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The optometric management of childhood myopia: a review of the evidence

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Abstract

The optometric management of myopia has traditionally involved prescribing concave spectacle lenses or contact lenses to mitigate the blurred distance vision caused by 'short sight'. However, these traditional optical corrections do not actively address or retard the progressive element of myopia which has been identified as a long-term ocular health concern. Given the increasing prevalence of myopia across the world,[1] including in the UK,[2] researchers have been concentrating on addressing this public health concern by exploring methods to prevent myopia onset and to slow myopia progression. Myopia management strategies aim to reduce myopia onset and progression, minimising the long-term risk of developing myopia-associated ocular pathology, instead of merely correcting myopic defocus. The present article discusses risk factors for myopia development, methods for predicting myopia progression and reviews the available optometric myopia management options for practitioners in the UK following recent publications of global and national guidance.[3] Present-day research is discussed along with possible future interventions for myopia management in the UK.

Introduction

Myopia has become a global concern. Recent projections estimate that 50% of the global population will be myopic by 2050 (Figure 1).[1] This equates to roughly five billion people worldwide. Myopia prevalence varies geographically and in some parts of the world has been likened to an epidemic affecting large proportions of the population. For example, in Hong Kong, 18.3% of 6-year-old children are myopic and 0.7% are highly myopic (<–6.00 D); by the age of 12 these figures reach 61.5% and 3.8%, respectively.[4] In Korea, 96.5% of 19-year-olds are myopic[5] and in Shanghai, China, 95.5% of university students are myopic.[6]

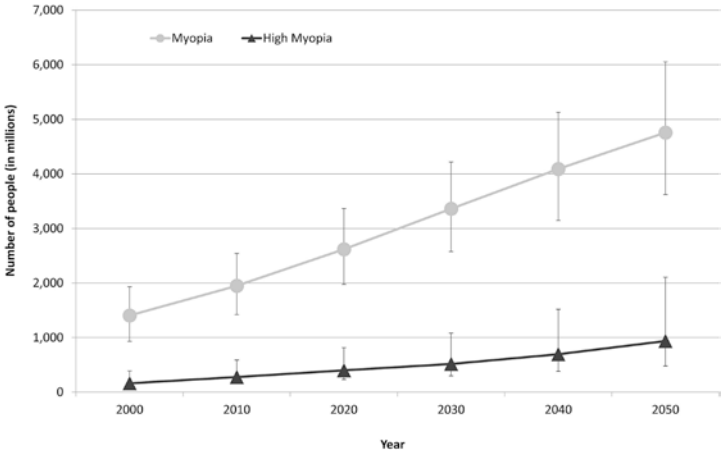

Figure 1. Graph showing the number of people estimated to have myopia and high myopia for each decade from 2000 to 2050. Error bars represent the 95% confidence intervals. (Reproduced from Holden et al. (2016),[1] with permission.)

In the UK, the amount of people affected by myopia is relatively small compared to Eastern Asia; however, research has shown that UK myopia prevalence is rising. The Northern Ireland Childhood Errors of Refraction (NICER) study is the largest study in the UK to examine how children's cycloplegic refractive error changes through childhood and adolescence. Relating contemporary refractive error data with comparable data published in the 1960s,[7] the NICER study demonstrated that the prevalence of myopia in UK teenagers has more than doubled in the previous 50 years – from 7.2% in the 1950s to 16.4% in the first decade of the 21st century.[2,7,8] Myopia was also found to be occurring at a younger age than previously recorded.[2] This is of concern due to the progressive nature of myopia: the younger myopia begins, the greater potential for ocular growth and therefore associated pathology. The rising prevalence of myopia has been recognised as a global concern by the World Health Organization (WHO)[9] and is featured as a research priority by many funding bodies.

It has long been recognised that individuals with high myopia (>–6.00D) are at risk of myopia-associated pathology including potentially blinding conditions such as macular degeneration, glaucoma, cataract and retinal detachment.[10] However, Flitcroft (2012) demonstrated that even individuals with relatively low levels of myopia (–1.00 to –6.00 DS) have significantly increased risks of developing ocular disease (Table 1).[11] In a unique analysis, Flitcroft compared the risk of ocular disease associated with myopia with the risk of cardiovascular disease associated with hypertension and smoking. Low levels of myopia (–1.00 to –6.00 DS), traditionally referred to as 'physiological myopia',

	Glaucoma	PSC cataract	Retinal detachment	Myopic maculopathy
Increasing dioptres of myopia	**2.3** –1.00 to –3.00 D	**2.1** –1.00 to –3.50 D	**3.1** –0.75 to –2.75 D	**2.2** –1.00 to –2.99 D
	3.3 < –3.00 D	**3.1** –3.50 to –6.00 D	**9.0** –3.00 to –5.75 D	**9.7** –3.00 to –4.99 D
		5.5 < –6.00 D	**21.5** –6.00 to –8.75 D	**40.6** –5.00 to –6.99 D
			44.2 –9.00 to –14.75 D	**126.8** –7.00 to –8.99 D
			88.2 ≤ –15.00 D	**348.6** ≤ –9.00 D

Table 1. The odds of glaucoma, posterior subcapsular (PSC) cataract, retinal detachment and myopic maculopathy occurring in individuals with increasing dioptres (D) of myopia, compared to those without myopia, as shown by odds ratio values summarised from Flitcroft (2012)[11]

were found to be a high-risk factor for ocular disease, comparable to the risk hypertension has for cardiovascular disease. The risk of glaucoma or cataract in myopic individuals was similar to the risk of stroke from smoking >20 cigarettes per day, and the risk of retinal detachment or maculopathy was in excess of any documented risk factor for cardiovascular disease. This fascinating analogy is relevant to optometrists relaying the importance of myopia management to patients, parents and the wider public.

