentration[36]. This is attributed to the lens design producing varying high order aberrations.

A study by Martinez-Alberquilla *et al* attempted to evaluate the visual performance, ocular surface integrity and symptomatology of EDOF lenses compared to a conventional multifocal contact lens[37]. The study concluded that visual performance, ocular surface integrity and symptomatology when fitted with EDOF lenses, was comparable to a conventional multifocal lens design. The only statistically significant difference was that the visual performance improved when fitted with EDOF lenses under mesopic conditions for low spatial frequencies.

Orthokeratology

Orthokeratology (ortho-K) is the process of intentionally altering the anterior corneal curvature using specialist contact lenses to temporarily and reversibly ameliorate refractive error after lens removal. Modern ortho-K lenses incorporate reverse geometry lens designs, which are worn overnight to reshape the anterior cornea and provide temporary management of refractive error. Considering refractive error, good patient candidates include myopes whose max spherical error is approximately -4.50DS with a maximum of -1.50DC with-the-rule astigmatism, though cyls up to -3.00DS may be fitted well with a toric lens design[38].

It is possible to manage presbyopia using ortho-K with a monovision correction: for example, a presbyopic emmetrope may be corrected using one lens only. This approach was highlighted in a 2013 study where thirteen emmetropic presbyopes achieved functional near vision using ortho-k in the non-dominant eye without compromising the distance vision[39]. The study did highlight that only a +1.00D change after one week of use was achieved.

Aspheric multifocal contact lenses are available in a range of designs	
FRONT SURFACE ASPHERIC LENSES	**Front surface aspheric lenses** typically generate negative spherical aberrations, which results in greater negative power in the periphery of the lens. This effectively creates a centre-near design lens.
BACK SURFACE ASPHERIC LENSES	**Back surface aspheric lenses** typically generate positive spherical aberrations, which results in greater positive power in the periphery of the lens. This effectively creates a centre-distance design lens.
For both front and back surface aspheric multifocal contact lenses, there is a limit to the amount of additional plus power that can be generated increasing the asphericity of the lens[22].	
BI-ASPHERIC LENS SURFACE LENSES	**Bi-aspheric lens surface** designs enable higher add powers to be achieved as these powers often require more complex surface geometry. However, this lens surface design produces abrupt changes in refractive power[14].

TABLE 1: ***Aspheric multifocal contact lenses***

Annular design multifocal contact lenses
Somewhat confusingly, **annular design multifocals**[14] have been assigned various names such as zonal aspherics[24] and concentric multifocal contact lenses[26]. For the purposes of this article, the term annular design multifocals will be used.
These lenses incorporate a central zone, which may be chosen to correct distance or near vision. This central zone is surrounded by one or more rings of alternative power. In centre distance zonal aspheric lenses, these surrounding zones may use refractive power to generate intermediate and near adds. In centre near zonal aspheric lenses, these surrounding zones produce the required power to correct distance vision[10].
Contact lenses that exhibit a monomodal through-focus image quality curve, which is linked a power profile that gradually transitions in power[33]. Contact lenses that exhibit a bimodal through-focus image quality curve are linked to a power profile that has a second peak[33].

TABLE 2: ***Annular design multifocal contact lenses***

Extended depth of focus contact lenses
EDOF lenses are an innovative multifocal lens design available to practitioners. The lens surface design is described as a non-monotonic (constantly varies in refractive power), non-aspheric, non-diffractive, and aperiodic (irregular). The variation in lens surface refractive power is generated through computer algorithms, which result in the purposeful manipulation of multiple high order aberrations to increase the depth-of-focus[9].
A potential issue with conventional multifocal contact lenses is the negative impact that variations in pupil size and illumination may have on the quality of vision[31,32]. EDOF lenses attempt to ameliorate the negative subjective visual response from presbyopic patients.

TABLE 3: ***Extended depth of focus contact lenses***

It is worth noting that at this moment in time, more research is needed to better understand and evaluate the effectiveness of ortho-k for the correction of presbyopia.

