Optical Interventions for Myopia Control

Nicola S. Logan, [1] Mark A. Bullimore[2]

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[1] School of Optometry, Aston University, Birmingham, United Kingdom

[2] University of Houston, College of Optometry, Houston, Texas, USA

Corresponding Author: Mark Bullimore, 356 Ridgeview Lane, Boulder, CO 80302, bullers2020@gmail.com, 614-202-0299, no fax.

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Abstract

Objectives: A range of optical interventions have been developed to slow the progression of myopia. This review summarizes key studies and their outcomes.

Methods: Peer-reviewed, randomized controlled clinical trials of at least 18 months duration were identified.

Results: Randomized clinical trials were identified and summarised: 13 for spectacles, 5 for overnight orthokeratology, 5 for soft contact lenses, and 3 for orthokeratology combined with low concentration atropine. Overnight orthokeratology trials were the most consistent with 2-year slowing of axial elongation between 0.24 and 0.32 mm. Other modalities were more variable due to the wide range of optical designs. Among spectacle interventions, progressive addition lenses were the least effective, slowing axial elongation and myopia progression by no more than 0.11 mm and 0.31 D, respectively. In contrast, novel designs with peripheral lenslets slow 2-year elongation and progression by up to 0.35 mm and 0.80 D. Among soft contact lens interventions, medium add concentric bifocals slow 3-year elongation and progression by only 0.07 mm and 0.16 D, while a dual-focus design slows 3-year elongation and progression by 0.28 mm and 0.67 D.

Conclusions: All three optical interventions have the potential to significantly slow myopia progression. Quality of vision is largely unaffected, and safety is satisfactory. Areas of uncertainty include the potential for post-treatment acceleration of progression and the benefit of adding atropine to optical interventions.

Key words: soft contact lens, spectacles, orthokeratology, myopia, children, axial length

In this paper we discuss the use of optical interventions for myopia management, focussing on mechanisms of action, evidence for their efficacy and what we still need to learn. This review is intended primarily for clinicians and complements a review on atropine for myopia management.[1]

In the world of evidence-based medicine, randomised clinical trials are the highest level of evidence and thus only publications employing this approach are discussed in detail here. In studies of myopia control, there are other design features that are considered highly desirable, some of which are germane to trials in all disciplines:

- Refractive error and myopia progression are measured by cycloplegic autorefraction as this avoids accommodative artefacts, minimizes examiner bias and is the most repeatable approach.[2]
- Axial length is measured, preferably by partial coherence interferometry or optical coherence tomography (OCT), as axial elongation underlies myopia progression.[2] Cycloplegia may be desirable, but valid measures can be obtained without.[3] In studies of overnight orthokeratology, refractive error is confounded by the intended corneal flattening, so axial length is often the primary outcome measure. Although the ratio varies with age and refractive error,[4] 0.1 mm can be considered to be equivalent to 0.20 to 0.25 D.[5, 6]
- Masking of both examiners and patients, when possible.[2]
- Concurrent controls, matched by, or analysed accounting for age, ethnicity, and other factors. Comparing data before and after Intervention is unacceptable as it is prone to recruitment bias and any slowing may merely represent regression to the mean.[7, 8]
- Multiple years of data, as results in the first 6 or 12 months may not be borne out by longer term results.[9] For this reason we only include studies with at least 18 months of follow-up.

Neither conventional soft contact lenses[10, 11] nor conventionally fit rigid contact lenses[12, 13] affect myopia progression. Likewise, undercorrection with spectacle lenses has no benefit[14, 15] and likely accelerates progression,[16, 17] in spite of its use in some countries.

Mechanism and Theory of Action

Optical interventions to slow myopia progression have been based on a number of theories. An early prevailing theory was that excessive or prolonged accommodation caused myopia[18] and that it resulted from permanent increase in the thickness and curvature of the crystalline lens. The demonstration that the majority of myopia is axial in nature prompted refinements of this theory to include the influence of intraocular pressure or the action of the extraocular muscles. In the 1990s this

mechanical theory was largely supplanted by an adaptive hypothesis, based on the observation that young animals exposed to minus lenses and thus hyperopic defocus, develop myopia.[19] It was also observed that individuals underaccommodate when viewing near objects and that this accommodative lag is greater in myopic children.[20] In summary, the accommodative lag theory postulates that an error in accommodation at near is a potential driver for myopia progression. This reinvigorated the interest in controlling myopia with multifocal spectacles, although as discussed below, these have been shown to be mostly ineffective. The current prevailing hypothesis is that even in the presence of a clear foveal image, the amount and type of blur falling on the peripheral retina influences refractive development.[19] Important observations from the animal myopia literature include:

- The fovea is not necessary for normal or manipulated refractive development.[21]
- When the fovea and the periphery are exposed to conflicting optical defocus, the periphery dominates refractive development.[22]
- When the periphery is exposed to conflicting optical defocus, the more myopic signal dominates refractive development.[23]

These important findings in animal models of myopia have been supported by clinical trials in children demonstrating that the most effective myopia control modalities are those that expose the peripheral retina to myopic defocus.[24] These modalities are discussed in detail below.

Literature Search

In June 2023 a search of PubMed was conducted using the following terms: (myopia or myopic) and (child or children) and (progression or elongation) and (spectacles or contact lens or orthokeratology) and (randomized). The search identified 212 unique papers. These were reviewed and 178 rejected, predominantly for redundancy (44), review/meta-analysis (35), less than 18-months duration, and no optical intervention. The remaining 34 studies form the basis of this narrative review. Consistent with recommendation of Brennan et al., efficacy is reported in mm and, when possible, dioptres and not as percentages.[8]

Spectacles and Myopia Control

Myopia control with spectacles has a 60-year history, beginning with bifocals.[25] Unfortunately, there have been multiple false dawns regarding effective treatment options. For example, a non-randomised study reported that progressive addition spectacle lenses (PALs) slowed myopia by 0.50 D or more over two years.[26] Unfortunately, this was not borne out by many randomized clinical trials that, collectively, report on over 1,000 children (Table 1).[9, 27-30] The largest, the US-based

Correction of Myopia Evaluation Trial (COMET), found a 3-year reduction in progression of 0.20 D and slowing of axial elongation of 0.11 mm among PAL wearers compared to single vision wearers in US children. Virtually all the effect was observed in the first year. A corresponding 2-year trial in Hong Kong found no significant difference in in myopia progression (0.14 D) or axial elongation (0.02 mm) between PAL and single vision wearers.[27] Collectively, these clinical trials and others summarized in Table 1 show that PALs are a largely ineffectual myopia control modality.

Greater success has been reported for executive bifocals. Cheng et al. randomized 135 Chinese-Canadian children to single-vision lenses, +1.50 D executive bifocals, and +1.50 D executive bifocals with 3-Δ base-in prism in the near segment of each lens. [31] Mean 3-year myopia progression was –2.06, –1.25, and –1.01 D for single vision lenses, bifocals, and prism bifocals, respectively. The corresponding axial elongation was 0.82, 0.57, and 0.54 mm, respectively. Curiously, these findings contradict a previous clinical trial of 207 children, randomized to single vision lenses, +1.00 D add, or +2.00 D add executive bifocals for a period of three years.[32] Although only 124 US children completed the study, the mean progression was –0.34, –0.36 and –0.34 D per year for subjects wearing single vision lenses, +1.00 D add bifocals, and +2.00 D add bifocals, respectively.[32] Likewise, a clinical trial of 230 Finnish children randomized to single vision lenses for continuous use, single vision lenses for distant vision only, or +1.75 D add bifocals found no difference in 2-year myopia progression.[33] It is unclear why the most recent trial found such contrasting results to the earlier studies. A third clinical trial of flat-top bifocals found a small slowing of myopia progression (0.25 D) and axial elongation (0.09 mm) in children wearing bifocals compared with single vision lenses over 30-months.[34]

The aforementioned COMET Study[9] observed an apparent larger treatment effect of PALs in children with higher accommodative lag and with esophoria. This prompted COMET2, a clinical trial of PALs limited to myopic children with these characteristics.[35] Children were again randomized to receive either +2.00 D PALs or single vision lenses. The mean 3-year progression was –0.87 and –1.15 D in the PAL and single vision groups, respectively—a difference of 0.28 D that, like the original COMET study, was statistically significant but not clinically important. The study did not measure axial length. The Cheng et al. executive bifocal study discussed above reported that the treatment effect, both with and without prism was independent of the child's near phoria status but found a marginal interaction between accommodative lag and slowing of progression. The prismatic bifocal was more effective for children with lower lags, but equally effective as the regular bifocal for children with higher lags.[31] It is possible that any increased efficacy of executive bifocals compared with PALs is not attributable

to their influence on accommodation, but rather the fact that with the former, half of the visual field is exposed to the more positive power of the bifocal, whereas with the latter, the positive power is confined to a much smaller area.

