Myopia Control: Methods to Slow the Progression of Childhood Myopia

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By

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Abstract

Myopia is one of the most common eye diseases that affect the U.S. and the world. Myopia, or nearsightedness, is a condition of the eye in which light focuses in front of the retina rather than on the retina. Recent studies have shown that myopia is a combination of both genetic and environmental factors. Myopia has increased dramatically in children due to increased near work and decreased time outdoors. As the disease has become increasingly more common, new treatments have been developed to manage and stop the progression of it. This review looks at recent literature and clinical studies to determine what works for myopia control. Low dose atropine and pirenzepine proved to be effective but is rarely used due to the multitude of side effects. Treatments such as undercorrection, bifocals, progressive lenses, orthokeratology contacts, and multifocal contacts were evaluated for effectiveness, safety, and practicality. The results of these studies showed that undercorrection was either harmful or had no effect on myopia progression. Bifocals and progressive corrective lenses showed positive results in some studies but were ineffective in others. Orthokeratology proved to be effective in slowing myopia progression, but often resulted in infections. Increased time outdoors and light exposure decreases the risk of developing myopia, but not slowing its progression. Multifocal contact lenses were the most effective and safest intervention as they slowed myopia progression by nearly 50% when compared to the control group.

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Introduction

Myopia, or nearsightedness, is a common eye condition that results in blurred vision when focusing on distant objects, but clear vision when viewing near objects (Smith and Walline 2015). Patients with myopia typically have abnormally long eyes. This anatomical change in the axial elongation, or length of the eye, is what causes the blurred vision. Refraction is the process by which light is bent due to differences in the speeds at which light travels through materials. In myopic patients, refractive errors prevent light from being focused onto the retina, the light-sensitive layer inside the eye. Because the symptoms of myopia can often be corrected with eyeglasses, contact lenses, and laser eye surgeries, it is often overlooked as a public health issue. However, myopia also has many physical, social, and economic effects on the patient’s life. Myopia has also been shown to increase the risk for other serious eye diseases such as glaucoma, retinal detachments, and cataracts (Mitchell et al. 1999, Burton 1989, Younan et al. 2002).

Children with parents who have high myopia have been shown to have an increased risk of developing myopia. Several genes that may lead to an increased risk of high myopia have been identified (Jones-Jordan et al, 2010). Myopia progression has been shown to increase in the winter and slow in summer months. Gwiazda et al. suggests that this increase in progression during winter months was due to the children’s decreased outdoor time, limited sunlight light exposure, and more time studying and performing near work activities in school (Gwiazda et al, 2013). Several other studies have also suggested a link between limited sunlight exposure and increased myopia progression (Read et al, 2015). This suggests that myopia is caused by a combination of genetic and environmental factors (Jones-Jordan et al, 2010).

The prevalence of myopia in the United States and in the world has dramatically increased over the past few decades and nearly a third of the United States population has myopia (Vitale et al. 2009). It is expected that nearly 5 billion people in the world will have myopia by the year 2050 (Holden et al. 2016). “In developed countries of East and Southeast Asia, the prevalence of myopia is now 80-90% in children completing secondary schooling at the age of 17-18 compared to the prevalence of 20-40% seen in many developed western countries” (Morgan et al, 2018).

As the prevalence of myopia and the more serious high myopia have increased significantly in recent years, new treatment methods have been developed to slow its progression. In this review I will give an extensive background on the condition, present its likely causes, and evaluate the efficacy and practicality of many of the non-surgical methods that are being used to slow the progression of myopia in children.

