

CURRENT METHODS OF MYOPIA CONTROL A LITERATURE REVIEW & UPDATE

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Abstract

Myopia affects up to one-third of the population in the United States today. It is a leading cause of low vision in Asian countries secondary to the increased risk of retinal detachments and glaucoma. Genetics, as well as environmental factors and nearwork have been hypothesized to play a role in myopia development. Current techniques to control its progression target these etiologies. Methods of myopia control that have been explored include: vision and behavioral therapy, contact lenses, multifocal lenses, and pharmaceutical agents. In the realm of vision and behavioral therapy, prior non-controlled studies are encouraging. Bifocal contact lenses appear to have high potential in reducing myopia. Atropine, pirenzepine, biofeedback, and progressive lenses have shown promising results, predominantly in young esophoric myopes. Many of the current studies, particularly those involving vision therapy, atropine, pirenzepine, and orthokeratology lenses, should be repeated to quantify the influence on myopia progression. Myopia control continues to be an area of active research.

Key Words

atropine, bifocals, biofeedback, contact lenses, esophoria, multifocals, myopia control, myopia progression, myopia reduction, nearwork, orthokeratology, pediatrics, pirenzepine, progressive addition lenses, vision therapy

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INTRODUCTION

Myopia is one of the most common visual conditions, affecting one in three adults in the United States today.¹ Internationally, it has been reported in up to 60 to 80% of young adults in Taiwan, Hong Kong, and Singapore.² The prevalence of myopia has been increasing; over the last ten years, with a 10% rise in prevalence in the United States alone. Demographically, myopia shows a racial predilection towards Asians; African Americans tend to show the least amount of myopia.³ Ocular health complications of severe myopia are secondary to elongation of axial length. This can increase the risk for retinal detachments, chorioretinal abnormalities, myopic degeneration, and development of glaucoma.⁴ Vision impairment secondary to myopia is the second most common cause of low vision in Taiwan (25%) in individuals over 50 years of age.⁵ Myopia is also costly: Americans spend up to 4.6 billion dollars each year for eye examinations, spectacles, and contact lens correction.¹

Because of the ocular health risks, fiscal impact, and high frequency of myopia, there has been great interest for research towards understanding its etiology and slowing its progression. The main goal of myopia control is to retard myopia at a young age—optimally, at its inception—in order to decrease the severity of the condition at maturity.⁵ High myopia (greater than -6.00 D) tends to develop in early childhood and may have a more genetic basis. Hyman et al showed that children in the United States' Correction of Myopia Evaluation Trial (COMET) with myopia of at least -1.25 D by age 7 years were at risk for faster progression of myopia than older children, regardless of other base-

line characteristics.³ Early-onset myopia tends to advance rapidly until early adulthood and presents a higher risk of ocular complications. This can be contrasted with functional myopia, which tends to show a later onset. Functional myopia is related to pseudomyopia or false myopia. It is often associated with nearpoint esophoria, reduced accommodation and accommodative spasm secondary to a long period of nearwork at a short working distance.⁶ Functional myopia is not associated with any chorioretinal findings and has a smaller magnitude of refractive error.

Eye care practitioners and vision researchers have also shown much interest in techniques that may diminish the magnitude of myopia. Concerned parents as well as patients themselves may desire to control the advance of myopia in hopes of improving unaided acuity, reducing dependence on glasses, decreasing lens thickness, and decreasing axial elongation to lower the risk of ocular disease.²

Currently, a variety of methods for myopia control have been explored with variable success. This ongoing area of active research has made much progress over the last decade, particularly with use of contact lenses and pharmaceutical agents. However, results of these most recent studies have not been compiled and reviewed to date. Additionally, there have not been any reviews consolidating VT and behavioral approaches to myopia control. The purpose of this paper is to explore the most current techniques used to slow the progression of myopia, including:

- vision and behavioral therapies,
- ophthalmic lenses,
- contact lenses, and orthokeratology,
- pharmaceutical agents, and
- other non-conventional techniques.

Vision & Behavioral Therapies

To understand the various therapies used today to control myopia, it is important to review the models from which they arise. The basis of VT specifically for myopia control is derived from two main models of myopia development with relation to nearwork: the use-abuse theory, and the Skeffington nearpoint stress theory.