Newer spectacle lens technology has since emerged with mixed success. Peripheral hyperopic defocus typically occurs when myopic children are corrected with single vision lenses. As described above, animal models suggest that this peripheral hyperopic defocus may drive myopia progression even in the presence of clear central vision and replacing it with myopic defocus could slow progression.[19] First, lenses designed to reduce peripheral hyperopic defocus—essentially concentric PALs—were evaluated.[36, 37] A pilot study randomized 210 Chinese children to three experimental lens designs or single vision lenses. [36] No differences were observed in the rates of progression with the novel designs compared to single vision lenses, although potential benefit was observed with one design in younger children with at least one myopic parent. This subgroup was subsequently evaluated using a design that was commercialized (MyoVision, Carl Zeiss).[37] The investigators randomized 207 myopic children aged 6 to 12 years with at least 1 myopic parent to single vision or MyoVision lenses. The mean 2-year progression and elongation in the treated group were no different from that in the control group (Table 1).

Greater success has since been reported with further novel spectacle lens designs. First, *Defocus Incorporated Multiple Segments* (DIMS) spectacle lenses[38] comprise a 9-mm central optical zone and a 33-mm annular zone with multiple 1-mm segments having a relative positive power of +3.50 D, thus making the lens appear to have multiple "dimples" in the periphery, although close inspection is required to see them. The developers randomized 183 myopic Chinese children to either DIMS or single vision lenses. Among the 160 children completing the 2-year study, the mean myopic progression was –0.41 D in the DIMS group and –0.85 D in the control group. Mean axial elongation was 0.21 and 0.55 mm in the DIMS and single vision groups, respectively. The lens is commercialized as MiYOSMART (Hoya).

A second effective design incorporates *highly aspherical lenslet* (HAL) technology.[39] The geometry of the aspheric lenslets (1.1 mm in diameter) generates a volume of myopic defocus from 1.2 to 1.9 mm in front of the peripheral retina. The contiguous lenslets are arranged in 11 concentric rings centred around a 9 mm-diameter clear central zone. The 1-year efficacy of the HAL lenses was compared to single vision lenses in a randomized clinical trial (54 children assigned to the HAL lenses group and 52 in the single vision group). The mean progression in the single vision group was –0.81 D,

while children wearing the HAL lenses progressed by only –0.27 D; a slowing of 0.54 D which was accompanied by a slowing of axial elongation of 0.21 mm. Interestingly, progression was faster in younger participants wearing single vision lenses, but age did not influence rate of progression in the HAL wearers. Two-year results confirm the high efficacy of the HAL lenses with slowing of progression by 0.80 D and axial elongation by 0.35 mm compared to single vision correction.[40] The efficacy beyond the first year of treatment is in contrast to the results with PALs.[9] Furthermore, full-time wearers of the HAL lenses (≥ 12 hours per day) showed lower myopia progression (–0.48 D vs. -0.93 D) than part-time wearers (< 12 hours per day). The lenses were well tolerated and their effects on vision are discussed in detail later in this paper. The Essilor Stellest lens is based on the same technology that as the HAL prototype. A different design with slightly aspherical lenslet (SAL) technology was shown to be less effective (Table 1). Finally, other novel, annular designs based on manipulation of retinal contrast are under investigation, with 1-year data published,[41] and additional years' finding presented at several meetings. All the above spectacle lens designs are available in Europe, but in the US, none are approved for slowing of myopia progression.

Overnight Orthokeratology

Overnight orthokeratology is the application of a rigid gas permeable contact lens with a base curve significantly flatter than the corneal curvature to temporarily reduce myopia. Reverse-geometry designs and highly gas permeable materials made this a viable and effective modality some 20 years ago, with night-time wear leading to good uncorrected visual acuity throughout the day.[42] Soon thereafter, reports of overnight orthokeratology for myopia control began to emerge.[43, 44] A number of subsequent non-randomized studies published broadly similar results (see Bullimore and Johnson[42] for a recent comprehensive review).