Recent guidelines and consensus on myopia management

In 2018, the College of Optometrists undertook an inaugural collaborative, interprofessional exercise to produce myopia management guidance for UK optometrists. The resultant College guidance (published in 2019) articulates that, while there was, at time of publication, insufficient evidence to support the widespread roll-out of myopia control strategies in the UK, practitioners who already offer myopia management can continue to do so safely and ethically, so long as sector guidance is adhered to. This advice will likely be re-evaluated as evidence for myopia management strategies in UK populations accumulates. Full guidance can be found on the College website (www.college-optometrists.org).

Concurrently, the International Myopia Institute (IMI) published a comprehensive series of open-access 'white papers' generating consensus covering myopia definitions and classifications, experimental models, interventions, clinical trials and instrumentation, industry guidelines and ethics, clinical management and genetics (www.myopiainstitute.org). The clinical myopia management guidelines paper provides advice and information for clinical practice.[12] It details evidence-based management of the pre-myope, stable myope and progressing myope, including risk factor identification, examination, selection of treatment strategies and guidelines for ongoing management.

Assessing risk factors for myopia development and progression

In clinical practice it is important to be able to identify individuals at risk of developing myopia.[13] Known risk factors include patient age, refractive error, recent eye growth, parental myopia, ethnicity, visual environment, education and binocular function. These quantifiable risk factors prompted the IMI to format a definition for 'pre-myopia'. This definition aims to help practitioners identify non-myopic children who have the greatest risk of myopia development:

> *Pre-myopia – a refractive state of an eye of ≤+0.75 D and >–0.50 D in children where a combination of baseline refraction, age, and other quantifiable risk factors provide a sufficient likelihood of the future development of myopia to merit preventative interventions*[14]

The IMI note that this definition relates to refractive state when accommodation is relaxed, and do not clarify what age they consider 'children' in their definition (see below for more age-specific values related to refractive error). Optometrists in primary care settings are clearly in a good position to identify individuals at risk of myopia. Individuals with pre-myopia may benefit from behavioural advice, discussed later, and should be monitored closely (annually or biannually) for myopia onset.

Age, refractive error, ocular biometry and rate of recent eye growth

In the UK, myopia is most likely to occur between 6 and 13 years of age.[2] Young infants with relatively high levels of myopia should be investigated for possible syndromic links to their refractive error. Low levels of hyperopia indicate a high risk for future myopia development and this 'at-risk' level of hyperopia reduces as children grow older. For example, a cycloplegic autorefraction of +0.75 D or less in a 6-year-old, ≤+0.50 in a 7–8-year-old, ≤+0.25 in a 9–10-year-old and emmetropia in an 11-year-old have all been associated with a high risk for future myopia development.[13] Where axial length data are available, rate of recent eye growth can also be informative in identifying children likely to develop myopia. Axial length naturally increases throughout childhood. However, this normal expansion is typically counteracted by compensatory changes in the refractive components of the eye to maintain emmetropia, i.e. the lens thins and the cornea flattens. Myopia results when axial growth is no longer compensated by changes in refractive components. Longitudinal data collected between 1995 and 2003 demonstrated that axial length of future myopes was significantly longer 3 years prior to the onset of myopia compared to children who maintained emmetropia. These valuable data also illustrated that the fastest rate of eye growth occurs in the year prior to myopia development.[15] To determine 'normal' eye growth patterns in childhood, a European study evaluated longitudinal axial length data between the ages of 6 and 9 years old. Researchers reported an overall average increase in axial length of 0.21 mm/year between these ages, with myopic children showing faster growth rates than emmetropes or hyperopes. The average axial length at 6 years of age was 22.36 mm and, where axial length exceeded 24 mm at 6 years of age, 73% of boys (and a higher percentage of girls) were myopic by 9 years of age.[16] A similar relationship was found in data from UK children.[17]

Parental myopia and ethnicity

UK children who have one myopic parent are almost three times more likely to be myopic by age 13 than a child with no myopic parents.[2] This risk increases to over seven times more likely when both parents are myopic.[18] Rudnicka et al. (2010) examined a multiethnic sample of British children aged 10–11 years old and found myopia prevalence to be 25.2%, 10.0% and 3.4% in South Asian, black African Caribbean and white European children, respectively. Adjusted odds ratios showed that South Asian children were 8.9 times more likely, and black African Caribbean children were 3.2 times more likely, to be myopic compared to white European peers.[19] An appreciation of these non-modifiable risk factors for myopia development, in terms of ethnicity and family history of myopia, should be considered by optometrists alongside modifiable risk factors, discussed below.