The use-abuse theory states that nearsightedness arises from excessive use of the eyes for nearwork.⁶ It was developed by Cohn who found that overuse of accommodation, largely due to intense schoolwork and other environmental factors, was correlated with myopia development.⁷ Several studies have confirmed that myopia does indeed increase during the school-aged years, but it is yet undetermined if this is due to genetic or other internal growth factors, versus environment, leading to the ongoing “nature versus nurture” debate.^{6,7} Saw found evidence that myopia may have strong environmental influences. In their large-scale cross-sectional study, they found an increased prevalence of myopia in urban versus rural areas of Asia correlating with increased nearwork demands seen in urban, school-aged populations. In India, they reported that urban areas likewise showed a prevalence of myopia of 7.4% versus only 4.1% found in rural areas. Additionally, 55% of 15-year-old males in urban China were myopic, versus less than 3% in the same age/gender group in rural Nepal, adding support for environment as a myopigenic factor.⁸ More recently, Ciuffreda and Vasudevan found that while nearwork induced transient myopia was associated with momentary accommodative spasm, it also decreased acuity both at near and at distance.⁹ They observed that temporary, short-term distance blur often experienced by later onset pseudomyopes may be an artifact of the accommodative system and may not directly induce myopia development. They concluded that nearwork may not specifically contribute to myopia advancement since transient myopia was not permanent and caused blur at all distances. The extent that nearwork and other environmental factors contribute to the advancement of myopia remains undetermined, however there is evidence indicating that they do play a role.

Skeffington proposed the other popular theory regarding myopia development. He believed that the increasing cultural emphasis on nearwork tasks is not com-

patible with our visual and ocular physiology.⁷ This incompatibility provokes a stress response to localize vergence closer than the plane of regard. The resulting mismatch causes the symptoms of asthenopia, decreased visual function and avoidance of close work.^{7,10} Myopia develops as a form of compensation. In other words, the key element to Skeffington’s model is “the drive for convergence to localize closer than accommodation due to the nearpoint visual demands of our culture.”¹⁰ One treatment for this mismatch is low-plus lenses at near to improve the match and visual efficiency. This eliminates the need for adaptation to nearpoint demands.^{7,10}

VT addresses both models of myopia development by treating any functional vision problems (associated or causative) and strengthening visual skills. Unfortunately, few large-scale well-controlled studies have been conducted to date validating the effectiveness of VT.¹¹ The majority of referenced studies used today are historical. More recent therapy regimens are based on individual case reports or anecdotes. The Baltimore Project (September to December 1943) is the largest study on VT for myopia control to date. It investigated the effect of VT directly on myopia progression on 103 school-aged and young adult patients with a wide range of myopia (-0.50 D to -9.00 D). Subjects received an average of 25 VT sessions conducted by optometrists and therapists. Overall, the study reported that unaided acuity improved.^{6,12} It should be mentioned that there was no standardization of therapy protocol, length or amount of therapy, or determination of refractive error.

It has been suggested that a full myopic correction coupled with plus therapy lenses and accommodative, vergence, and anti-suppression training was best for adult-onset myopia.¹² It was least effective in children under 12 years old. Sherman and Press incorporated Birnbaum’s therapy strategies. This included a plus add at near, emphasis on proper visual hygiene (glare free light, frequent breaks from nearwork, relaxed reading posture), and distance visualization and peripheral awareness training. They reported limited success in controlling myopia.¹³

Other therapies for managing myopia are primarily indicated for patients exhibiting signs of pseudomyopia, including nearpoint esophoria, accommodative excess, and convergence insufficiency. These

therapies work on strengthening the vergence and accommodative systems via in-office techniques such as Vectograms and Brock string.¹⁴ The goals, therefore, are to resolve these binocular deficiencies with a reduction or halt in progression of myopia. This often requires 12 to 24 in-office sessions.¹⁴ The accuracy and efficacy of these therapies has not been assessed by large-scale controlled studies and warrants further standardized investigation.

Biofeedback has also been used to control myopia by increasing accommodative accuracy. With this method, non-visual feedback (often an audible tone) is used to indicate the magnitude of the accommodative response to the patient. The most widely-researched instrument is the Accommotrac® Vision Trainer (Biofeedtrac, Inc., Seattle, Washington). It was developed by Trachtman in 1987 and combines an infrared optometer with auditory feedback sensitive to about 0.05 D of accommodative response. Trachtman, as cited by Rosenfield and Gilmartin, showed that in an average of eight sessions, the Accommotrac® decreased myopia from 2.37 D to 0.75 D.⁶ The uncorrected acuity increased from 20/187.5 to 20/30 in patients ranging from 8 to 62 years old (average 27.5 years old). A 1999 update to this study by Trachtman et al used 1,334 subjects in 21 clinics, aged 7 to 62 years old. Patients again used the Accommotrac® for an average of 19 sessions (range 1-140), with supplemental in-office, non-instrument visualization therapy if indicated. On average, unaided acuity improved from 20/170 to 20/32. Myopia decreased by one diopter (range 0.50 to 7.50 diopters) by session 17.¹⁵ The researchers did not state how the refractive error was determined. The wide range of ages and results show that the outcomes may be quite variable for each patient. Subsequent studies have not repeated these results. Koslowe et al showed that the Accommotrac® could increase unaided acuity in 15 patients when compared to 15 controls, but did not affect refractive error. Three patients complained of significant monocular diplopia or triplopia.¹⁶ A summary of current vision and behavior based therapies used to manage myopia progression are found in Table 1.