Anatomy and Physiology of the Eye

The outermost layer of the eye is the fibrous tunic, which is made up of the cornea and sclera (figure 1). The sclera is the firm, white layer that surrounds most of the outer portion of the eye. The cornea is the clear, curved layer that protrudes from the sclera. The transparency of the cornea allows for light

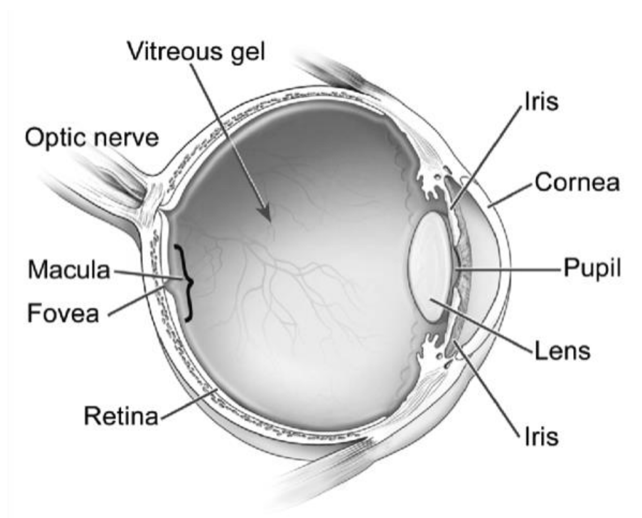

Figure 1: Anatomy of the Eye. Image available from: https://www.flickr.com/photos/nationaleyeinstitute/7544457228/in/photostream/

rays to enter the eye. The middle layer of the eye is the vascular tunic and contains the iris, ciliary body, and choroid (Asbury, et al. 2011). The iris is the colored part of the eye that surrounds the pupil. The innermost layer of the eye is the retina. The retina is a thin, multilayered sheet on the inner posterior portion of the eye that surrounds the vitreous gel (Asbury, et al 2011). The center of the retina is the macula that functions in central vision. The small central fovea has the sharpest vision of all due to a high density of photoreceptors (Callier and Balintfy 2017).

As light passes through the cornea, it enters the aqueous humor before entering the lens of the eye. The lens is located posterior to the iris and is suspended by the zonular fibers that protrude from the ciliary body (Asbury, et al 2011). The crystalline lens refracts the light rays and focuses them towards one focal point in the back of the eye. After passing through the lens, the light rays travel through the vitreous humor. The vitreous humor is the viscous fluid (gel) that fills the vitreous chamber in the center of the eye. The light then reaches the retina. The retina is a thin layer of tissue that contains photoreceptors, such as rods and cones that have visual pigments inside them to detect the incoming light. This causes a change in membrane potential causing a change in the level of neurotransmitters that are released by these cells onto bipolar cells. These bipolar cells connect the photoreceptors to retinal ganglion cells. Axons of the retinal ganglion cells convene at the optic disk and leave the eye as cranial nerve II, the optic nerve that carries the impulse to the brain (Asbury, et al 2011).

Accommodation is the process the lens of the eye uses to adjust refractive power to be able to focus on both objects that are up close and others that are far away. A diagram of accommodation can be seen in figure 2. This adjustment in focal power of the lens is achieved through physical changes of the lens of the eye. The ciliary muscles of the eye have an antagonistic relationship with the tension of the zonular fibers (McDougal and Gamlin 2015). When focusing on a distant object, the suspensory ligaments or zonular fibers tighten when the ciliary muscle relaxes. This action causes the lens to flatten as it is pulled upon (Asbury, et al. 2011). The flattened lens acts as a concave or diverging lens in order to increase the focal length of the lens. When viewing a close object, such as reading a book, the zonular fibers relax as the ciliary muscle contracts. This causes the lens to thicken as it balls up. This action allows for the lens to act like a convex or converging lens in order to decrease the focal length of the eye's lens. With age, ultraviolet light exposure and other environmental factors, the lens loses its pliability and stiffens. This decreased flexibility can lead to patients having decreased near vision, as the lens tends to hold its flatter shape (Maheshwari R, et al 2011). Excessive near work has been shown to increase the risk for developing and advancing the progression of myopia (Woodman et al 2011, Ghosh et al 2014, Zhong et al. 2014, Saw 2002). Many recent treatments focus on reducing the strain that is put on ciliary muscles that are involved in near accomodation.

