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Clinical management of progressive myopia

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Abstract

Myopia has been increasing in prevalence throughout the world, reaching over 90% in some East Asian populations. There is increasing evidence that whereas genetics clearly have an important role, the type of visual environment to which one is exposed to likely influences the onset, progression, and cessation of myopia. Consequently, attempts to either modify the environment or to reduce the exposure of the eye to various environmental stimuli to eye growth through the use of various optical devices are well under way at research centers around the globe. The most promising of current treatments include low-percentage atropine, bifocal soft contact lenses, orthokeratology, and multifocal spectacles. These methods are discussed briefly and are then categorized in terms of their expected degree of myopia progression control. A clinical strategy is presented for selecting the most effective treatment for the appropriate type of patient at the optimal stage of refractive development to achieve the maximum control of myopia progression.

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Myopia has become the focus of attention and concern because of recent dramatic increases in its prevalence worldwide, especially in East Asian populations. For example, figures of over 90% have been reported for some university student populations in Asia,[1,2] as well as for a population of 19-year-old male conscripts in South Korea.[3] A similar trend of increasing myopia prevalence has been reported in an US-based study reaching 42% in the period 1999–2004 compared with 25% in the same population surveyed 30 years earlier.[4]

Whereas there is scarcely any debate about the increasing prevalence of myopia, there remains debate as to whether myopia is merely an inconvenience well-treated by conventional spectacles and contact lenses or whether the risks associated with increased levels of myopia in society merit a more serious approach.[5–7] A recent review by Flitcroft,[8] however, outlines the clinical ramifications of myopia in terms of significant odds ratios for myopic maculopathy, retinal detachment, cataracts, and glaucoma, all potentially blinding diseases, even for low and moderate levels of myopia. These odds ratios increase further with higher levels of myopia; thus, the benefit to society from a more proactive approach to reduce the amount of myopia that a patient experiences is clear.

Although there is accumulating evidence that environmental influences have an important role in the development of myopia, the underlying contributing factors remain poorly understood. The Cochrane Collaboration is a comprehensive review of the dominant theories about myopia progression along with an in-depth analysis of the most promising therapies.[9] The entirely appropriate criteria of placing more credence in studies that met their gold standard of multi-year randomized controlled clinical trials limited the degree to which they were able to make recommendations to clinicians concerned about their patients experiencing persistent myopia progression.

Given the self-imposed limitations on the research that could be considered, their strongest statement was that topical antimuscarinic medication is the most likely effective treatment to slow myopia progression. Indeed, the Atropine Treatment of Myopia 2

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(ATOM2) study and related studies offer enticing evidence that doses as low as 0.01% atropine can quite effectively slow myopia progression in children with very low levels of pupil dilation, photophobia, cycloplegia, and allergy.[10–12] The findings from ATOM2 in particular have encouraged clinicians to consider low-dose atropine therapy, although there are difficulties in prescribing such doses as they are not easily available. The Cochrane group further suggests that corneal reshaping or orthokeratology and bifocal soft contact lenses are promising treatments, although still in need of more randomized controlled clinical trials. As the consequences of widespread and long-term use of atropine are as yet unknown, practitioners may wish to consider these promising optical treatments that expose their patients to no similar risks.

Background

While bifocal and progressive multifocal spectacles have been prescribed and studied for many years as treatments for myopia, the results on unselected populations are usually clinically insignificant.[13] Goss and Grosvenor[46] reported significant slowing of myopia progression with bifocal spectacles in children with near point esophoria compared with single vision corrections.[14] Numerous studies that have looked at the use of bifocals or PALs in children with esophoria and/or high accommodative lags have found from 30 to 47% slowing, although many of these studies suffer from study design shortcomings and sample size limitations because of their use of *post hoc* subgroup analyses. The one notable exception is the study that evaluated the use of executive style bifocal eyeglasses on Chinese Canadian children with rapidly progressing myopia.[15] Table 1 summarizes these studies, their findings, and their limitations.

Almost without exception, all of the papers and studies that explore or discuss the role that binocular dysfunction at near may have in myopia onset or progression or spectacle treatments refer to esophoria. Esophoria at near merely means that one eye is converged relative to the target while behind a cover during monocular fixation of a target at near. How the behavior of an eye behind a cover has been assumed to be the best way to describe or predict its role in triggering myopia progression in response to near work really should be examined.