Altogether, vision and behavioral therapies appear to be particularly promising in managing adult-onset and functional myopia. It would be of interest to see the effects of VT in conjunction with other modalities of myopia control. Most evi-

Table 1: Vision and behavior based techniques used for myopia control.

Technique	Indications	No. Sessions recommended	Goal of therapy	Experimental results
Traditional in-office vision therapy ^{11,14}	Esophoria Pseudomyopia Accommodative spasm Convergence insufficiency	12 to 24	Improve accommodative and vergence function Decrease myopia	Improved stability and range of binocular function, as well as improvement in unaided acuity. Effects on myopia not reported.
Plus lenses at near (with proper visual hygiene) ^{6,7,10}	Incipient myopia Binocular instability	Not stated; variable by patient	Reduce myopia Relax accommodation	Limited success in controlling myopia, but improvement in unaided acuity.
Biofeedback ^{15,16}	Incipient myopia Binocular instability	Variable by patient; average 1.00 D reduction after 17 sessions	Reduce myopia Relax accommodation	Limited success in controlling myopia, but improvement in unaided acuity.

dence for VT alone remains anecdotal. Larger, updated clinical trials are needed to further explore the effects of VT on all myopes, including those with physiologic, early-onset myopia, in addition to functional myopia.

Ophthalmic Lenses

There are a variety of therapeutic lens types and prescriptions that might slow myopia progression. Prescriptions are determined with the accommodative-convergence relationship in mind to: ease adaptation, improve image quality in patients with large accommodative lags, optimize accommodative accuracy, minimize retinal blur, and increase peripheral awareness.¹² Optical devices that have been investigated include: bifocals, undercorrection of distance correction, multifocals or progressive addition lenses.

Therapeutic bifocals reduce the need to accommodate by virtue of the near addition of convex lens power in the bifocal segment. The addition of base-in prisms may also be used to simultaneously reduce the need to converge.¹⁷ Bifocals without prisms have been used in the last 20 years with mixed results. Goss and Grosvenor compared the use of executive bifocals with +1.00 and +2.00 adds to single vision lenses in 97 patients. They found no significant difference in myopia progression per year in patients who were orthophoric or exophoric (0.44 D in control versus 0.42 D in bifocal group). They did find a decrease in myopia progression of 0.20 D in those who were esophoric. There was a 0.51 D progression in the control versus 0.31 D in the bifocal group.^{12,18} Fulk et al examined 28 esophores exclusively between six and 13 years old and used a flat-top 28-mm segment bifocal with +1.25 D add. They reported less myopia progression in bifocal wearers, showing 0.57 D more myopia per year in single vision wearers to 0.39 D per year in bifocal wearers. They verified these findings in their expanded study in 2000.¹⁹ These

data suggest that bifocals may have some efficacy in slowing myopia progression rates in patients with esophoria at near. In general, bifocals offer poor cosmesis and compliance with minimal effect on myopia progression in most children.^{2,20}

Progressive addition lenses (PALs) have been used with myopic children.^{2,12} PALs have the added benefits of cosmesis and a more natural progression of accommodation as the child looks from distance to near. Challenges remain with fitting progressives in this young patient population. Many subjects may not get the full treatment effect by not utilizing the full add, having a poor fitting PAL or not being able to adapt. A variety of adds have been tried with the average being +1.50 to +2.00 D. Jiang et al measured accommodation, phoria, and fixation disparity through multiple adds starting from 0.00 to +2.00 in half-diopter increments in 30 adults. They found that low power adds around +1.25 D were most effective in slowing myopia progression in myopes with esophoria at near, a low positive relative accommodation measure and greater plus-acceptance on binocular cross-cylinder measurement. For best results they recommended that the prescribed add be customized depending on the patient's binocular and refractive status.²¹ Although their patient base was older than most incipient myopes, their findings have proved useful for subsequent PALs studies.

The largest randomized trial to date investigating the use of PALs in children is the Correction of Myopia Evaluation Trial (COMET), which included 469 children with low to moderate myopia. Patients who used PALs showed a 0.20 D adjusted mean difference in spherical equivalent refractive error over three years versus patients using single vision lenses. This was statistically but not clinically significant. In patients who also had poor accommodation, the mean difference increased to 0.55 D. Treatment results occurred mostly

