BSRS
PO Box 5184
Cardiff
CF5 9DN

02920 224 443

adminBSRS@googlemail.com

Refractive Errors

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Between 68 and 79% of the general population achieve 6/6 (equivalent to 20/20) distance vision in at least one eye without any spectacle correction (Martin, 1949; Sorsby *et al.*, 1960). A further 7% of the population require a small refractive correction for distance vision but can manage without any correction for some visual tasks. The remainder have a larger degree of refractive error in the form of short-sight (myopia) or long-sight (hypermetropia), with or without a degree of astigmatism and require a refractive correction to achieve good distance vision. The ability to focus for near tasks gradually reduces with increasing age, necessitating the use of reading glasses for the vast majority of individuals over 45 years of age (presbyopia)

Myopia (short sight)

Visually significant myopia, or short sight (greater than -1.00D), affects approximately 14% of the population in the United Kingdom, although the prevalence is higher among certain ethnic groups (McCarthy *et al.*, 1997; Sorsby *et al.*, 1960). It occurs due to a mismatch between the refractive power of the eye and its length: the refractive components are too powerful for the length of the eye with the result that the light rays focus in front of the retina (figure 1)

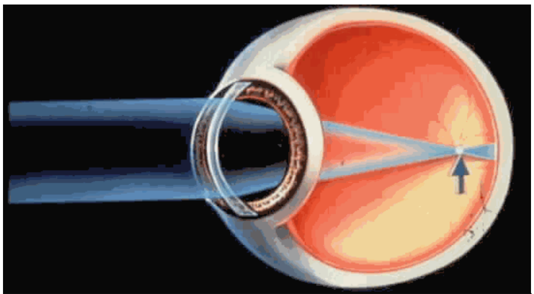


Figure 1: The light rays from a distant object are focussed in front of the retina due to a mis-match between the refractive power and the length of the myopic eye

The visual implications are significant, even for low degrees of myopia. Distant objects are out of focus and the higher the degree of myopia, the smaller the range of clear vision, e.g. a person with only –2.00D of myopia cannot clearly see any object more than 50cm from the eye.

The Correction Of Myopia

A concave lens in the form of a spectacle or contact lens placed on the cornea can be used to produce a clear retinal image (figure 2). Both methods of correction have certain disadvantages.

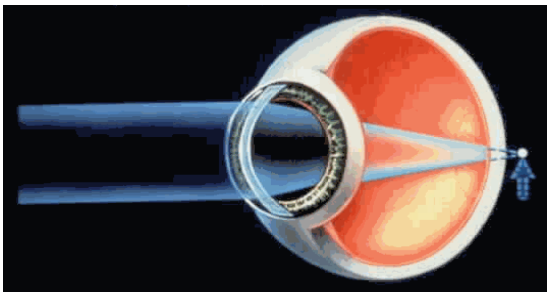
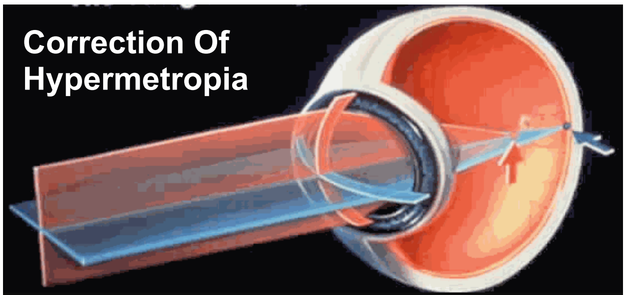


Figure 2: Correction of myopia using a concave spectacle lens

Hypermetropia (long sight)

Hypermetropia occurs when the refractive components of the eye are too weak for its length with the result that light rays attempt to focus behind the retina (figure 3). Hypermetropia does not always require correction because young patients can accommodate to overcome part or all of their long sight, hence achieving good distance vision. Accommodation is the thickening of the crystalline lens within the eye that is normally reserved for viewing near objects. The ability to accommodate reduces with age; consequently many low hyperopes (less than about +4.00D) only need glasses for close work if at all, but find they also need glasses for distance once they reach about 30-35 years of age. Because hypermetropia is less debilitating visually, the demand for hypermetropic refractive surgery has been significantly less than for myopic treatments.



A convex lens spectacle or contact lens placed on the cornea can be used to correct hypermetropia and focus the light rays on the retina (figure 4).

Astigmatism

An astigmatic eye has a different refractive power in each of two perpendicular meridians either due to the shape of the cornea or tilting of the crystalline lens, or most commonly, a combination of both. In simple terms, an astigmatic eye tends to be rugby ball shaped ather than football shaped. Uncorrected it results in distortion and elongation of the image on the retina (figure 5), and is usually combined with some degree of myopia or hyperopia. The degree of blurring is approximately half that produced by an equal degree of myopia. The prevalence of significant astigmatism (> 1.25DC) in the population is approximately 15.7% (Bennett, 1965).