Fixation disparity is a measure of the degree to which the eyes are misaligned with respect to the object of regard in real time. Clinically, fixation disparity has been used to characterize the accuracy of fixation, to predict the level of asthenopia, and to monitor the effectiveness of treatments with lenses or orthoptics.[16] As an eso fixation disparity can be measured in the presence of esophoria, orthophoria, and exophoria and it may be absent in the presence of an esophoria, it can be argued that in the absence of a fixation disparity, the underlying heterophoria may not be relevant.

Fixation disparity, however, may not be the best measure for determining the lens power that might be necessary to treat the fixation disparity. Associated phoria is a measure of the amount of prism or the lens power necessary to neutralize the fixation disparity. The amount of plus lens power necessary to neutralize the eso fixation disparity at near may be used to determine the add power necessary in a bifocal or a single vision spectacle lens to properly treat the binocular vision dysfunction characterized by the fixation disparity. This plus lens-neutralized-associated phoria may also be used to select and verify the effectiveness of the add power of a bifocal contact lens to treat the fixation disparity. By eliminating this presumed trigger

Table 1 A summary of myopia progression studies involving the use of bifocal, progressive, and peripheral plus spectacles

Authors	*Treatment*	*Ages*	*Control rate (D/Yr)*	*Tx rate (D/Yr)*	*Tx effect (%)*	*Comments*
Grosvenor[14]	BF	6–15	−0.34	−0.32	−6	No subgroups no differences
COMET[13] (2003)	PALs	6–11	−0.49	−0.43	−12	Clinically insignificant
Yang[42]	PALs	7–13	−0.75	−0.62	−17	Randomized prospective 2 years
Sankaridurg[43]	Peripheral Defocus Rx	6–16	−0.97	−0.68	−32	Only in younger subgroup with one or more myopic parent with asymmetric design
Berntsen[44]	PALs	6–11	−0.52	−0.35	−33	Either low myopia with high lags or higher myopia with esophoria at near
COMET[45]	PALs	6–11	−0.57	−0.36	−37	Effect greatest in esos, high lags, + family Hx myopia
Goss and Grosvenor[46]	BF esos	6–15	−0.51	−0.31	−39	Not statistically significant, small subgroup
Goss[47]	BF esos	6–15	−0.54	−0.32	−41	Retrospective, multiple practices
Yang[42]	PAL esos	7–13	−0.83	−0.44	−47	Eso subgroup analysis
Cheng[15]	Exec BF w and w/o base in prism	8–13	−0.78	−0.48 −0.35 Prism	−38 −0.55	Fast progressing Chinese Canadian children. Less myopia with base in prism but same axial length change

to myopia progression, the add power properly selected may provide an optimized treatment for myopia.[17]

Clinical strategies

For the purposes of developing a clinical strategy for the treatment of myopia progression, it may be useful to categorize the various treatment strategies in terms of their expected myopia control effects. This stratification is based on reported results in various studies of different designs; however, it can help in deciding which therapy to choose for which patient.

Figure 1 shows the optical profiles of some popular soft contact lenses.[18] What is notable is that for most of the standard single vision soft lenses measured, there is significantly more minus power in the periphery. If one were to assume that peripheral hyperopic defocus is a stimulus for axial elongation and myopia progression,[19] prescribing lenses that intentionally add minus power at the periphery of the optic would amount to intentionally causing myopia progression. There are no published studies, however, that prove that standard single vision soft contact lenses accelerate myopia progression relative to spectacles.

A 3-year retrospective study of myopia progression among wearers of Alcon Focus Night and Day lenses found significantly less myopia progression than with other soft contact lenses.[20] They attributed the slower progression found to the difference in oxygen transmissibility, although it could very well have related to the flat optical profile of the Night and Day lens *vs* contacts with more minus in the periphery as shown in Figure 1.

Figure 2 blends some data from several similar studies[21,22] showing relatively high myopia progression rates found with standard single vision soft lenses with extra minus peripheries to the 18% lower progression rates found with a lens with a flat optical profile as compared with spectacles to the 37% lower rates found with a lens that was designed with additional plus power in the periphery. This one graph makes a strong argument for clinicians to strategically choose the optical design of the contact lenses that they prescribe for their myopic patients.