within the first year.²² Three years later, Hasebe et al replicated the COMET study design in 92 children. They found a statistically significant, but clinically insignificant treatment effect of 0.17 D reduction in myopia after 18 months. They also verified the increased efficacy of PALs on patients with a larger accommodative lag and esophoria at near.²³ There have been some studies refuting these findings as well.²⁴ While evidence seems to indicate that PALs may be helpful in this subset of myopes, further evidence is needed.¹⁹ In some areas, particularly in Japan, it is common to undercorrect the distance prescription. This is thought to counteract myopia development by addressing the adaptive response to the stimulus to accommodate during reading and other nearwork.²² Undercorrection of more than one diopter is not recommended due to the reduction of distance vision, which may actually cause the myopia to progress. Hyperopic retinal defocus, which results from undercorrection, causes form deprivation, provokes axial length elongation and subsequently increases myopia.^{2,25} Philips conducted a case study investigating the use of monovision in 18, 11-year-old students where one eye was undercorrected or uncorrected by up to 2.00 D. The original intent was for the subject to read with the undercorrected eye; but all subjects used the fully-corrected eye for both distance and near. It was hypothesized that the subjects used their dominant eye at all distances since patients had to converge and, therefore, accommodate at near to maintain fusion while reading. Philips reported that the near eye progressed more slowly than the distance eye by 0.36 D per year.²⁶ This correlated with the measured vitreous chamber depth and axial elongation. Chung et al also conducted a masked, randomized clinical trial comparing fully corrected low myopes, ages nine to 14 years old, to those undercorrected by 0.75 D. After two years the fully corrected

group showed less myopia progression compared to the control.²⁷

Thus, PALs show the most promising results for the available lens options for myopia control, particularly in esophores. While the benefits of treatment largely occur within the first twelve months of use, they are cosmetically acceptable and provide more “natural” viewing situations.^{16,21,22} With esophores, PALs relieve the accommodative stress and help restore binocular integrity, and may contribute to reducing myopia advancement. The amount of near add recommended varies with the patient and their presenting findings, and their visual demands depending on age and the environment. Compliance may also be a factor in determining success, although PALs were well tolerated in the majority of studies. In general, PALs are the most beneficial form of optical correction for myopes with nearpoint esophoria and accommodative deficiencies.

Contact Lenses

Soft, rigid, and most recently, orthokeratology contact lenses have been used with the anticipation of retarding myopia. The philosophy is that flattening the cornea may decrease peripheral retinal defocus and delay axial elongation. Animal studies demonstrate that blur at the retinal periphery, not the fovea, contributes to the development of refractive error.^{28,29} Hyperopic form deprivation is strongly correlated with increases in axial length and vitreous chamber depth, leading to myopia development.^{19,28}

Spherical soft contact lenses (SCL) appear not to affect myopia positively or negatively, according to the Adolescent and Child Health Initiative to Encourage Vision Environment (ACHIEVE) study results.³⁰ This multi-center study examined the use of soft contact lenses in 484 children with moderate myopia over a three-year period. The average rate of myopia progression was about 0.06 D per year in soft contact lens wearers that, after adjustment, was not significant when compared to spectacle lens users. There was also no appreciable difference in corneal curvature.

Some practitioners have used bifocal contact lenses in children on a case-by-case basis, but no large-scale randomized studies have been conducted to date. A case report demonstrated the use of simultaneous design bifocal lenses versus single vision SCL in twin 12-year-old girls with myo-

pia and esophoria. After one year, the twin wearing the single vision SCL showed significantly more myopia progression than her sister (-1.06D) who wore the bifocal SCL. She was then switched to the bifocal lenses, and after the second year, both girls showed a decrease in myopia progression.³¹

Rigid gas permeable lenses (RGPs) have also been thought to halt myopia progression, although studies have shown mixed outcomes regarding their clinical success. Katz et al conducted a randomized clinical trial at the Singapore Eye Research Institute comparing spectacles to RGPs in myopes. They reported no decrease in the rate of myopia progression even when the RGP lenses were used consistently and regularly. Additionally, there was a high dropout rate of 33%, indicating that the RGP lenses generally were not well tolerated.³² The Contact Lens and Myopia Progression (CLAMP) study compared RGP to SCL wear. It showed that RGPs temporarily flattened the corneal curvature mostly within the first year of wear, but that after three years the cornea returned to its baseline curvature. Myopia progression was decreased when compared to soft contact lens wearers, but was not clinically significant.³³

Orthokeratology

In June 2002 the Food and Drug Administration authorized the use of overnight orthokeratology (OOK) lenses for refractive error correction. These lenses correct low to moderate amounts of myopia by using a reverse geometry design to flatten the central cornea and subsequently thicken the peripheral cornea. This provides temporary optical correction during the day when the lenses are not worn.³⁴ OOK has been widely used in children not only to treat concurrent myopia, but also in hopes of decreasing myopia progression from reduced peripheral retinal defocus.

Clinically, contact lenses have been used with caution in young children due to increased risk of adverse effects, including epithelial insult, abrasions, and infections. The FDA has not placed any age restrictions on the two OOK lenses currently approved (Paragon CRT™ and Emerald™).³⁵ In 2007, Mika et al investigated the safety and efficacy of the Emerald™ Lens. This pilot study indicated that short-term correction of mild to moderate myopia correction was safe in the 16 subjects used; however, compliance was poor (25% did not complete the study) and most adverse

effects associated with OOK lens wear have previously been shown to occur after six months of wear.³⁶