The first randomized clinical trial assigned 102 Hong Kong Chinese children to either overnight orthokeratology or spectacles (Table 2).[45] For the 78 patients completing the 2-year study, the mean axial elongation was 0.36 and 0.63 mm in the orthokeratology and control groups, respectively. The same group conducted a similar trial of partial reduction orthokeratology in high myopic children.[46] Fifty-two high myopic children with at least –5.75 D were randomly assigned into orthokeratology and control groups. The orthokeratology group were partially corrected by up to –4 D. Both groups had their refractive error or residual refractive error corrected with spectacles. The mean 2-year increase in axial length was 0.19 and 0.51 mm in the orthokeratology and control subjects, respectively. The group recently reported a 2-year randomized clinical trial where conventionally fitted orthokeratology lenses were compared to lenses fitted with a base curve 1 dioptre flatter (increased compression

factor).[47] An unacceptable number of the control group (63%) discontinued the trial, mainly due to concerns about myopia progression. Considering only the two orthokeratology groups, the mean axial elongation was 0.53 mm for those wearing conventional orthokeratology lenses and 0.35 mm for those wearing the increased compression factor. Another randomized clinical trial of Hong Kong Chinese children was recently conducted by a different group of investigators.[48] The mean 2-year axial elongation was 0.37 and 0.60 mm in the orthokeratology and control groups, respectively.

While early non-randomized studies suggest that overnight orthokeratology is effective in slowing axial elongation in children of European descent,[42] a recent randomised clinical trial has confirmed this.[49] Sixty Danish children with myopia between –0.50 and –4.75 D were randomly assigned to either overnight orthokeratology or single-vision spectacles: The 18-month follow-up was completed by 19 of the orthokeratology group and 28 of the spectacle group. Mean adjusted axial elongation was 0.17 and 0.41 mm in the orthokeratology and spectacle wearers, respectively—a difference of 0.24 mm (Table 2). Finally, a randomized clinical trial compared atropine, orthokeratology, and their combination in Chinese children.[50] The results of combination therapy are discussed below, but for the orthokeratology and control groups the mean 2-year axial elongation was 0.43 and 0.81 mm, respectively.

Meta-analysis of the efficacy of orthokeratology on myopia progression suggests that, on average, the 2-year slowing of axial elongation is 0.28 mm (95% CI: 0.20 to 0.35 mm).[51] Long-term follow-up (> 5 years) of small cohorts have shown continued slowing of axial elongation of over 0.4 mm.[52, 53]

In the US, marketed orthokeratology lenses are not approved for myopia control, so their use for this purpose is considered off label. In Europe several have received CE marking for myopia control (*Conformitè Europëenne*, or European Conformity, indicates conformity with health, safety, and environmental protection standards within the European Union).

Soft Contact Lenses

Soft contact lenses with a central distance zone and increased positive power in the periphery can significantly slow myopia progression. The lens designs vary, with manipulation of power in the lens periphery by either spherical areas of positive power,[54, 55] or multiple concentric treatment zones.[5, 56-59] or induction of spherical aberration.[60] A comprehensive summary table of early findings appears elsewhere,[5] but discussion here will be limited to randomized clinical trials with at least 18 months of data (Table 3).

A Defocus Incorporated Soft Contact (DISC) lens incorporating concentric rings with a +2.50 D add was evaluated in 2-year study of Hong Kong Chinese 221 children.[57] Subjects were assigned to the DISC or single vision contact lenses. Only 128 children completed the study (58%), the majority of withdrawals due to an unwillingness to wear the lenses. Mean myopia progression was –0.59 D and –0.79 D for the DISC and single vision groups, respectively. Corresponding mean axial elongation was 0.25 mm and 0.37 mm. Treatment effect was correlated with lens wearing time, with the slowing of myopia progression over 0.50 D among those children wearing the lenses at least 7 hours per day, compared to 0.20 D overall. A US-based trial of soft contact lenses with positive spherical aberration did not have sufficient 2-year follow-up (< 20%).[60]

Sankaridurg et al. reported a 2-year, five-arm randomized clinical trial,[61] in which myopic Chinese children were randomized to single vision soft contact lenses, one of two soft lens designs that imposed myopic defocus across peripheral and central retina, or one of two extended depth of focus (EDOF) soft lenses incorporating higher order aberrations to modulate retinal image quality. The single vision group progressed by –1.12 D while all other groups had progression ranging from –0.78 to –0.87 D. The corresponding axial elongation was 0.58 mm in the single vision group compared with 0.41 to 0.46 mm in other groups. One of the EDOF designs is now available in some markets from Mark'ennovy as the MYLO lens and is CE marked for myopia management.