Correction Of Astigmatism

Spectacle lenses can be manufactured with a different power in each of two perpendicular meridians. Precise alignment of the lens with the principal meridians of the eye is essential. Rigid contact lenses automatically neutralise low and medium degrees of corneal astigmatism but specially designed "toric" contact lenses are needed if the patient is a soft lens wearer.

Presbyopia

As the eye ages, the crystalline lens within the eye becomes harder and increases in diameter. In addition, the ciliary muscle that constricts to alter the shape of the lens gradually reduces in strength. The result is a reduction in the ability of the lens to accommodate leading to blurred near vision. The majority of patients reach presbyopia around the age of 45 years and start to require glasses for all detailed near tasks. Since presbyopia is independent of the refractive status of the eye, laser surgery for the treatment of myopia, hyperopia or astigmatism does not overcome the need for reading glasses.

Correction of Presbyopia

Many patients simply use reading glasses but those with a distance refractive error or those who need to see clearly at a range of distances simultaneously, require a bifocal or multifocal lens. Both have their drawbacks such as a blurred view of your feet when descending stairs, and distortion in the peripheral field of view. Bifocal and multifocal contact lenses are also available but tend to compromise visual quality, particularly at night. A number of refractive surgeons advocate monovision for presbyopic patients, allowing them to continue to manage without spectacles for the majority of tasks. Full correction is attempt for the dominant eye but the non-dominant eye is left with a small myopic undercorrection, usually in the region of about -1.25D. The majority of patients are happy with monovision although some find the imbalance disturbing and opt to have the undercorrected eye retreated (Goldberg, 2001). Wright and colleagues (Wright *et al.*, 1999) examined binocular function in a group of 21 patients with a monovision correction and compared them to a group of patients who had been fully corrected in both eyes. Both groups were treated with PRK. All patient's maintained binocular fusion and some degree of stereopsis. From personal experience in Optometric practice (CMC), some monovision patients complain of poor contrast acuity at night, probably due to the reduced stimulus to the binocular cortical cells. Those who are most satisfied appear to be those with lower visual expectations. The implications of monovision for tasks such as rapid response driving have not been studied.

The Disadvantages Of Traditional Methods Of Refractive Correction:

Spectacles

Spectacle lenses are capable of correcting short sight, long sight, astigmatism and presbyopia. They provide good visual quality unless the lenses become dirty, scratched or broken. Under emergency conditions, glasses may fog or become covered in water droplets, severely reducing the quality of vision (Margrain and Owen, 1996). In a study of the use of refractive correction by the Royal Canadian Mounted Police, 75% of spectacle wearers reported having to remove their spectacles due to such problems at some point (Wells *et al.*, 1997). The risk of glasses being dislodged is also a concern for certain professions (Good *et al.*, 1998; Wells *et al.*, 1997), and there have been reports of spectacles being knocked off or steaming up during combat or military aircraft manoeuvres.

Lenses for the correction of higher refractive errors lead to minification or magnification of the image with associated restrictions of the field of view (Ford and Stone, 1997). In an attempt to minimise such optical effects and also for cosmetic reasons, many high-powered spectacle lenses are made from high index materials with aspheric surfaces. The trade-off is a reduction in acuity away from the optical centre of the lens. Patients who undergo a successful refractive surgery procedure for the correction of short sight greater than about –5.00DS, generally demonstrate an increase in their best-corrected vision following surgery, as the retinal image is no longer minified by the spectacle lens

Contact Lenses

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Contact lenses wearers often prefer the quality of vision they achieve with lenses compared to spectacles due to the improved peripheral field of vision (Ford and Stone, 1997). In addition, contact lenses reduce the image minification caused by spectacles in more short-sighted individuals. Contact lenses are less likely to be dislodged in a struggle than spectacles (Wells *et al.*, 1997), however they are not without their problems. The Canadian Mounted Police considered accepting individuals who required a refractive correction to attain functional vision as long as they were successful contact lens wearers. They showed that contact lenses fog or are dislodged less frequently than spectacles (21%), but 35% of wearers were forced to wear their spectacles for an average of 3.14 days out of a two year period, due to lens intolerance/discomfort (Wells *et al.*, 1997). The permanent discontinuation of contact lenses has been reported in 5% of contact lens wearers (Keech *et al.*, 1996), associated with complications, dry eyes, age or a lack of motivation.