In Hong Kong and other Asian countries, there is heightened interest in OOK for myopia control due to the high incidence of myopia. The Longitudinal Overnight Research in Children (LORIC) pilot study compared OOK to spectacle lens wear in low to moderate myopic children from eight private practices. They reported no adverse complications with lens wear, as well as high variability in axial length and vitreous chamber depth changes between the two groups.³⁷ Additionally, the Children’s Overnight Orthokeratology Investigation (COOKI) pilot study found that OOK lenses were effective in reducing myopia short-term, but long-term effects were not investigated as the study ceased after six months.³⁸ Preliminary reports of the Controlling Astigmatism and Nearsightedness in Developing Youth study show that myopia progression may be reduced with OOK, but did not state to what extent.³³ Studies that are in progress include the Stabilization of Myopia through Accelerated Reshaping Technologies study. It indicated preliminary stability of myopia after one year of OOK lens wear, rather than an increase in myopia progression.³⁹ An update of the Corneal Reshaping and Yearly Observation of Nearsightedness study showed promising results after two years. They reported significantly less change in axial length and vitreous chamber depth when compared to soft contact lens wearers. These results should be taken cautiously, however, considering the 30% drop-out rate.⁴⁰

Based on these preliminary findings, it is safe to assume that OOK may have the potential to slow myopia progression in individual cases; however, no large-scale, randomized, case-controlled studies have been conducted to reliably prove these findings. Smaller pilot studies show limited promise with guarded prognosis. Many young patients tend to discontinue lens wear due to compliance or comfort. Rigid and soft single vision contact lenses have not been demonstrated to appreciably affect myopia progression. Of all contact lens treatment modalities, bifocal soft contact lenses and OOK show the most initial promise since they combine the benefits of good cosmesis, comfort, and patient compliance.

Pharmaceutical Agents

Most pharmaceutical agents used to control myopia target the ciliary muscle to decrease or paralyze the accommodative response. These cycloplegics are muscarinic receptor antagonists and block the M1 receptors in the ciliary muscle. Activation of the ciliary body results in scleral growth and axial elongation. Based on this theory, inactivation of the ciliary body should impede axial elongation and therefore halt or slow myopia progression.

Tropicamide and cyclopentolate are readily available topical ophthalmic solutions commonly used in routine examinations for dilation and cycloplegia, particularly in children. They are better tolerated than other anti-muscarinic agents because of their fewer side effects (less dilation, accommodative paralysis, and systemic side effects). In chicks, they have been shown to be as effective as pirenzepine ophthalmic gel in blocking form-deprivation myopia.⁴¹ Pilot studies in humans, however, have shown no appreciable effect on myopia progression for either tropicamide or cyclopentolate when compared to saline.⁴² While there have been no large scale or randomized studies conducted with these agents, they are currently not recommended for myopia control.⁴³

Topical atropine solutions have been used historically for a variety of purposes, including long-term cycloplegia and dilation, in addition to myopia control. It is a nonspecific anti-muscarinic for M1, M2, and M3 receptors. Therefore, a wide number of systemic side effects may occur with its use, including tachycardia, dry mouth, skin rashes, and in extreme cases, respiratory failure.^{41,43} One of the largest randomized clinical trials investigating the use of atropine in young myopes was the Atropine for the Treatment of Childhood Myopia study at the Singapore National Eye Center. A drop of 1% topical atropine was used twice daily in only one eye with a vehicle used in the other. Notably, 86.5% of the subjects completed the two-year study, which may be attributed to the unocular study design thus alleviating functional difficulties such as near blur, glare or photophobia. Additionally, subjects were provided with photochromic lenses to further minimize transient side effects. They reported an impressive 77% reduction in the mean progression of myopia in the atropinized eye with the majority of the treatment effect seen in the first year (0.79 D).⁴⁴ The three-year update noted that the effect of atropine treat-

ment, although weaker, was still present after cessation of the eyedrops.⁴⁵ Fan et al also showed favorable results with 1% topical atropine in a smaller case-control study at the Hong Kong Eye Hospital. The cycloplegic agent used for refractive error determination was not standardized, however, and there was no placebo.⁴⁶

The concentration of atropine used has varied across studies without affecting its effect on myopia control. Several studies have reported success with a variety of concentrations, although some researchers found 0.5% atropine to be most effective.^{47,48} Lee et al also confirmed reduction in myopia progression even with 0.05% atropine solution when used regularly.⁴⁹ Some researchers used 0.5% atropine in 227 school-aged myopes in conjunction with multifocal lenses.⁵⁰ They investigated three groups of subjects: those using PALs alone, those using atropine once nightly with PALs, and a control group using single vision lenses. The best results were achieved with atropine therapy in conjunction with multifocal use. This showed 0.77 D and 0.98 D less progression in myopia compared to the multifocal lens group and the single vision lens group respectively. Although the long-term effects of atropine treatment are yet unclear, this agent remains a viable option for reducing myopia progression, particularly when used with multifocal lenses.¹⁹ Pirenzepine ophthalmic gel is a relatively new pharmaceutical agent for myopia control. In Europe, it is used for treatment of dyspepsia and pediatric endocrine disorders and is generally very safe to use in both children and adults. It has advantages over atropine in that it is selective for the M1-receptor, and therefore has fewer side effects than atropine. It is less likely to cause cycloplegia and mydriasis, which are two of the most common complaints with atropine use.⁵⁰ The United States Pirenzepine Study Group conducted a two-year phase two clinical trial investigating the use of 2% pirenzepine ophthalmic gel in 400 children. They reported a 50% reduction in myopia progression (0.30 D) over the first year, which was sustained through the second year after the gel was discontinued. The gel was well tolerated without any serious side effects as demonstrated by the low withdrawal rate of 6%. Despite its safety and effect on refractive error, pirenzepine did not significantly affect axial length, implying that it may not actually retard ocular growth.^{51,52} Additional study is recommended to support