Visual environment: time spent outdoors and in near-vision activities

It is broadly accepted that genetics cannot exclusively explain the rapid global rise in myopia prevalence. Environmental factors must play a role, and there is ongoing debate whether gene inheritance in isolation results in myopia, or whether gene inheritance increases an individual's susceptibility to myopia-promoting environments.[20] Such myopia-promoting environments are often shaped by myopic parents. For example, research has shown that Australian children of myopic parents spend less time outdoors and more time reading than children of emmetropic parents.[21] This indicates that myopic parents may promote the myopiagenic environments that their children experience, as spending both less time outdoors and more time in near-vision tasks have been associated with increased risk of myopia.[22] A systematic review and meta-analysis evaluated children's near-work habits and refractive error in 10,384 participants; results suggested that more time spent on near-work activities was associated with a rather modest, but statistically significant, 1.14× higher risk of myopia.[23] Spending more time outdoors has also been associated with delaying the onset, but not yet the progression, of childhood myopia.[22] The protective effects of spending more time outdoors are apparent even if the child partakes in high levels of near work. Rose et al. (2008) examined 1,765 6-year-olds and 2,367 12-year-olds in the Sydney Myopia Study and found that higher levels of total time spent outdoors, gauged through questionnaires, were associated with fewer myopic refractions after taking the amount of time spent doing near work, parental myopia and ethnicity into account.[21] Children with low outdoor and high near-work activity were 2.6× more likely to be myopic compared to children with high levels of outdoor activity and low levels of near work (adjusted odds ratio of 2.6; 95% confidence interval 1.2–6) (Figure 2). The mechanism by which spending more time outdoors is protective against the onset of myopia has not yet been established. Possible explanations include greater exposure to high levels of light intensity,[24,25] short-wavelength light (360–400 nm) and ultraviolet light.[26,27]

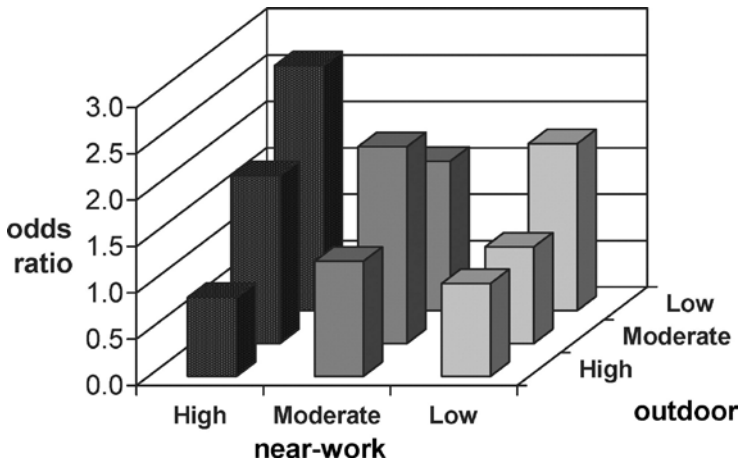

Figure 2. Multivariable-adjusted odds ratios (adjusted for gender, ethnicity, parental myopia, parental employment and education) for myopia by reported average daily hours spent on near work versus outdoor activities in 12-year-olds. Activities were divided into tertiles of high, moderate and low levels of activity. The group with high levels of outdoor activity and low levels of near work is the reference group. (Reproduced from Rose et al. (2008), [21] with permission.)

Outdoor environments also present a more uniform dioptric 'diet' for the visual system when compared with indoor environments.[11] Further, as yet unidentified, mechanisms could also be implicated.

Education

Spending more years in education has also been linked to an increased risk of myopia. The impact of education is difficult to evaluate in isolation from other risk factors such as less time spent outdoors and increased near work – factors which are likely interlinked. A UK Biobank study explored 44 genetic variants associated with myopia and 69 genetic variants associated with years of schooling in 67,798 men and women, aged 40–69 years, and found that each additional year of education was associated with 0.27 D more myopia.[28] Attending an academically selected school is also associated with a significantly increased risk of myopia in UK and Australian children.[18,29]

Binocular function

Reduced accommodative facility[30] and higher levels of esophoria, accommodative lag[31,32] and accommodative convergence to accommodation (AC/A) ratios[33,34] have been reported in myopes compared to emmetropes. However, it is unclear whether these observations are causative or a feature of myopia.[12] Lag in accommodation induces hyperopic defocus during near work, where the image is focused behind the retina, and has been postulated to encourage axial elongation. Similarly, other binocular vision anomalies may promote myopia progression and research suggests that the efficacy of myopia management strategies may be influenced by binocular status[35]; further work in this area may help practitioners to stratify management options in the future. In the meantime, binocular status should be explored before starting myopia management and reassessed following intervention to ensure binocular fusion is maintained.