For the purposes of crafting a myopia treatment protocol, PALs and bifocal spectacles used for children with high accommodative lags and/or esophoria may be called Myopia Control 33 (MC33) for the expected 33% slowing of myopia progression. Most of the studies, however, seem to show a treatment effect only in the first year. This limited effect may be a consequence of study design and may not reflect the long-term effectiveness of these lenses when prescribed for individual patients in clinical practice. In the clinic, one may prescribe whatever add power might be most appropriate, given the amount of eso fixation disparity and/or the amount of the accommodative lag, for example. In clinical practice, given that the purpose of such lenses is at least partially to reduce accommodative lag and esophoria while being engaged in near vision tasks, one may prescribe special purpose spectacles optimized for viewing computers. Even in myopia control studies with careful training protocols in place, children frequently misuse PALs by failing to use the near zone for near viewing.[23]

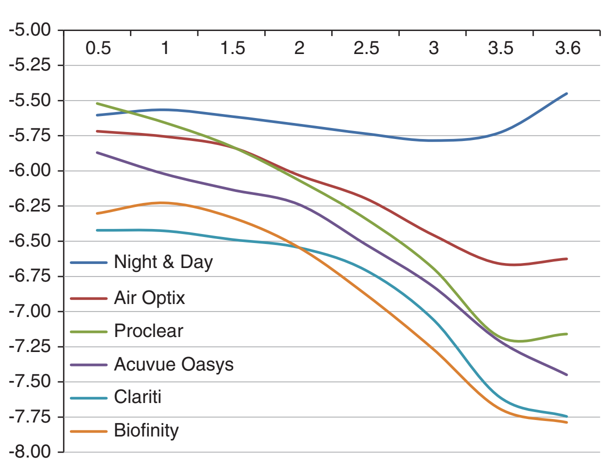

Figure 1 Shows the mean of five measures of the power profiles through the optical zone for some single vision soft contact lenses. Power measurements in the central 1 mm are less precise and are not shown. Data are re-plotted from Wagner.[18]

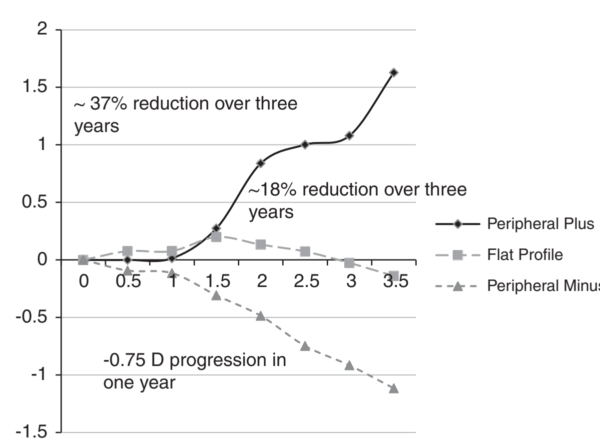

Figure 2 Shows the power profiles for a single vision soft contact lens with additional minus power in the periphery, a lens with a flat optical profile and a lens with additional peripheral plus power. Also shown are the myopia progression rates associated with such lenses from several studies. Data are re-plotted from Holden.[22]

It is becoming well established in multiple clinical trials,[24–26] including a recent 2-year-randomized clinical trial,[27] that orthokeratology slows myopia progression by 50% on average in children. These studies further showed that the slowing of myopia was not limited to the first year. There are trends in several of the studies that could lead one to conclude that the effectiveness is positively correlated with the level of myopia that is being treated.[28] Practitioners might then expect less effective control with orthokeratology with lower initial myopia and greater control with higher levels. This is by no means proven or well understood, as one study recently showed the inverse effect;[24] however, it may be useful to guide clinical choices. It should be noted as well that the primary goal of an orthokeratology patient is to achieve good daytime vision and this tends to be more challenging at myopia levels higher than −6.00 diopters. From the published studies, this treatment can be categorized as Myopia Control 50 (MC50) for the average expected 50% slowing of myopia.

Bifocal or multifocal soft contact lenses have been shown to slow myopia progression in several studies by around 50%.[29–31] Importantly, one of these papers[31]on a 2-year study and a conference report[32] on a 4-year study each showed that the control effect was not limited to the first year as with the spectacle studies. Some of these studies describe the test lenses as being different than bifocals; however, all of the studied lenses have been bifocals designed and sold for presbyopia, or they have multiple zones of power, generally with the distance correction in the center surrounded by plus power in various configurations. Various amounts of peripheral plus have been studied; however, generally the plus power has tended to be lower ‘adds’ and usually the same add power was prescribed to every subject. These studies did not limit the subjects to those with esophoria at near. While most of the studies reported no association between the initial level of myopia and the treatment effect, one has shown greater control with lower initial myopia.[31] Thus, there may be a strategy that would call for this type of lens in low initial myopia as well as in myopia too high to correct with orthokeratology. On the basis of these studies, these lenses could also be labeled as MC50 lenses.