Forward light scatter reduces the contrast of the retinal image and in extreme circumstances causes glare problems. In addition, some individuals experience an increase in the optical aberrations of the eye when wearing contact lenses, further reducing retinal image contrast (Atchison, 1995). A reduction in retinal image contrast does not affected high contrast acuity (Snellen) except in extreme cases, but does reduce the visibility of medium and low contrast targets, possibly taking them below the discrimination threshold. There is evidence of a reduction in both low contrast acuity and contrast sensitivity in contact lens wearers (Hess and Carney, 1979; Woo and Hess, 1979; Lohmann *et al.*, 1993; Briggs, 1998). Although clinically important, the significance of these findings for "real-world" visual performance is difficult to predict. Many rigid lens wearers report flare and halos (bright annulus in periphery of vision) when driving at night, due to a mismatch between the pupil and optic zone of the lens. This is not particularly debilitating and most wearers are well adapted to such effects. The quality of vision with rigid lenses is generally better than with soft lenses but they are not as comfortable.

During the last couple of years, extended wear contact lenses have made a return to the market place. Serious corneal infections occurred in the past when standard soft lenses were worn on an extended wear basis (Zantos and Holden, 1978; Adams *et al.*, 1983). The new lenses are made from silicone hydrogel materials, allowing significantly more oxygen to reach the cornea. Initial studies suggest that these lenses are a very promising modality although other complications associated with continuous wear have not necessarily been solved, such as acute red eye associated with trapped debris behind the lens (Zantos and Holden, 1978).

Temporary or permanent discontinuation of soft lenses at some point over a 3.5 year period was reported in 27% of cases (Cunha *et al.*, 1987). However, lenses have developed significantly since this study was undertaken, resulting in a reduction in the complication rate. There is no guarantee that an individual will always be able to wear contact lenses, making it difficult to recruit individuals in to a profession on the assumption that their poor unaided vision will be corrected by contact lenses throughout their career

The most common reasons for cessation of wear are ocular complications resulting from over wear such as corneal neovascularisation, contact lens associated papillary conjunctivitis (soft lenses), or chronic discomfort (particularly with rigid lenses). Poor hygiene greatly increases the risk of contact lens induced bacterial keratitis or acathamoeba keratitis (Radford *et al.*, 1995; Radford *et al.*, 1994) and unfortunately compliance is not always good (Radford *et al.*, 1993).

Many contact lens wearers suffer from discomfort in the presence of certain environmental conditions such as a dry atmosphere/air conditioning (North, 1993; Gasson and Morris, 1998). Such conditions reduce tear quality, causing drying of the contact lens and anterior ocular surface. Both soft and rigid lenses are affected by this problem, which may lead to symptoms of asthenopia (eye-strain), frontal headache, and reduced visual quality due to poor wetting of the lens surface. Rigid lenses can cause temporary disability if small particles such as dust, become trapped beneath the lens, resulting in excessive lacrimation and discomfort (Gasson and Morris, 1998; Stone, 1997). Nowadays the majority of patients are fitted with disposable soft lenses but such lenses are poor at correcting small degrees of astigmatism. The quality of the vision will depend on the hydration of the lens material, the level of fatigue of the wearer and their sensitivity to blur.

Most contact lens materials are not designed to be worn for more than 12-14 hours a day and are certainly not suitable for patients to sleep in. Reduced oxygen results in corneal swelling which is known to cause an increase in scattered light within the eye and hence a reduction in visual quality. This effect occurs on top of the increase in scattered light noted in contact lens wearers even without significant corneal swelling, (Lohmann *et al.*, 1993; Hennelly *et al.*, 1997; Woodward, 1996), which has been attributed to chronic microscopic tissue changes. In addition, some individuals require significantly more oxygen than the average patient, resulting in more severe tissue changes. This may only be discovered if the patient is examined towards the end of a full day of contact lens wear.

Research indicates that the quality of vision when wearing contact lenses may be slightly reduced compared to spectacles. There is overwhelming evidence that contact lenses do in some way increase forward light scatter (Bergevin and MILLODOT, 1967; Elliott *et al.*, 1991; Applegate and Wolf, 1987; Lohmann *et al.*, 1993; Barbur *et al.*, 1993) whether through lens deposition (Olsson *et al.*, 1979) or microscopic changes in the corneal structure. Lens wear can cause a degree of corneal oedema if the transmissibility of the lens material is poor (Woodward, 1996), they are worn for too long or the patient's cornea has a particularly high oxygen demand, although no evidence of corneal swelling was detected in eyes showing raised light scatter following contact lens wear in one study (Woodward, 1996). Elliott and colleagues detected slightly more intraocular scatter in rigid contact lens wearers than soft lens wearers (Elliott *et al.*, 1991). The increase in forward light scatter appeared to be associated with the material or design of the rigid lenses, whereas the soft lenses increased scatter by inducing physiological changes such as corneal oedema. The results were highly variable, indicating that increased intraocular light scatter is not significant for all lens wearers.