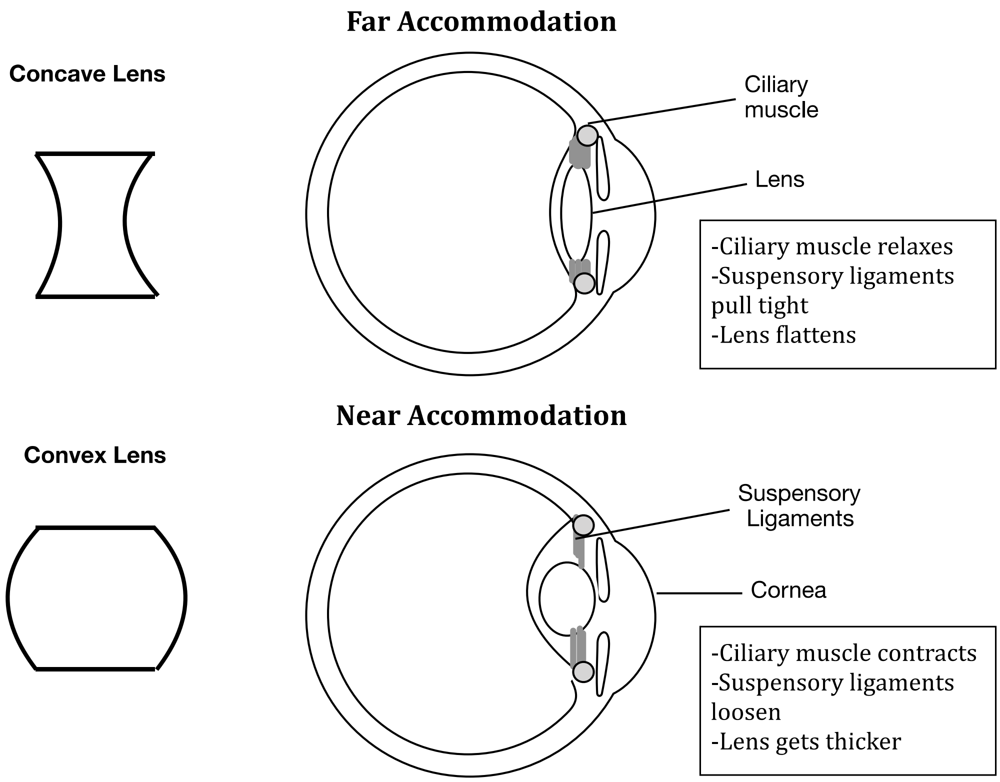

Figure 2: The anatomical changes of the lens of the eye during far and near accommodation can be seen in this diagram. Concave and convex lenses can also be seen above on the left. During accommodation, the lens of the eye changes shape and resembles either a convex or concave lens, much like those used in corrective lenses.

Optics of Myopia

Myopia is an example of a refractive error, or improper focusing of light through the eye. Common types of refractive errors include myopia, astigmatism, and presbyopia. In emmetropic people, or people with normal vision, clear vision is achieved when light is focused onto the retina (Figure 3). Astigmatism is a refractive error caused by an irregularly shaped cornea. In astigmatic patients, one side of their cornea is more curved than the other and rather than being shaped like one half of a basketball, it is more like one side of a football. This type of refractive error causes light to come to a focal point in multiple spots on the retina, rather than converging on one point. Presbyopia is the condition in which the lens of the eye becomes more stiff and rigid with age. This decreases the pliability of the lens and therefore its ability to accommodate. This causes the patient to lose their ability to focus on near objects while their distance vision is not affected (Asbury, et al. 2011).