Predicting myopia progression

Myopia progression is typically more rapid in younger individuals, those with higher baseline myopia and those who have experienced >0.50 D myopia progression in the previous year.[36-38] Myopia also seems to progress more rapidly in winter than in summer months.[39] However, progression is difficult to predict on an individual basis. Having the ability to estimate progression would be beneficial when counselling myopic individuals about their likely end-point refractive error and determining which patients would benefit most from intervention. The Brien Holden Vision Institute (BHVI) myopia calculator is a web-based tool which uses peer-reviewed data[40] to

estimate likely myopia progression based on ethnicity (Caucasian or Asian), age (6–16 years old) and presenting refractive error (–0.50 to –5.00 D) (https://calculator.brienholdenvision.org). The BHVI calculator also allows users to compare the predicted progression trajectory with the anticipated refractive outcome when different myopia management strategies are applied. This online calculator provides easy-to-interpret graphics to illustrate to parents and patients what they may expect with and without intervention. Outputs should be interpreted with caution as the data used by the myopia calculator are derived from the control arms of intervention trials in the USA and may not be entirely applicable to clinical populations living in the UK.[41] In addition, predicted progression trajectories are extrapolated from the efficacy of relatively short intervention trials. Intervention studies generally show greatest myopia control efficacy in the first year of treatment with reducing efficacy in subsequent years of treatment.

Myopia management options available to UK optometrists

Years of research involving different species have improved our understanding of the role of visual experience and feedback mechanisms in influencing eye growth, including the excessive axial growth that is usually associated with myopia. The majority of animal species studied can be encouraged to develop myopia in response to visual form deprivation, are able to regulate axial length when hyperopic (negative lenses) or myopic (positive lenses) defocus is optically imposed and can also recover from these induced refractive errors when optical defocus or form deprivation interventions are removed.[42] It is clear from these animal studies that the retina is able to detect the sign of image defocus, allowing the growth and refractive status of the eye to be manipulated by imposing retinal defocus. Hyperopic defocus focuses light behind the retina and promotes axial growth (myopia) and, conversely, myopic defocus focuses light in front of the retina and encourages retardation of axial elongation (hyperopia). Initially discovered in animal models and more recently identified in humans, manipulation of peripheral retinal defocus whilst providing clear axial focus results in similar growth-regulating responses.[43] This finding has encouraged the development of various optical intervention strategies for myopic eye growth, which will be discussed in the next section.

When considering myopia management, it is important to appreciate that current strategies aim either to reduce the risk of myopia onset or to limit the progression of myopia, as opposed to removing the risk of myopia onset or halting progression entirely. It is also important to consider that the efficacy of myopia management strategies varies significantly from one individual to another, and across research studies. This is especially true when percentage efficacy is considered rather than the cumulative absolute reduction in axial length, which has been shown to be more comparable across studies.

The best evidence available for the impact of a particular treatment comes from randomised controlled trials where individuals and researchers are masked with regard to whether individual participants are on the treatment under test or a 'placebo'. This approach is easier for some potential myopia control strategies than for others. 'Headline' outcomes, from studies evaluating the efficacy of myopia control strategies, generally relate to the average effect seen in the treated group, compared to the untreated group. However, individual responses to the treatment often vary widely from the average. The potential for treatments to have less than average or greater than average effects should be acknowledged and explained to patients and parents. Individual variation is not well understood but is a strong indication for regular follow-up and practitioners should be receptive to discontinuing strategies that are not impactful and exploring other management options.

A further limitation in the research evidence base is the lack of long-term studies evidencing prolonged benefits or, conversely, the risks of different myopia management strategies. There are also limited data illustrating whether rebound effects are likely, i.e. whether once myopia control interventions are ceased, myopic eye growth (and refractive error) accelerates unacceptably. With these limitations acknowledged, optical and pharmacological myopia management strategies have demonstrated the capacity to slow myopia progression by up to 60%, and furthermore, simply encouraging children to spend more time outdoors can reduce the risk of myopia onset. In the following paragraphs we will briefly review myopia management options currently available to optometrists in the UK.

Behavioural modifications

Increasing the amount of time spent outdoors is simple modification to behaviour which UK optometrists can encourage, especially for those at risk of myopia development. Studies examining school-aged children suggest 8–15 hours of outdoors activity per week may mediate against the onset of myopia.[44-46] However, a caveat to spending more time outdoors is the consideration of the known harmful effects of lifelong ultraviolet exposure. While there are legitimate concerns with respect to myopia-related ocular disease, the risk of skin melanoma, especially in countries with high ultraviolet index, should be acknowledged. The timing of outdoor exposure may also become an important consideration when providing advice for families (see section on sleep and circadian rhythms, below). Further research is required to refine the messages eye care professionals relay to parents and patients in the UK.

Reading at close distances (<20 cm) and reading continuously for more than 45 minutes have both been associated with a higher risk of myopia in Chinese children.[47] It is currently unclear if this relationship exists in non-Chinese children, but it may be appropriate to discourage children at risk for myopia from using truncated reading distances and undertaking prolonged periods of near work without a break. No specific causal link has been established to date between screen use and myopia development or progression; however parents are often concerned about the potential impact of these devices on visual health and general well-being. Practitioners can refer to recent WHO guidelines when discussing screen use with parents of young children (https://apps.who.int). The WHO reports that sedentary screen time is not recommended for children

under the age of 2 years, that children aged 2–4 year olds should spend no more than 1 hour in sedentary screen time, and that less screen time is generally better. Excessive screen time has been negatively associated with diet, physical activity, sleep and behaviour; therefore, adherence to these guidelines may provide a host of health benefits. The 20-20-20 rule, commonly prescribed for digital eye strain, can also be recommended to children who partake in intense near work. Every 20 minutes the child should be advised to take a 20-second break to focus on something at least 20 foot in the distance (or as far away as possible).