Chamberlain et al. conducted a 3-year randomized clinical trial of the MiSight 1-day dual-focus soft contact lens,[5] a derivative of a previously evaluated experimental dual-focus soft contact lens.[56] Myopic children were randomized to either the MiSight lens or single vision Proclear 1-day spherical lens, with both worn on a daily disposable basis. Both contact lenses are identical in all regards apart from optical design. For the 109 of the 144 enrolled subjects who completed the clinical trial, adjusted mean myopia progression was 0.67 D less in the MiSight group than in the control group (–0.65 vs. –1.31 D). Likewise, adjusted axial elongation was 0.28 mm lower in the MiSight group (0.34 vs. 0.62 mm). The trial was conducted in Europe, North America and Singapore and the efficacy was unaffected by study site. These results formed the basis of the approval of MiSight by the US Food and Drug Administration for myopia control in children—the first such indication—and follows its previous CE marking. A similar 2-year clinical trial of the MiSight lens reported on children in Spain of whom 41 wore the MiSight lens and 33 single vision spectacles.[59] The treatment effect was similar, albeit slightly smaller to Chamberlain et al., with less axial elongation in the MiSight group compared to the single-vision group (0.28 vs 0.44 mm). Chamberlain et al. recently published 6-year data.[62] Following

the original 3-year clinical trial, subjects completing were invited to continue for an additional three years during which all wore MiSight lenses and 85 completed the 6-year study. During the second three years, those who had worn MiSight for all six years progressed by –0.45 D and showed axial elongation of 0.22 mm. Those who had switched MiSight for the second 3-year period progressed by –0.29 D and showed axial elongation of 0.18 mm. The findings indicate that the MiSight lens also has efficacy in controlling myopia in slightly older children and those with greater magnitudes of myopia.

A recent US study evaluated distance-centre multifocal soft lenses designed for presbyopia.[63] A total of 294 children with –0.75 D to –5.00 D of spherical equivalent were randomly assigned to wear high add power, medium add power, or single-vision contact lenses. Adjusted 3-year myopia progression was –0.60, –0.89 and –1.05 D for high add, medium add, and single-vision lenses, respectively. The corresponding adjusted mean axial elongation was 0.42, 0.58 and 0.66 mm. Importantly, the trial demonstrates a dose-response relationship with high add multifocal soft lenses producing greater benefit than medium add lenses.

Safety

Safety is paramount in myopia management in young children. A recent publication makes a compelling argument that the benefits of myopia control far outweigh the associated risks.[64]

Quality Of Vision

One legitimate concern is the vision of children wearing novel spectacle or contact lens designs. Distance visual acuity and contrast sensitivity was measured in a large group of myopic children wearing HAL, DIMS and single vision lenses.[65] Measurements were made with subjects viewing only through the lenslets zone. The HAL lenses had a significantly lower impact on VA and contrast sensitivity than the DIMS lenses. The impact of the HAL design on vision was evaluated further in a subsequent publication.[66] Visual acuity and reading speed was measured for high and low (10%) contrast letters for foveal fixation through the peripheral portion. There was no significant impact of the HAL lens on visual acuity and reading speed at high contrast, but at low contrasts, both measures were slightly reduced compared to a single vision lens. The impact of the lenslets on peripheral vision was also assessed, while subjects fixated through the centre of the lens. The HAL design did not affect peripheral motion perception or useful field of view (a test of visual attention). Most importantly children adapt to the lenses within a week with no complaints or reported discomfort.[40]

Studies evaluating visual performance of children wearing multifocal and dual focus soft contact lenses demonstrate good best-corrected high contrast visual acuity. In the aforementioned study comparing high add, medium add and single-vision soft contact lenses, mean distance visual acuity with over-refraction at the 3-year study visit was between −0.03 and –0.05 logMAR (better than 6/6) for all three groups.[63] Likewise, at the end of the 3-year MiSight trial, mean visual acuity with over-refraction was –0.05 logMAR with both the dual-focus and single vision lenses.[5] Self-reported questionnaire data also showed children adapted well to the dual-focus contact lens, with no perceived impact on vision.[67] Overnight orthokeratology has little effect on high contrast best-corrected visual acuity, but low contrast best-corrected visual acuity reductions of 0.07 and 0.12 logMAR were found with natural and dilated pupils, respectively.[68]