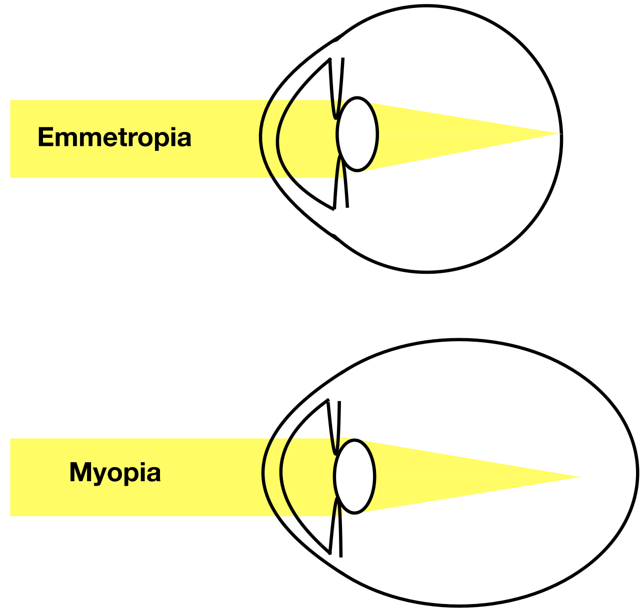

Figure 3: These light ray diagrams demonstrate the differences between refraction in emmetropia (normal vision) and the refractive error in myopia (nearsightedness).

When an emmetrope focuses on a distant object, the ocular lens flattens to mimic a concave or diverging lens. A diagram of these lenses can be seen in figure 2. This allows the person to have clear vision of distant objects. In myopic patients, light rays come to a focal point before the retina. In most myopic patients, this is the result of abnormal elongation of the eye, which prevents the light from being properly focused onto the retina (Asbury, et al. 2011).

The common treatment for myopia is through the use of diverging lenses. These diverging lenses help to expand the focal length of incoming rays of light. These lenses compensate for the irregular length of the eye to allow for the light rays to converge onto the retina. Diverging lenses have a negative power while converging lenses have a positive power. The power of a lens is equivalent to the inverse of the focal length in meters (P=1/f). The focal length is the distance in meters that it takes for the light rays to converge or come to a focal point. The SI unit for power is diopters (D). The number of diopters represents the optical power of a lens. Because traditional myopia treatments require diverging lenses, a myopic prescription would have a negative power or minus diopters. Converging lenses, or convex lenses, are those with a positive power or plus diopters. An example of convex and concave lenses can be found in figure 2.

Every substance has a different index of refraction. The index of refraction is the ratio of the speed of light in a vacuum to that in the material (Hecht 1998). This index of refraction is the speed at which light passes through the material. When light rays pass from one substance to another, the light rays bend due to a difference in the index of refraction of the two substances. Snell's law, or the law of refraction, can be used to calculate the degree to which the light rays are bent (Hecht 1998). Each layer of the eye has a different index of refraction as well as optical power that naturally help to refract light through the eye and onto the retina. The cornea, which has an index of refraction of 1.378, provides the largest refractive power. This is because amongst all of the layers of the eye, there is the largest change in the index of refraction between the cornea and the air outside of the eye, which has an index of refraction of 1.00 (Joo and Jung 2012). The lens provides the remaining power necessary to refract the light in order to form an inverted, real image on the retina (Asbury, et al. 2011).

Myopia severity is generally characterized by the power of the corrective lenses that are required to correct the patient's vision. The power of the corrective lenses is on a scale from 0 diopters to negative infinity. The more negative the number, the higher the prescription is and the more severe the myopia is. An emmetropic person would require a corrective lens with 0.00 diopters of power. This is because they do not require any additional refractive power in order for light rays to be focused onto the retina. A patient with myopia may be prescribed a prescription of -2.00 D. This prescription indicates that the patient requires an additional two diopters of power in order to properly focus the light rays onto the retina. These corrective lenses are diverging in order to extend the normal focal length of the eye in order to accommodate for the longer myopic eye. High myopia is a condition in which the power of the corrective lenses is -5.00 D or less (WHO 2015).

Single Vision Diverging Lenses

The most common treatment for myopia is through the use of single vision diverging lenses. Single vision lenses are those that correct for refractive errors in distance vision or near vision, but not both. The single vision diverging lenses add to the refractive power of the myopic eye in order to refocus light onto the retina. In contrast, bifocal or progressive eyeglass lenses correct refractive errors that result in both blurred distance and near vision. Typical myopia treatment may involve the use of contact lenses or spectacle lenses which both correct myopia in a similar way. This treatment corrects the symptoms of myopia, but not the disease itself as the eye is still abnormally long or the cornea still has an irregular shape.