Atropine has been shown to control myopia progression quite effectively. Low-dose atropine 0.01% has shown promise for controlling myopia by over 50% with much lower side effects and is becoming more popular as a treatment option. A recent study showed that the highest percentage dose that induces no more than clinically insignificant side effects was 0.02% and the paper suggests that this would be a good minimum dose to consider since the myopia control effect rises with the percentage dose.[33]

Simultaneous vision bifocal contact lenses of every imaginable design have been used by the author for over 20 years. Clinically and in studies, they have primarily been used to attempt to slow myopia progression in those patients with eso fixation disparity at near.[34–36] In this patient population group, these lenses prescribed with this method slow myopia progression by 80–90%. The best measure of effectiveness for these lenses would be the reduction in axial length increases found in the randomized clinical trial where there was an 80% slowing of axial elongation in children wearing bifocal contact lenses. Prescribed by the method described and for this subgroup of patients, these lenses could be described as Myopia Control 80 or MC80 lenses.

Myopia control protocol

All of the methods described have been shown to varying degrees to be effective in slowing myopia progression. As they cannot reliably stop progression, prevent onset, or cause true regression of myopia, these methods are limited to reducing the rate of change. Consequently, for best long-term clinical effect that will result in the lowest level of myopia when progression stops because of aging or other factors, there are only two ways to cause the final myopia level to be lower. One must either intervene earlier or one must prescribe more effective treatments.

Take, for example, a family of five girls separated in ages by about 1 year, and consider the effectiveness of various clinical approaches as illustrated in Figure 3. This is a family with moderate to high levels of myopia in each parent, living in an urban environment, immersed in a culture that embraces educational achievement, and possessing computers, smart phones, and video games, which is typical these days. The first daughter presents for her initial eye examination at the age of 5 and is found to have +2.25 diopters of hyperopia and by the age of 7 this has decreased to +0.75, a level that has been shown to predict myopia at that age.[37,38] By the age of 9, she has reached −1.25 and is prescribed single vision spectacles for full-time use. Her power increases rapidly at first and then more slowly as she ages and she ends up graduating college as a −10.50 myope. This describes the current standard of care, and yet the eventual refractive outcome subjects this patient to significant levels of risk.

The second daughter is genetically similar and having been raised in the same environment starts out in life refractively matching her sister. At myopia onset at the age of 9 with a measured myopia of −1.25 diopters, her concerned parents opt for a MC33 treatment strategy consisting of PALs. This presupposes that sister number two exhibits either esophoria and/or high accommodative lags and that the clinical application of

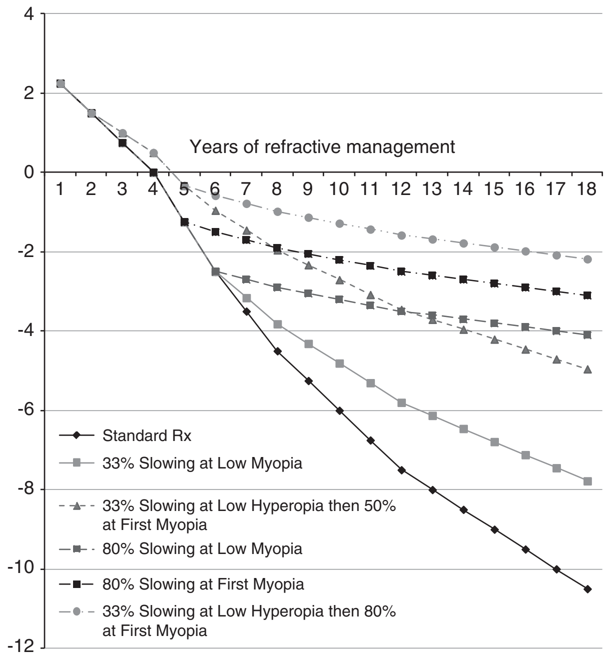

Figure 3 Illustrates possible final refractive outcomes for five mythical sisters with identical initial refractive errors treated with five different treatment strategies over 18 years of refractive management.