Adverse Events

Rates of microbial keratitis associated with soft contact lens wear have been well researched over the past few decades. The incidence is 20 to 25 per 10,000 patient years (1 in 400 - 500 years of wear) in patients wearing soft hydrogel or silicone hydrogel lenses on an overnight basis. The rate is greatly reduced (around 2 per 10,000 patient years) for daily-wear patients.[69-75] These large epidemiological studies tell us little about children wearing contact lenses, as most of the largest studies only report cases in patients 15 years and older.[75-77]

The Contact Lens Assessment in Youth (CLAY) Study[78] sought to address this gap and reviewed charts from 3,549 patients.[79] Across all patients there were 187 corneal infiltrative events, including 8 cases of microbial keratitis, over 4,663 soft contact lens patient years. Importantly, the incidence varied dramatically with age with the 8- to 12-year-olds having the lowest rates of adverse events and young adults having markedly higher rates. Regarding microbial keratitis, there were no cases among the 8- to 12-year-olds.

These findings were confirmed by comprehensive reviews of prospective studies of soft contact lens wear in young children.[80, 81] Seven published studies were identified with at least 150 patient years of lens wear reporting safety outcomes.[10, 13, 82-86] These comprise 3,752 patient years of soft contact lens wear, mostly in children between 8 and 12 years. There was a single case of microbial keratitis that resolved without consequence,[86] representing an incidence of 2.7 cases per 10,000 patient years of wear.[81] A recent study combined data from clinical chart reviews in the US and from two international clinical trials representing a total of 782 children. All were aged 8 to 12 at initial soft contact lens fitting, with a range of materials and replacement schedules, and followed until up to 16

years of age. The authors identified two cases of probable microbial keratitis.[87] This was at a rate of 7.4 per 10,000 patient years and neither were associated with loss of visual acuity. This rate is comparable with established rates in adults who wear soft contact lenses.

The safety of overnight orthokeratology was reviewed by the American Academy of Ophthalmology.[88] The paper documents a large of number reports of serious infections, mostly in children and in South-East Asia. The first estimate of the incidence of microbial keratitis associated with overnight orthokeratology was from a retrospective study of randomly selected practitioners. Each provided information on patients based on up to 50 randomly-selected lens orders, including comprehensive details on any episode of painful red eye in these patients that required a visit to a doctor's office.[89] Data were submitted by 86 practitioners on 1494 unique patients, resulting in sample of 1,317 patients (49% adults 51% children) representing 2,599 patient years of wear. Of the 50 episodes of painful red eye reported, eight presented with a corneal infiltrate of which two were judged to be microbial keratitis by a five-person masked, expert review panel and neither resulted in any long-term loss of visual acuity. Both cases occurred in children giving an incidence of 13.9 per 10,000 patient years (95% CI: 1.7 to 50.4). Based on the upper confidence interval, the expected incidence of microbial keratitis is no greater than 50 in 10,000, or 1 in 200 years of wear. A subsequent study documented five cases of microbial keratitis in children, none of which resulted in loss of vision, and produced lower estimates of the incidence of microbial keratitis (5.3 per 10,000 patient years).[90]

Rebound

One key question is what happens when a child no longer wears an optical myopia control intervention, is there a rebound or acceleration in myopia progression, or does the myopia progress at the expected rate for the child's age? The limited data to answer this question suggest that there is little or no rebound effect with optical methods of myopia control. Children randomized to a soft contact lens with positive spherical aberration versus a single vision control contact lens wore their lenses for up to two years.[60] Children subsequently wore a standard daily disposable contact lens for 18 months. During the treatment phase differences in growth rate were found between the two cohorts, however, during the follow up after cessation of treatment, no differences in either rate of axial elongation or rate of myopia progression were found between the groups. More recently, children who had worn MiSight contact lenses for three or six years were all switched to wear a single vision contact lens for year 7 of the study.[91] Their growth rates matched the expected growth rates of untreated children of the same age.[92] This suggests that the treatment effects gained are

maintained after cessation of the intervention and that the axial elongation and myopia progression do not show acceleration after stopping an optical intervention. These findings are supported by a separate smaller study where a small proportion of children discontinued MiSight contact lens wear.[93] Equivocal data from a study of orthokeratology suggest that younger children may have a small rebound effect after ceasing wear, however, sample size was small and discontinuation was not randomized. Those stopping wear had lower levels of axial elongation prior to discontinuation and thus their more rapid elongation thereafter might represent regression to the mean—wherein those progressing much faster than average during one time period will progress at a rate closer to the mean during a subsequent period, even if the mean progression is unchanged.[94] Finally, a long-term, non-randomized follow-up of children who wore and then discontinued wearing DIMS spectacle lenses, shows no evidence of rebound.[95]