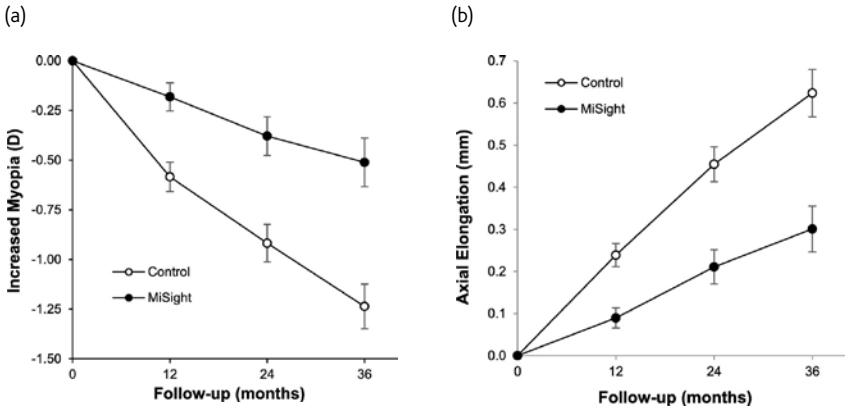

Figure 3. Mean unadjusted changes in (a) spherical equivalent refractive error (D) and (b) axial elongation (mm) for the test (MiSight) and control (Proclear 1-Day) study groups. The filled and open symbols represent the MiSight and control groups, respectively, for the 36-month study period. The error bars denote the 95% confidence interval of the mean changes. The mean unadjusted differences were 0.40 D less with MiSight at 12 months, 0.54 D less at 24 months and 0.73 D less at 36 months. (Reproduced from Chamberlain et al. (2019),[56] with permission.)

Single-vision lenses

Despite the fact that single-vision spectacles do not actively control myopia progression, they remain the most commonly prescribed form of myopia correction in the UK. Studies evaluating the efficacy of undercorrection of myopia in reducing the rate of progression have not been promising, either demonstrating no effect on myopia progression[48] or identifying an increasing rate of myopia progression when undercorrection is utilised.[49,50] Neither of these outcomes is favourable when considered in combination with the sacrifice of optimum distance visual acuity. Given the potential acceleration of myopia progression with undercorrection and the associated suboptimal distance vision, it is currently considered best practice to prescribe the full myopic prescription and advocate full-time wear to maximise acuity when prescribing single-vision distance spectacles. The same is true for single-vision contact lenses; however, given the development of licensed multifocal contact lenses for myopia control and their proven efficacy, discussed below, myopia control lenses should be the first recommendation for progressing myopes interested in/already wearing contact lenses.

Multifocal soft contact lenses

Multifocal soft contact lenses (MFSCLs) have been shown to reduce the rate of myopia progression. This is likely due to the induced peripheral myopic defocus which, as discussed previously, discourages axial elongation. Reported efficacy of MFSCLs varies across studies where different lens designs and wear modalities are utilised; however, efficacy usually ranges between 30% and 60% reduction in progression rate compared to control groups.[51-55] Typically, lenses with a central correction zone for clear distance vision (centre-distance) and concentric peripheral positive addition (i.e. myopic defocus treatment zone) show the best efficacy for myopia control. Specialised lenses, such as CooperVision's MiSight 1-Day and VTi NaturalVue Multifocal 1-Day, have been specifically licensed for myopia control in the UK. Fitting of alternative presbyopic MFSCLs, which are not CE-marked for myopia control, would be considered 'off-label'. A recent 3-year double-masked, randomised, clinical trial demonstrated 59% less myopic progression and 52% less axial elongation in 8–12-year-old children wearing MiSight 1-Day, compared to those wearing Proclear 1-Day lenses on the same wearing schedule (Figure 3). Average wearing schedule for the MiSight group was 13.7 hours per weekday, 12.1 hours per weekend day and 6.5 days per week.[56]

Wearing schedule is an important factor when prescribing MFSCLs. Lenses will only have a treatment effect when being worn for a large portion of the day, therefore, parents and patients need to be content with the intensive wearing schedule. Whilst MFSCLs provide peripheral myopic defocus treatment in all directions of gaze, and provide a larger myopia control effect than multifocal spectacle lenses, contact lens wear is associated with complications, the most significant of which (microbial keratitis) can, in a small number of cases, result in visual impairment. Age is a significant non-linear risk factor for contact lens-related complications. Individuals aged 15–25 years old have the highest risk for corneal infiltrative and inflammatory events. Younger individuals aged 8–15 years have a lower risk compared to older teens and adults.[57] A change from standard contact lenses to a contact lens designed for myopia control is unlikely to pose an additional risk of complication. However, consideration should be given to wearing schedule: a longer wear time for best myopia control effects will impose a higher risk of adverse events and this should be fully discussed with prospective wearers.