Undercorrection of Myopia

One intervention to slow myopia progression is under correction of myopia. One hypothesis for the myopia development and progression is that it is caused by annual correction of myopia. It was thought that the eye may adapt to the new prescription and therefore this constant correction is leading to increased myopia. This treatment would give patients slightly less then their required corrective prescription in order to focus light in slightly in front of the retina rather than back onto the retina. This would in turn reduce the accommodative response necessary for these individuals to focus on near objects as this reduced prescription is helping to naturally focus their eyes less for distance only (Vasudevan et al, 2014). In other words there is less of a minus prescription for these individuals to have to look through in order to allow for easier near accommodation for viewing near objects (Adler and Millodot 2006). Animal studies with chicks in which myopia was induced using corrective lenses have shown that myopic defocus may stop axial elongation from occurring (Whatham and Judge 2001). Myopic defocus is when the image is formed in front of the retina (Adler and Millodot 2006). Emmetropization is the process in which ocular defocus guides proper development of the eye. This feedback system instructs the eye to grow longer or prevents growth when necessary to prevent refractive errors (Chung et al, 2002). This process regulates and is meant to ensure proper development of the eye. It has been surmised that by correcting myopia with diverging lenses, we are interfering with this normal feedback mechanism and encouraging further myopia progression. Undercorrection has been proposed as a potential solution to this problem. Unfortunately undercorrection has been shown to either increase myopia progression or have no effect (Chung et al, 2002; Adler and Millodot 2006, Vasudevan et al, 2014 Li S.M et al, 2012).

Bifocal and Progressive Eyeglass Lenses

Another treatment that has been shown to slow the progression of myopia is through the use of multifocal or progressive eyeglass lenses. One clinical study known as the COMET study investigated the efficacy of these progressive addition lenses (PAL) compared to the traditional single vision lenses (SVL). Progressive lenses, like bifocals provide refractive correction for both near and distant vision. However, progressive lenses have correction for distance vision on the top and the power in the lenses progressively changes to a reading prescription on the bottom portion. A representation of progressive lenses can be found in Figure 4. Numerous studies have shown a connection between excessive near work and increased myopia progression. The excessive accommodation theory states that myopia is caused by excessive near work

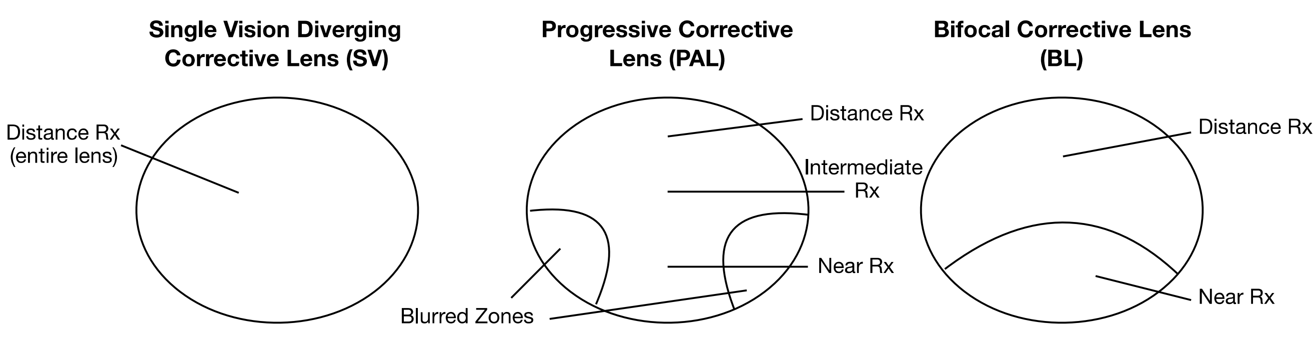

Figure 4: These are three common types of corrective lenses that are also used in myopia treatments. The first diagram shows single vision diverging corrective lenses (SV) in which the entire lens contains the same prescription. The second diagram shows the design of progressive addition lenses (PAL). These lenses progressively transition from a distance prescription on the top to a near prescription on the bottom of the lens to allow for focusing on objects at various distances. The last diagram shows the design of bifocal corrective lenses (BL). These lenses contain a distance prescription on the top and an additional power on the bottom for near vision. Unlike PALs, BLs have a noticeable line and do not correct for refractive errors at an intermediate distance