PALs would result in a 33% slowing throughout the treatment period, a condition not proven in long-term studies. If, however, a 33% inhibition is achieved long term, at the time of graduation from college 'Two' would end up as a −7.78 myope, certainly better than the first daughter, but still subjecting her to significant risks of ocular pathology.

Encouraged by the somewhat slower myopia progression experienced by 'Two', daughter number three is treated a bit more aggressively and a little bit earlier as she initiates myopia control at the point at which her hyperopia has decreased from +2.25 to +1.50 and she begins wearing PALs prescribed to correct her eso fixation disparity. She experiences a 33% slowing of her myopia progression, or hyperopia reduction, but when she reaches a low level of myopia (−1.00) at the age of 10 her myopia control treatment is increased to MC50 with +2.00 D distance center soft bifocal contact lenses. Alternatively, executive bifocals, orthokeratology, or low-dose atropine could be prescribed to achieve an MC50 effect. Upon graduation from college, 'Three' is a −5.00 D myope and has a much better outcome with less risk of myopia-related pathology, lower costs from less frequently replaced spectacles and has retained the ability to have good refractive outcomes from orthokeratology and would remain a good refractive surgery candidate.

Inspired by daughter number three, the fourth daughter initiates myopia control at the onset of low myopia but is treated with a bifocal contact lens that is expected to slow myopia by 80%. This has been shown to be achievable with bifocal soft lenses in patients with near eso fixation disparity using the author's clinical method of add selection. It may also be achievable in non-esos when the add power is selected as the highest add that provides for good distance vision or if the add power is selected on the basis of maximum correction of peripheral hyperopia as measured by peripheral refraction or peripheral axial lengths. With this more aggressive approach, 'Four' graduates college with a −3.10 diopter prescription, and in addition to all of the advantages incurred by her sisters with more moderate slowing she begins to benefit from improved unaided vision that will serve her well after developing presbyopia.

Daughter number five takes the most aggressive approach beginning MC33 when her hyperopia is seen to decrease, switching to MC80 at the onset of any myopia, graduating from college with a very healthful and useful level of myopia, −2.18 diopters. Sadly, as myopia appears to be linked to intelligence,[39] 'Five' experiences the most difficulty in completing her coursework.

Although there are undeniable, measurable components of visual performance that may be influenced by lenses that impose multiple foci on the visual system,[40] the subjective acceptance demonstrated by children wearing this category of lenses has been shown to be quite high. Indeed in a study that had users rating their overall quality of life (QOL) after switching from single vision spectacle correction to either bifocal soft contact lenses or single vision soft contact lenses, participants in each contact lens group rated their QOL as being higher in most categories, including distance vision quality with either type of contact lens.[41]

Practitioners who were hesitant to prescribe multifocal contact lenses based on their negative experiences with presbyopes, or because of expectations of lower visual quality, should consider the average visual acuity and visual performance of a child wearing single vision spectacles or single vision contact lenses *vs* a child wearing a multifocal contact lens who is experiencing slowed progression. The child wearing single vision spectacles or contact lenses who starts out the year with a crisp 20/20 might end up at 20/70 at 1 year after progressing to −1.25 diopters. He certainly will spend a great deal of time in that year experiencing subnormal corrected vision. Contrast this experience with a child wearing a multifocal contact lens who may start the year out seeing 20/20− or 20/25+ and after 1 year, having progressed by −0.25 diopters or less, may still be seeing 20/25 or better. In which case has the practitioner met his obligation to provide good vision and help preserve sight?

Summary

Evidence is accumulating of what amounts to an epidemic of myopia throughout the world, concentrating in Asia in particular and urban environments in general. It is further becoming clear that there are effective means to slow myopia progression in clinically meaningful ways. Myopia progression is typically associated with axial elongation and control of myopia results in slower axial length. Although it is reasonable to assume that retarding the axial elongation of a child or young adult rapidly progressing in myopia will result in less risk of glaucoma, cataract, retinal detachment, and myopic macular degeneration, this is yet to be established. Individual practitioners simply need to decide whether they will start using the optical control strategies discussed to help their patients today or whether they feel compelled to wait for multiple, multi-year clinical trials and FDA indications and CE marks before they adopt this technology.

Conflict of interest

TA Aller is author or co-author on several patents on methods and optical designs for the control of myopia progression.

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