Another example is a presbyopic myope who may be corrected using ortho-k in the dominant eye to neutralise the refractive error for distance only. Although this approach does not correct the presbyopia, the outcome may result in patient achieving satisfactory levels of vision for distance and near.

Although ortho-k can be used to correct presbyopia, it is less predictable and consistent compared to correcting myopia[38]. Ortho-k is not currently licensed in the UK for the correction of presbyopia (or hyperopia). Therefore, it can only be used 'off-label' by practitioners. It is prudent to ensure that informed consent is obtained prior to commencing fitting[39,40].

The correction of presbyopia with ortho-K lenses requires the central back optic zone radius to be fitted steeper than the flattest keratometry reading. Assessing the fit with fluorescein results in a central island pattern, which demonstrates that the central corneal region is steepening. This region is followed by an annulus of corneal flattening[38]. As the central cornea becomes increasingly steep, this results in an increase in positive refractive power.

Early studies on the structural changes to the cornea demonstrated that corneal epithelium thickens more in the centre compared to the mid-periphery[41,42]. Recent research using pachymetry demonstrates central stromal thickening and mid-peripheral epithelial thinning[43]. The timeframe to correct approximately +1.50 dioptres is approximately one week. However, the largest refractive change takes place after the first night of wear[44,45].

CONSIDERATIONS FOR SUCCESS

Several studies that attempt to evaluate the effect of visual function when using contact lenses to correct presbyopia fail to attempt to directly compare the different options of correction. There are valid reasons for this issue, as there are many direct and indirect factors that impact on the visual function when using multifocals to manage presbyopia. These include:

- Patient selection
- The methods used to measure visual acuity, stereopsis, and contrast sensitivity
- The refractive power of the reading addition
- The diameter of the pupil
- The contact lens surface design, which generates the contact lens power profile
- The patient's ocular dominance, aberrations and cortical adaption of the patient to the retinal images[37]

A 2018 study looked to better understand how visual performance may be affected by presbyopic contact lens correction, to support patient understanding of the adaptation requirement to multifocal contact lenses. To reduce the variables found owing to ageing that may also affect these visual factors, the study was conducted on non-presbyopic participants aged 18-30 years.

The study compared the following presbyopic contact lens corrections immediately following application, without time allowed for adaptation:

- Monovision contact lenses
- Multifocal lenses *(aspheric lenses with a low add in each eye)*
- Multifocal lenses *(aspheric lenses with a high add in each eye)*
- Multifocal lenses *(low add, centre distance for the dominant eye and centre near for the non-dominant eye)*
- Multifocal lenses *(high add, centre distance for the dominant eye and centre near for the non-dominant eye)*

Stereopsis demonstrated the greatest reduction when using monovision contact lenses. Stereopsis was reduced with all multifocal options in this study but to a lesser degree compared to monovision.

With a period of neural adaptation, simultaneous design multifocal contact lenses can allow the wearer to improve binocular visual function in a way that is not possible with a monovision correction as stereopsis there will not improve[45-47]. Therefore, although the initial contact lens on-eye experience in the testing room may be recorded more favourably for monovision, once neural adaptation has taken place, the multifocal correction may allow for a better real-world visual experience[37].

One study has highlighted that patients have a preference towards multifocal lenses that optimise the distance visual acuity[49]. Comparisons of the spectacle acuity for the distance versus the multifocal distance acuity is often cited as a useful metric of predicting success. However, this is likely to be an unfair comparison as a considerable number of presbyopic spectacle wearers use progressive power lenses (PPL)[49].

PPLs produce surface aberrational astigmatism in the periphery of the lens, which is perceived by patients as 'distortion'. A recent study compared the visual performance of presbyopic patients who were habitual PPL wearers who were then fitted with multifocal contact lenses. The study revealed that 70 per cent of participants preferred multifocal contact lenses compared to their PPL spectacles[50], and that that there was a strong preference for multifocal contact lenses when patients were 'dining out' and 'working out'.