or refute this study. It would also be interesting to use pirenzepine in combination with multifocal use, as with prior atropine and multifocal studies, to see if this option continues to show potential in halting myopia progression.

Other Techniques

Other non-traditional techniques have also been used on a case-by-case basis in hopes of controlling myopia. These are mostly from the Eastern countries and include *Qi gong* (Chinese ocular exercises), acupuncture, eye massage, and electro-photomagneto-stimulation. To date, there are no papers published with current research using these methods, and positive results remain anecdotal.²

Conclusions

Overall, current research shows that bifocals alone as well as soft and rigid gas permeable lenses are not effective in significantly controlling myopia in children. Atropine and topical pirenzepine used alone has shown mildly promising results, but further studies are needed to verify their efficacy. Other concerns include their long-term safety profile, which has not been established and may be of particular concern in children. Further studies using pirenzepine are especially needed to verify its efficacy.

Orthokeratology continues to be a viable option for myopia correction in children, particularly with its effect on minimizing peripheral retinal defocus. However, larger-scale, randomized clinical studies are needed to examine their use in prophylactic control of nearsightedness.

The most positive results appear to be with the subcategory of myopes with esophoria or accommodative insufficiency, or those with a functional component to their myopia development. The use of progressive addition lenses with adjunct pharmaceutical therapy has yielded the most significant treatment effects according to current research. VT is also an excellent option particularly with patients who are motivated not to use optical correction. Soft bifocal contact lenses have shown promising initial results also. Biofeedback has also shown some promise, but additional, placebo-controlled, large-scale studies are needed to validate their success. These and additional clinical recommendations are summarized in Table 2.

More studies are needed to investigate using a combination of therapies. It would be useful to see the effects of a mixture of multifocals, pharmaceuticals, and/or

Table 2: Summary and clinical recommendations for current myopia control methods.

	Method	Clinical Recommendations
Vision therapy	In-office therapy	<ul style="list-style-type: none"> o Optimal results with concurrent accommodative and binocular anomalies o Indicated primarily for functional school-aged or adult-onset myopes o Set reasonable expectations with patients o 12 – 24 in-office sessions recommended o Home maintenance therapy is key to success
	Biofeedback training	<ul style="list-style-type: none"> o Optimal results with concurrent accommodative and binocular anomalies o Variable experimental results; more research needed
Ophthalmic lenses	Bifocals	<ul style="list-style-type: none"> o Somewhat effective in esophores
	Distance undercorrection	<ul style="list-style-type: none"> o Not recommended for myopia control; may increase amount of myopia
	Progressive addition lenses	<ul style="list-style-type: none"> o Minimal clinical effect; somewhat effective in esophores o Generally not recommended as initial therapy for myopia control
Contact lenses	Soft contact lenses	<ul style="list-style-type: none"> o Spherical lenses not recommended for myopia control o Do not increase amount of myopia o Bifocal contact lenses an option for esophoric myopes based on preliminary studies
	Rigid contact lenses	<ul style="list-style-type: none"> o Not recommended for myopia control
	Overnight Orthokeratology	<ul style="list-style-type: none"> o Safe to use in children; however, patient compliance may be an issue o Mixed pilot studies results, but overall shows promise
Pharmaceutical agents	Tropicamide or Cyclopentolate	<ul style="list-style-type: none"> o Not recommended for myopia control
	Atropine	<ul style="list-style-type: none"> o 0.5% topical atropine used once daily shows optimal results o Use with photochromic lenses to minimize side effects and increase compliance o Majority of treatment effect seen in first year of use o Additional myopia reduction and increased patient compliance if used with multifocal lenses o Counsel patients regarding adverse systemic effects
	Pirenzepine	<ul style="list-style-type: none"> o Less side effects – more specific o Minimal effect on myopia progression o May not be readily available in the United States
Other techniques	Qi gong, acupuncture, eye massage, etc.	<ul style="list-style-type: none"> o Not proven to reduce myopia progression

VT. Larger OOK studies are needed as well, examining both the short term and long term effects on myopia progression. Further studies using pirenzepine may add additional insight to the existing United States study. However, there is much promise and active research in myopia control, which is of impending need as the prevalence of myopia increases.