Combination Treatments

There is currently limited evidence for combining myopia management strategies, however, three 2-year trials have shown that combined orthokeratology and low dose atropine is more effective than orthokeratology alone.[50, 96, 97] Atropine slowed axial elongation by between an additional 0.11 and 0.18 mm compared with orthokeratology alone. In one study,[96] atropine only benefited children with lower levels of myopia and in all studies most of the benefit of adding atropine occurred in the first 6-12 months. Nonetheless, the indications for using this intervention and the subset of patients for which this may be the most beneficial is still unclear. One study has assessed the effect of combining 0.01% atropine with soft multifocal contact lenses with a +2.50D add[98] compared with an age matched cohort from the BLINK study[63] who wore the same contact lens design. The combination therapy did not result in any additional slowing of myopia progression, although the 0.08 mm additional mean slowing of axial elongation just failed to reach statistical significance (P = 0.05). A recent short-term, non-randomized study suggests treatment with both 0.01% atropine and DIMS spectacle lenses may slow progression more than either treatment alone.[99] Future studies should evaluate higher concentrations, e.g., 0.05%, and explore whether its benefit is optical in nature due to increased pupil size.

Gaps in the Literature

The above evidence demonstrates that various optical interventions will slow myopia progression in children, however, studies have focused on children aged between 7 and 12 years as this is the age where rate of myopia progression is typically fastest. The efficacy of these interventions for older and younger[100] children is less clear, but it may be reasonable to extrapolate the data to older

children.[62] Clinical trials rarely recruit children with astigmatism above 1 D,[101] so the interaction of astigmatism, myopia progression, and myopia control is unknown. Ongoing trials of new spectacle and contact lens designs for myopia control have also enrolled similar, relatively homogenous cohorts.

Published randomized clinical trials on efficacy of spectacle lenses designed to control myopia have been limited to children of Chinese ethnicity living in Hong Kong or China,[38, 40] although case series on European children have begun to appear.[99, 102] Further evaluation of efficacy in more diverse cohorts would be valuable, although the weight of evidence indicates that treatment effect is similar in East Asians and western children when expressed in mm or D.[5, 103, 104]

There is limited evidence to help practitioners predict how an individual will respond to intervention[105] and to choose the most appropriate modality. Study data are primarily reported as means across a cohort and individual variations in response to treatment exist. Translation of research findings to clinical practice need to be mindful of this. Ways to better predict outcomes and individualised treatment strategies are longer-term research goals.

Summary

A range of effective optical interventions for myopia control have been developed and evaluated. All have adequate safety, with no additional risks beyond single vision corrections, and the best options in each category have similar efficacy—at least 0.25 mm of slowing over two to three years of treatment. This gives practitioners alternatives that can be matched to the lifestyle of the myopic child.

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Table 1. Results of randomised clinical trials of the efficacy of various spectacle lens designs for myopia control.