Orthokeratology

Orthokeratology (OK) exploits reverse-geometry rigid gas-permeable contact lenses worn overnight to remodel the anterior corneal surface. Remodelling temporarily reduces myopic refractions, allowing those with low to moderate myopia to forgo daytime spectacle wear, and induces peripheral myopic defocus which is believed to reduce myopia progression. Longitudinal studies and clinical trials have demonstrated that children fitted with OK lenses have reduced myopia progression and axial elongation compared to children wearing daytime spectacles or soft contact lenses.[58-60] In cases of high myopia, 'partial' OK may be used to reduce the required 'daytime' refractive correction for clear distance vision. OK therefore defers a dual benefit – reducing myopic refractions during the day and slowing myopia progression. For maximum myopia control and optimum daytime

vision, lenses should be worn every night for a minimum of 8 hours. The safety of overnight OK lens wear in children over a 10-year wearing period is comparable to the safety and risk associated with soft contact lens wear over the same period.[61] Myopia control effects have been demonstrated for up to 10 years of lens wear[60-62]; however, discontinuation of OK lenses after 2 years of wear has been shown to result in a rapid increase in axial elongation in children aged 8–14 years old.[63] This reiterates that the possibility of post-treatment 'rebound' should be considered and discussed with parents before commencing myopia management strategies.

Bifocal and progressive spectacles

Bifocal and progressive addition spectacle lenses were first prescribed to non-presbyopic patients as a means of reducing accommodative lag during near work, and were subsequently reported to have myopia control effects. However, it is not clear exactly how these lenses function to reduce myopia progression. Possible explanations include reducing accommodative demand, reducing lag of accommodation and/or inducing myopic defocus to the superior retina when viewing distance. In addition, the literature records a wide range of treatment effects. Cheng et al. (2011) reviewed evidence investigating myopia control properties of bifocal and progressive lenses and concluded that bifocal and progressive lenses can limit myopic progression in rapidly progressing individuals with near esophoria and/or high lags of accommodation.[35] It was hypothesised that the variability in the myopia control effect was due to the lack of personalised treatment options provided within research studies, i.e. that most studies used the same near-addition power for all children despite differences in binocular status. However, a further study by Cheng et al. (2014) reported that the positive treatment effect of executive bifocals and executive prismatic bifocals was independent of near phoria status. The 3-year trial reported 0.81 D and 1.05 D less myopia progression in children aged 8–13 years who wore executive bifocals and executive prismatic bifocals (6ΔBI) respectively, compared to those wearing single-vision lenses. This was regardless of the near phoria status.[64] Practitioners who prescribe bifocal or progressive lenses to myopic children in clinical practice as a myopia control intervention should also consider visual comfort, cost, aesthetics, compliance, add accessibility, i.e. fitting height and progressive lens design (fitting height should be higher than normally chosen for presbyopic patients and a short-corridor progressive lens design chosen) and appropriate frame selection, especially for young children with underdeveloped bridges.

Potential future therapies and antimyopia strategies

Novel spectacle lens designs

An exciting spectacle design for myopia control has recently been released on the Hong Kong and Chinese market. Hoya's MyoSmart spectacle lens was designed with Defocus Incorporated Multiple Segments (DIMS) technology in partnership with the Hong Kong Polytechnic University. The DIMS lens consists of a central optical zone for correcting distance refractive error surrounded by a region containing a multitude of tiny +3.50 D 'lenslets' which provide constant myopic defocus extending to the lens mid-periphery (Figure 4). A 2-year double-masked randomised controlled trial of 160 Chinese children aged 8–13 years found 59% less myopia progression and 60% less axial elongation in children wearing DIMS lenses compared with those wearing the single-vision lenses. In addition, 21.5% of children who wore DIMS lenses demonstrated no myopia progression over 2 years, compared to 7.4% of children wearing single-vision lenses.[65] Novel spectacle lens designs are expected to become available on the European market, provided trials on European children demonstrate efficacy.

Atropine

Prolonged daily atropine eye drops (of varying concentrations: 1.0%, 0.5%, 0.05%, 0.025%, 0.01%) are extensively prescribed 'off-label' for myopia management in Asia due to their high efficacy for myopia control (Figure 5). In contrast to original belief, atropine does not function through an accommodative mechanism. Rather, it is currently thought that atropine exerts its myopia control properties via a neurochemical cascade within the retina, although the exact mechanism remains unclear. Evidence demonstrates a dose-dependent efficacy for myopia control, where higher concentrations of atropine reduce myopia progression the most (Figure 6). However, increasing the concentration of atropine also increases side effects and shows greater rebound effects when treatment is stopped.[66-68] Potential side effects of atropine instillation include temporary discomfort and blurred near vision and photophobia due to the accompanying cycloplegia and mydriasis. Atropine eye drops are typically instilled before bed to reduce daytime side effects although, depending on the dose, residual daytime effects may still prove challenging in terms of daily school and home activities. Additional spectacles may be required to reduce symptoms of photophobia (i.e. tints) and to improve near visual acuity (i.e. reading addition) depending on the prescribed dose.

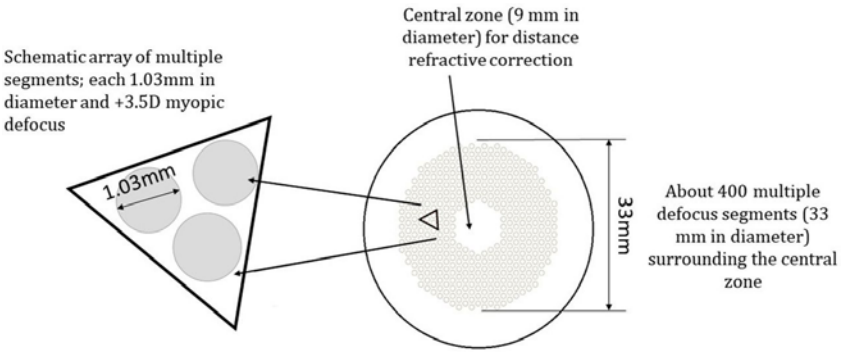

Figure 4. The design of the Defocus Incorporated Multiple Segments (DIMS) spectacle lens. (Reproduced from Lam et al. (2019),[65] with permission.)