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References

1. Vitale S, Ellwein L, Cotch MF, Ferris FL, et al. Prevalence of refractive error in the United States, 1999-2004. Arch Ophthalmol 2008;126:1111-19.
2. Saw S, Shih-Yen E, Koh A, Tan D. Interventions to retard myopia progression in children. Ophthalmol 2002;109:415-27.
3. Hyman L, Gwiazda J, Hussein M, Norton TT, et al. Relationship of age, sex, and ethnicity with myopia progression and axial elongation in the correction of myopia evaluation trial. Arch Ophthalmol 2005;123:977-87.
4. Xie R, Xiang-Tian Z, Lu F, Chen M, et al. Correlation Between myopia and major biometric parameters of the eye: A retrospective clinical study. Optom Vis Sci 2009;86:E503-E508.
5. Saw S, Gazzard G, Shih-Yen E, Chua W. Myopia and associated pathological complications. Ophthalm Physiol Opt 2005;25:381-91.
6. Rosenfield M, Gilmartin B. Methods of myopia control and reduction. In: Rosenfield M and Gilmartin B. Myopia and Nearwork. Oxford: Butterworth Heinemann, 1998:101-201.
7. Birnbaum M. Optometric Management of Nearpoint Vision Disorders. Santa Ana, CA: Optometric Extension Program, 2008.
8. Saw, S. A synopsis of the prevalence rates and environmental risk factors for myopia. Clin Exp Optom 2003;86:289-94.
9. Ciuffreda K, Vasudevan B. Nearwork-Induced transient myopia (NITM) and permanent myopia—is there a link? Ophthalm Physiol Opt 2008;28:103-14.
10. Bowan M. Stress and eye: New speculations on refractive error. J Behav Optom 1996;7:115-22.
11. Barrett B. A critical evaluation of the evidence supporting the practice of behavioural vision therapy. Ophthalm Physiol Opt 2009;29:4-25.
12. Grosvernor T, Goss D. Clinical Management of Myopia. Boston: Butterworth-Heinemann, 1999.
13. Sherman A, Press LJ. Myopia control therapy. In: Press, LJ. Applied Concepts in Vision Therapy. Santa Ana, CA: Optometric Extension Program, 2007:298-309.
14. Scheiman M, Wick B. Clinical Management of Binocular Vision, 2nd ed. Philadelphia: Lippincott Williams & Wilkins, 1993.
15. Trachtman J, Pelcyger S, Venezia C. Myopia reduction with biofeedback training of accommodation. J Behav Optom 1999;10:87-93.
16. Koslowe K, Spierer A, Rosner M, Belkin M. Evaluation of accommodative biofeedback training for myopia control. Optom Vis Sci 1991;68:338-43.
17. Cheng D, Schmid K, Woo G. The effect of positive-lens addition and base-in prism on accommodation accuracy and near horizontal phoria in Chinese myopic children. Ophthalm Physiol Opt 2008;28:225-37.
18. Goss D, Grosvernor T. Rates of childhood myopia progression with bifocals as a function of near point phoria: consistency of three studies. Optom Vis Sci 1990;67:637-40.
19. Fulk G, Cyert L, Parker D. A randomized trial of the effect of single-vision vs. bifocal lenses on myopia progression in children with esophoria. Optom Vis Sci 2000;77:395-401.
20. Gwiazda, J. Treatment options for myopia. Optom Vis Sci 2009;86:1-5.
21. Jiang B, Bussa S, Tea Y, Seger K. Optimal dioptric value of near addition lenses intended to slow myopic progression. Optom Vis Sci 2008;85:1100-05.
22. Gwiazda J, Hyman, L, Hussein M, Everett D, et al. A randomized clinical trial of progressive addition lenses versus single vision lenses on the progression of myopia in children. Invest Ophthalmol Vis Sci 2003;44:1492-1500.
23. Hasebe S, Ohtsuki H, Nonaka T, Nakatsuka C, et al. Effect of progressive addition lenses on myopia progression in Japanese children: A prospective, randomized, double-masked, crossover trial. Invest Ophthalmol Vis Sci 2008;49:2781-89.