Lead Author	Duration (years)	Treatment	Participant Age Range (years)	N (complete/enrolled)		Progression (D)		Treatment Effect (D)	Axial Increase (mm)		Treatment Effect (mm)
				Treated	Control	Treated	Control		Treated	Control	
Grosvenor[32]	3	Executive bifocal: +1.00 D add	6 to 15	41/69	39/69	–1.08	–1.02	**0.06**	—	—	**—**
Grosvenor[32]	3	Executive bifocal: +2.00 D add	6 to 15	44/69	39/69	–1.02	–1.02	**0.00**	—	—	**—**
Parssinen[33]	2	Flat-top bifocal	9 to 11	79/80	79/80	–1.22	–1.06	**–0.16**	—	—	**—**
Fulk[34]	2.5	Flat-top bifocal	6 to 12	36/42	39/40	–0.99	–1.24	**0.25**	0.40	0.49	**0.09**
Edwards[27]	2	PALs	7 to 10.5	121/138	133/160	–1.12	–1.26	**0.14**	0.61	0.63	**0.02**
Gwiazda[9]	3	PALs	6 to 11	229/235	233/234	–0.87	–1.15	**0.20**	0.64	0.75	**0.11**
COMET Group[35]	3	PALs	8 to 11	52/59	58/59	–0.87	–1.15	**0.28**	—	—	**—**
Hasebe[28]	1.5	PALs	6 to 12	46/46	44/46	–0.89	–1.20	**0.31**	—	—	**—**
Yang[29]	2	PALs	7 to 13	74/89	75/89	–1.24	–1.50	**0.26**	0.59	0.70	**0.11**
Hasebe[30]	2	PALS: +1.00 D add	6 to 12	58/67	60/67	–1.32	–1.38	**0.28**	0.63	0.69	**0.05**
Hasebe[30]	2	PALS: +1.50 D add	6 to 12	60/67	60/67	–1.19	–1.38	**0.28**	0.60	0.69	**0.08**
Cheng[31]	3	Executive bifocal	8 to 13	48/50	50/50	–1.25	–2.06	**0.81**	0.57	0.82	**0.25**
Cheng[31]	3	Executive bifocal with prism	8 to 13	46/50	50/50	–1.01	–2.06	**1.05**	0.54	0.82	**0.28**
Kanda[37]	2	Reduce relative peripheral hyperopia	6 to 12	102/105	101/102	–1.43	–1.39	**–0.04**	0.73	0.69	**–0.04**
Lam[38]	2	DIMS	8 to 13	79/93	81/90	–0.38	–0.93	**0.55**	0.21	0.53	**0.32**
Bao[40]	2	HAL	8 to 13	54/58	50/55	–0.66	–1.46	**0.80**	0.34	0.69	**0.35**
Bao[40]	2	SAL	8 to 13	53/57	50/55	–1.04	–1.46	**0.42**	0.51	0.69	**0.18**

Table 2. Results of randomized clinical trials of the efficacy of orthokeratology for myopia control. Only axial length was measured and reported.

Lead Author	Duration (years)	Range (D)	Participant Age Range (years)	N (complete/enrol)		Axial Increase (mm)		Treatment Effect (mm)
				Treated	Control	Treated	Control	
Cho[45]	2	Up to –4.00 D	6 to 15	37/51	41/51	0.36	0.63	**0.27**
Charm[46]	2	–5.75 D or worse, partial correction	6 to 15	12/26	16/26	0.19	0.51	**0.32**
Jakobsen[49]	1.5	Up to –4.75 D	6 to 12	19/30	28/30	0.17	0.41	**0.24**
Xu[50]	2	Up to –6.00 D	8 to 12	34/40	30/40	0.43	0.81	**0.37**
Choi[48]	2	Up to –4.00 D	8 to 12	43/52	28/39	0.37	0.60	**0.22**

Table 3. Results of randomised clinical trials of the efficacy of multifocal, dual-focus, or extended depth of focus (EDOF) soft contact lenses for myopia control.

Lead Author	Duration (years)	Treatment	Participant Age Range (years)	N (complete/enrolled)		Progression (D)		Treatment Effect (D)	Axial Increase (mm)		Treatment Effect (mm)
				Treated	Control	Treated	Control		Treated	Control	
Lam[57]	2	DISC—Defocus Incorporated	8 to 13	65/111	63/110	–0.59	–0.79	**0.20**	0.25	0.37	**0.11**
Sankaridurg[61]	2	Multifocal I	8 to 13	47/103	47/104	–0.87	–1.15	**0.28**	0.41	0.60	**0.19**
Sankaridurg[61]	2	Multifocal II	8 to 13	45/101	47/104	–0.88	–1.15	**0.27**	0.46	0.60	**0.14**
Sankaridurg[61]	2	EDOF III	8 to 13	45/98	47/104	–0.78	–1.15	**0.37**	0.45	0.60	**0.15**
Sankaridurg[61]	2	EDOF IV	8 to 13	47/104	47/104	–0.85	–1.15	**0.30**	0.43	0.60	**0.17**
Chamberlain[5]	3	Dual-Focus	8 to 12	53/65	56/70	–0.65	–1.31	**0.67**	0.34	0.62	**0.28**
Ruiz-Pomeda[59]	2	Dual-Focus	8 to 12	41/46	33/33	–0.45	–0.74	**0.29**	0.28	0.45	**0.16**
Walline[63]	3	High Add Distance Centre	7 to 11	97/98	97/98	–0.60	–1.05	**0.46**	0.42	0.66	**0.23**
Walline[63]	3	Medium Add Distance Centre	7 to 11	98/98	97/98	–0.89	–1.05	**0.16**	0.58	0.66	**0.07**