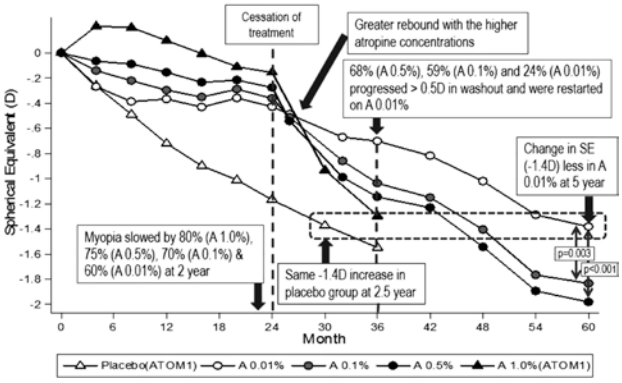

Figure 5. Summary of findings from the ATOM1 and ATOM2 studies: change in spherical equivalent (SE). ATOM, Atropine for the Treatment of Myopia; D, dioptre. (Reproduced from Chia et al. (2016),[66] with permission.)

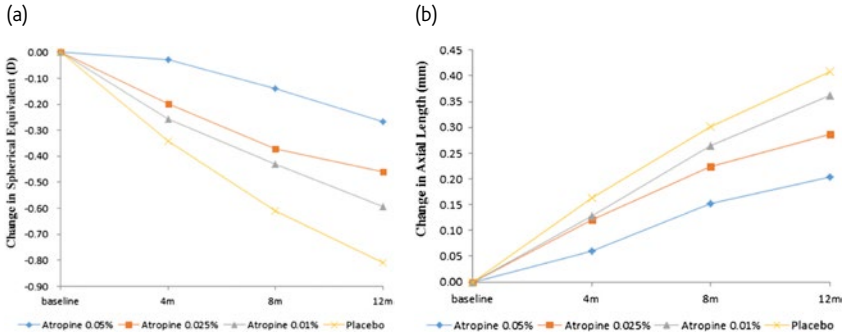

Figure 6. Change in (a) spherical equivalent (SE) and (b) axial length in treatment groups across time. D, dioptre; M, month. (Reproduced from Yam et al. (2018),[86] with permission.)

Evidence for atropine's efficacy and safety is almost exclusively drawn from studies investigating cohorts of Asian children. This has restricted the adoption of atropine treatment in western societies, with children of predominantly European ancestry, and currently atropine is not licensed for use as a myopia control agent in the UK. In addition, there is little consensus on how to stratify patients to a particular treatment dose, when to increase/reduce the treatment dose and when to cease treatment. Recent pilot studies have demonstrated the acceptability, short-term efficacy and the safety of low-dose atropine eye drops in European populations.[69,70] Several multisite randomised clinical trials are currently underway in the UK and Ireland to evaluate myopia progression, comfort, visual quality and safety in European children. Outcomes from the treatment phases of the trials will be available over the next 3–4 years and, depending on the findings, low-dose atropine may be added to the myopia management 'armoury' of optometrists in the UK in the not too distant future.

Sleep and circadian rhythms

Sleep and circadian/diurnal rhythms are emerging areas of interest in myopia research.[71] The human eye is known to demonstrate relatively robust diurnal rhythms in many ocular parameters, including significant diurnal variation in central corneal thickness, corneal power, lens thickness, vitreous chamber depth, axial length, retinal thickness, choroidal thickness and intraocular pressure.[72,73] Perhaps of most interest to myopia researchers is the diurnal variation seen in axial length and choroidal thickness (Figure 7): two parameters which typically differ significantly between myopic and non-myopic eyes – longer axial length and thinner choroid are characteristic features of the myopic eye. When monitored over a 24-hour period, axial length and choroidal thickness vary in antiphase; the choroid is normally thickest at night and axial length longest during the day.

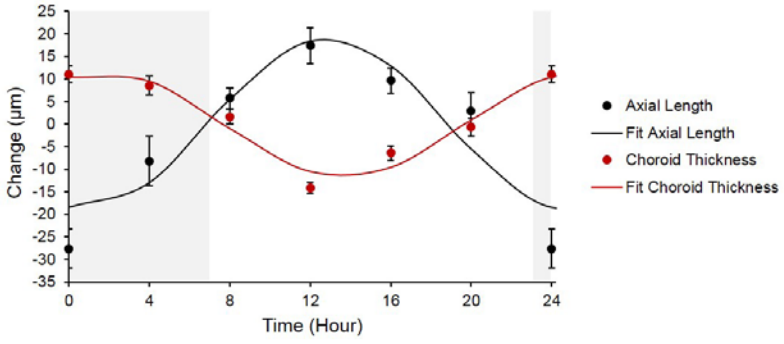

Figure 7. Mean (± standard error) 24-hour change in axial length (µm, black) and choroidal thickness (µm, red) for all subjects (n = 18); solid lines are cosinor fits to the data; grey areas represent the dark period. (Adapted with permission from Ostrin et al. (2019)[72].)