such as reading on phones and from books. Excessive accommodation causes the eye to grow and elongate in order to minimize its need to accommodate. By giving PALs to children, who normally would not require a reading prescription, the need for the eye to accommodate is eliminated. PALs provide the refractive power that would otherwise have been provided by near accommodation of the eye thus eliminating the children's need to accommodate (Gwiazda et al, 2003).

The National Eye Institute and National Institute of Health funded the Correction of Myopia Evaluation Trial (COMET). The study was designed by researchers at the New England College of Optometry and was implemented at four different colleges of optometry in Birmingham, Alabama; Boston, Massachusetts; Houston, Texas; and Philadelphia, Pennsylvania. In total, 450 children between the ages of 6 and 11 were randomly assigned either SV or PAL to wear for three years. The myopic children required between -1.25 and -4.50 D of correction at the start of the study. The children were examined every six months over the three-year study to evaluate the progression of their myopia. The children with the progressive lenses were given their normal distance prescription with +2.00 D add power. This add power represents the additional power added onto the patient's distance prescription in order to create their reading prescription for the bottom of the lens. This additional power was used because it has been shown to be more effective than smaller add powers (Gwiazda et al, 2003).

The results of the COMET study showed that the use of progressive lenses led to a decreased progression of myopia when compared to the children with the single vision lenses. The progression of myopia was slowed by 17% as compared to the SV group (Gwiazda et al, 2003). According to Smith and Walline, a treatment is only considered to be clinically significant if myopia progression was slowed by at least fifty percent (Smith and Walline 2015; WHO, 2015). Therefore the results of the COMET study were statistically but not clinically significant. These patients who were fitted with progressive lenses showed the slowest myopia progression during the first year.

It is also important to consider the adaptability of myopic children from SV to PALs. A portion of the COMET study looked into the ability of children to adapt to progressive lenses. Many adults who are fitted with PALs often have difficulty adapting to PALs due to the peripheral blur of the induced astigmatism in the blurred regions of the lens (Kowalski et al, 2005). A future standard myopia control treatment must also be practical in addition to safe and effective. The COMET researchers wanted to ensure that these PALs were not compromising the children's vision. Kowalski et al reported that children can safely and comfortably wear PALs for at least three years (2005).

Another study by Cheng et al. used bifocal lenses (BL) to try to slow myopia progression. Bifocals are eyeglass lenses that contain a distance prescription on the top and a reading prescription on the bottom. Unlike progressive lenses they have a line that divides the two zones and do not contain any prescriptions for intermediate distances. A diagram of these lenses can be found in Figure 4. This three year clinical study enrolled 135 children between the ages of 8 and 13 with average myopia of -3.08 D. The patients also had myopia progression of at least -0.50 D per year in the years before the study. The subjects were randomly assigned either BL or SV lenses. The patients with the BL were given a near add power of 1.50 D. One group was also given BL with prism added to test whether or not the prism would have an effect on myopia progression in individuals who did not normally require corrective lenses with prism (Cheng et al.

2014). Prism shifts the optical center, or the strongest prescription in the lens, slightly up, down, right, or left. Prism is typically used to correct double vision that is caused by strabismus, which is when the eyes do not focus on the same point at the same time. This condition is also referred to as having crossed eyes (AOA 2018).