24. Brown B, Edwards M, Leung J. Is esophoria a factor in slowing of myopia by progressive lenses? *Optom Vis Sci* 2002;79:638-42.
25. Langaas T, Riddell P, Svarverud E, Ystenaes A, et al. Variability of the accommodation response in early onset myopia. *Optom Vis Sci* 2008;85:37-48.
26. Philips JR. Monovision slows juvenile myopia progression unilaterally. *Br J Ophthalmol* 2005;89:1196-200.
27. Chung K, Mohidin N, O'Leary DJ. Undercorrection of myopia enhances rather than inhibits myopia progression. *Vision Res* 2002;42:2555-59.
28. Smith EL, III, Kee C, Ramamirtham R, Qiao-Grider Y, et al. Peripheral vision can influence eye growth and refractive development in infant monkeys. *Invest Ophthalmol Vis Sci* 2005;46:3965-72.
29. Smith EL, III, Ramamirtham R, Qiao-Grider Y, Hung LF, et al. Effects of foveal ablation on emmetropization and form-deprivation myopia. *Invest Ophthalmol Vis Sci* 2007;48:3914-22.
30. Walline J, Jones L, Sinnott L, Manny R, et al. A randomized trial of the effect of soft contact lenses on myopia progression in children. *Invest Ophthalmol Vis Sci* 2008;49:4702-06.
31. Aller T, Wildsoet C. Bifocal soft contact lenses as a possibly myopia control treatment: A case report involving identical twins. *Clin Exp Optom* 2008;91:394-99.
32. Katz J, Schein O, Levy B, Cruiscullo T, et al. A randomized trial of rigid gas permeable contact lenses to reduce progression of children's myopia. *Am J Ophthalmol* 2003;136:82-90.
33. Walline J, Jones L, Mutti D, Zadnik K. A randomized trial of the effects of rigid contact lenses on myopia progression. *Arch Ophthalmol* 2004;122:1760-66.
34. Sorbara L, Fonn D, Simpson T, Kort R. Reduction of myopia from corneal refractive therapy. *Optom Vis Sci* 2005;82:512-18.
35. Answers to Questions Commonly Asked by Practitioners. Paragon Corneal Refractive Therapy. <http://www.paragoncrt.com/ecp/faqs.asp>. Accessed 08 April 2009.
36. Mika R, Morgan B, Cron M, Lotoczky J, et al. Safety and efficacy of overnight orthokeratology in myopic children. *Optom* 2007;78:225-31.
37. Bartels D, Wilcox P. CANDY: Controlling astigmatism and nearsightedness in developing youth. <http://www.wavecontactlenses.com/download/candy.pdf>. Accessed 24 Mar 2009.
38. Walline JJ, Rah MH, Jones LA. Children's overnight orthokeratology investigation (COOKI) pilot study. *Optom Vis Sci* 2003;81:407-13.
39. Nichols J. Contact Lenses Today newsletter, *Contact Lens Spectrum*. 2008; October 26. http://www.cltoday.com/issues/CLToday_102608.htm. Accessed 24 Mar 2009.
40. Walline J, Jones L, Sinnott L. Corneal reshaping and myopia progression. *Br J Ophthalmol* 2009; published online 04 May 2009. Accessed 08 May 2009.
41. Frazier M, Jaanus S. Cycloplegics. In: Bartlett J, Jaanus S, ed. *Clinical Ocular Pharmacology*, 5th ed. St. Louis: Butterworth-Heinemann, 2007:125-38.
42. Luft WA, Ming Y, Stell WK. Variable effects of previously untested muscarinic receptor antagonists on experimental myopia. *Invest Ophthalmol Vis Sci* 2003;44:1330-38.
43. Yen MY, Liu JH, Kao SC, Shiao CH. Comparison of the effect of atropine and cyclopentolate on myopia. *Ann Ophthalmol* 1989;21:180-87.
44. Chua W, Balakrishnan V, Chan Y, Tong L, et al. Atropine for the treatment of childhood myopia. *Ophthalmol* 2006;113:2285-91.
45. Tong L, Huang X, Koh A, Zhang, X, et al. Atropine for the treatment of childhood myopia: Effect on myopia progression after cessation of atropine. *Ophthalmol* 2009;116:572-79.
46. Fan D, Lam D, Chan C, Fan A, et al. Topical atropine in retarding myopic progression and axial length growth in children with moderate to severe myopia: A pilot study. *Jpn J Ophthalmol* 2007; 1:27-33.
47. Shih YF, Chen CH, Chou AC, Ho TC, et al. Effects of different concentrations of atropine on controlling myopia in myopic children. *J Ocul Pharmacol Ther* 1999;15:85-90.
48. Chou AC, Shih YF, Ho TC, Lin LL. The effectiveness of 0.5% atropine in controlling high myopia in children. *J Ocul Pharmacol Ther* 1997;13:61-67.
49. Lee J, Fang P, Yang I, Chen C et al. Prevention of myopia progression with 0.05% atropine solution. *J Ocul Pharmacol Ther* 2006;22:41-46.
50. Shih Y, Hsiao CK, Chen C, Chang CW, et al. An intervention trial on efficacy of atropine and multi-focal glasses in controlling myopic progression. *Acta Ophthalmol Scan* 2001;79:233-36.
51. Siatkowski M, Cotter S, Miller J, Scher C, et al. Safety and efficacy of 2% pirenzepine ophthalmic gel in children with myopia. *Arch Ophthalmol* 2004;122:1667-74.
52. Siatkowski M, Cotter S, Crockett RS, Miller J, et al. Two-year multicenter, randomized, double-masked, placebo-controlled, parallel safety and efficacy study of 2% pirenzepine ophthalmic gel in children with myopia. *J AAPOS* 2008;12:332-39.

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