There are a considerable number of parameters and 'bulk' properties available to consider when prescribing contact lenses for a patient[51] (***Table 4- page 6***).

It is prudent to attempt to identify candidates who have a greater likelihood of acceptance of presbyopic contact lens correction[52].

- Ametropia: Greater requirement for distance correction is linked with a higher acceptance compared to emmetropes
- Ocular surface physiology: Tear break-up time and tear prism height indicate appropriate stability and volume
- Is the patient a current contact lens wearer?
- Does the patient have realistic expectations and are they willing to accept some compromise?
- Degree of presbyopia[22]: lower adds are generally correlated with increased acceptance

INNOVATION IN BIOMATERIALS AND LENS DESIGN

Contact lens discontinuation is associated with lens discomfort and ocular dryness[53,54]. As mentioned earlier, ageing is correlated with reduced lacrimal output and a reduced functionality of the meibomian glands. Physical-chemical properties that can help to reduce the impact of ocular dryness is an area of interest for contact lens manufacturers. Innovation within contact lens manufacturing has led to the integration of surface treatment and internal wetting agents within biomaterials to enhance the biocompatibility with the ocular surface[55-61].

Interpenetrating hydrogels are formed when a primary material has a secondary material embedded within the polymer-network. Yanez *et al* demonstrated that interpenetrating networks of HEMA and polyvinyl pyrrolidone (PVP) could be developed to enhance comfort of contact lenses. The idea behind this approach to chemical engineering is that the PVP would 'leech' from the lens and thus function as a wetting agent.

This manufacturing method formed the basis for research that is ongoing into double-network hydrogels. This is where two hydrogel materials are interconnected through chemical engineering to form a novel hydrogel material. The purpose of double-network hydrogel formation is to improve the 'bulk' properties of a biomaterial. Formation of these novel biomaterials has been shown to improve the biocompatibility of the hydrogels[61-66].

Liquid crystal contact lenses is one area where innovative lens design is being explored for its potential to correct presbyopia[67,68]. The liquid crystal lens has anisotropic refractive indexes. Once a voltage is applied, this realigns the molecules within the material to alter the lens power by approximately +2.00 dioptres. Presently, PMMA is the most commonly used material to support the liquid crystal phases. Therefore, further work is required to enable this technology to be available in a lens material that will enable good ocular health[69].

TABLE 4: ***Contact lens parameters and properties that may be considered when fitting patients***

- Total diameter
- BOZR
- Back surface design
- Optical design
- Edge profile
- Thickness
- Power
- Colour (tint)
- UV protection
- Wearing modality
- Replacement frequency
- Surface treatment
- Internal wetting agent
- Oxygen permeability
- Water content
- Modulus
- Refractive power[24]
- Centre of gravity[24]

CONCLUSION

In conclusion, a holistic approach to assessing current visual correction requirements, vocational needs, previous and current concerns (optical, therapeutic, and cosmetic), alongside effective communication between team members, and between the practitioner and patient, helps deliver an effective service and dispense.

With the technological advances in lens design over the last few years, it is imperative to keep abreast of these innovations so that the most appropriate lenses can be offered to the patient at the time of dispense.

REFERENCES: ***References and a bibliography are available with the online version of this article.***

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LEARNING OUTCOMES FOR THIS CPD ARTICLE

DOMAIN: Communication

2.1: *Appropriately adapt your communication to provide presbyopic patients with information in a way that is understandable to the individual.*

DOMAIN: Clinical Practice

5.3: *Understand the latest contact lens options available for the management of presbyopia.*

7.5: *Provide effective patient care for presbyopic patients and recommend contact lens options based on current good practice.*

DOMAIN: Contact Lens Speciality

Understand up-to-date contact lens options available to support presbyopic patients and consider ageing and pathological changes that may be present and require consideration for suitable contact lens selection and patient care.

Communication
Clinical Practice
Contact Lens Speciality

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