Animal research has demonstrated that manipulation of the timing, wavelength and intensity of light exposure and the sign (positive or negative) and timing of retinal defocus can disrupt these diurnal rhythms in choroidal thickness and axial length,[71] and similar patterns are being reported in the human eye.[74-76] Australian researchers demonstrated that daily morning light therapy, applying short-wavelength light (500 nm) at a relatively low intensity (approximately 500 lux), increases choroidal thickness and the amplitude of choroidal thickness variation over a 24-hour period.[76] Conversely bright light at night promotes choroidal thinning and reduces the magnitude of the diurnal variation in choroidal thickness.[77] Recent reports also identify that hyperopic defocus rapidly promotes choroidal thinning, at least in a transitory fashion,[78] but more potent to the human eye is the effect of myopic defocus which, particularly when applied in the evening,[79,80] promotes choroidal thickening. These experiments suggest that the eye's local diurnal rhythms are influenced by light (timing, intensity and spectral content) and the sign of retinal defocus, and each may impact singly or in combination on regulating ocular growth.

Additional evidence that refractive errors may, at least in part, arise from disturbances in circadian signals to the eye is provided by the recent study of Stone et al.[81] Stone et al.[81] demonstrated that knockout of circadian genes in the mouse retina and fruit fly (*Drosophila melanogaster*) produces myopic phenotypes. In humans, at a systemic level, serum levels of melatonin (which is considered a robust biomarker for circadian rhythm) have been shown to differ between myopes and non-myopes[82] and reduced sleep quality and quantity have been reported in myopic individuals compared to non-myopic peers.[83-85]

While these human data point to a relationship between the disruption of ocular and systemic circadian rhythms further prospective data are required to ascertain robustly whether these interactions influence eye growth and promote or inhibit the development of myopia. With more information, future therapies may aim to promote healthy sleep, circadian rhythm and ocular growth through behavioural interventions limiting evening light exposure and promoting daytime light exposure, and/or optical interventions which restrict short-wavelength exposure at night whilst allowing broad-spectrum light exposure throughout the day. Consideration of the timing of visual behaviours which promote hyperopic and myopic defocus may also be important.

Conclusion

There is a growing number of children at risk for myopia, partly as a consequence of modern lifestyles and environments. Research is focused on ensuring that the optometrists of the future have a range of strategies, treatments and advice from which they can tailor a bespoke, evidence-based management package for each child, designed either to delay or prevent the onset of myopia and slow its progression. This unfolding and dynamic clinical area offers exciting opportunities for primary care optometrists not only to detect and correct refractive deficits, but to play an active role in modifying refractive outcomes and improving long-term visual health and quality of life.

Summary

Myopia management strategies aim to reduce myopia onset and progression, minimising the long-term risk of developing myopia-associated ocular pathology, instead of merely correcting myopic defocus. Evidence demonstrates good efficacy for interventions that aim to reduce myopia progression. However, there are some limitations to consider. The present article discusses risk factors for myopia development and methods for predicting myopia progression and reviews the available optometric myopia management options for practitioners in the UK following recent publications of global and national guidance. Present-day research is discussed along with possible future interventions for myopia management in the UK.

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CET multiple choice questions

This article has been approved for one non-interactive point under the GOC's Enhanced CET Scheme. The reference and relevant competencies are stated at the head of the article. To gain your point visit the College's website www.college-optometrists.org and complete the multiple choice questions online. The deadline for completion is 31 January 2021. Please note that the answers that you will find online are not presented in the same order as in the questions below, to comply with GOC requirements.

1. What is the prevalence of myopia in UK teenagers, as determined by the NICER study?

- 16.4%
- 7.2%
- 96.5%
- 61.5%

2. How many times more likely is a –4.00 D myopic individual to have a retinal detachment in his or her lifetime compared to an individual without myopia?

- 3 times
- 15 times
- 9 times
- 60 times

3. How many times more likely to be myopic is a child with two myopic parents?

- 7
- 2
- 10
- 15

4. If prescribing single-vision spectacles to a progressing myope:

- The full myopic refraction should be prescribed
- Regular reviews should be organised
- Behavioural advice should be discussed
- All of the above

5. Which of the following would be considered good behavioural advice for children both with, and at risk of, myopia?

- Spend more time outdoors in sunlight (with adequate sun protection)
- Increase near working distance (to more than 20 cm)
- Reduce time spent in continuous near activities (advise 20-20-20 rule)
- All of the above

6. During a 3-year clinical trial, children wearing MiSight 1-Day contact lenses demonstrated ____ % less myopia progression compared to peers wearing Proclear 1-Day lenses:

- 59%
- 30%
- 100%
- 75%

CPD exercise

After reading this article, can you identify areas in which your knowledge of the optometric management of childhood myopia has been enhanced?

How do you feel you can use this knowledge to offer better patient advice?

Are there any areas you still feel you need to study and how might you do this?

Which areas outlined in the article would you benefit from reading in more depth, and why?