The results of the study showed that the SV subjects had an average prescription change of -2.06 D, BL subjects had an average prescription change of -1.25 D, and the BL with prism group had a -1.01 D change over the 3 years study. Axial length, or length of the eye, was also measured and the increase was 0.82mm for the SV group and 0.57mm for the BL group and 0.54mm for the BL with prism group. This study suggests that BL with prism can be an effective treatment to slow myopia progression as well as axial elongation (Cheng et al. 2014).

Both of these studies report decreased myopia progression in the BF and PAL groups as compared to the SV group. The results of both were statistically significant, but not clinically significant. Other studies have also evaluated the use of PAL/BF lenses for myopia control and found little or no effect (Berntsen et al, 2012; Edwards et al, 2002).

Multifocal Contact Lenses

Multifocal contact lenses are typically prescribed to adults over the age of forty who suffer from presbyopia. These multifocal contact lenses contain an additional power or reading prescription that compensates for the eye’s inability to undergo successful accommodation. These lenses contain prescriptions to allow for clear vision at near and far focal points. Multifocal contact lenses are designed in various ways, but the lenses used in myopia control are primarily distance center multifocal lenses. Distance center lenses, like the multifocal lens in Figure 5, contain a distance prescription in the middle and a near prescription on the outer portion of the lens.

Multifocal contacts (MF) have shown promise in slowing myopia progression. In a myopic individual, these multifocal lenses act in a similar way. The reading prescriptions in these MF contact lenses mitigate the eye's need to accommodate when focusing on near objects. These lenses also create a blurred effect for peripheral vision and induce myopic defocus (Figure 5). This blur may act as a signal to slow eye growth (Ticak and Walline 2013). According to Dr. David Berntsen, O.D., Ph.D. of the University of Houston College of Optometry, both bifocal contact lenses and bifocal eyeglasses focus light onto the macula at the center of the retina. However, spectacle glasses focus peripheral light behind the peripheral retina, which may be causing the axial elongation. Conversely, both multifocal and bifocal contact lenses focus light slightly in front of the peripheral retina (Callier and Balintfy 2017). Animal studies have shown that focusing light in front of the retina stops further axial elongation (Smith et al, 2014). This is the theory behind the use of multifocal contact lenses in slowing myopia progression.

Dr. Jeffrey Walline and his team conducted a clinical trial to test whether

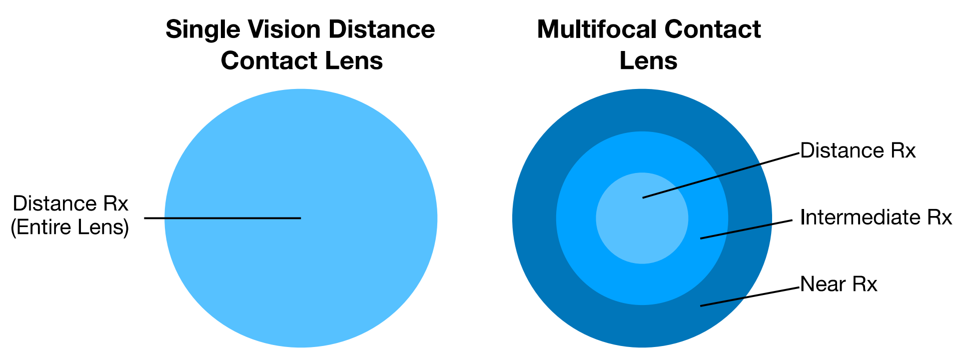

Figure 5: Single vision distance contact lenses compared to distance center multifocal contact lenses. Single vision or spherical contact lenses have one prescription strength throughout the entire contact lens. Multifocal contact lenses contain three prescription strengths to allow for focusing on various distances.

commercially available multifocal contact lenses would be an effective myopia control treatment. The study utilized 40 participants, between the ages of 8 and 11, who were randomly assigned either SV or MF contact lenses. The children also had prescriptions between -1.00 and -6.00D and minimal astigmatism or other ocular conditions in order to eliminate unnecessary variables. The SV lenses acted as a control, or the standard treatment method. The MF lenses contained the children's normal corrective distance prescription along with +2.00 D of additional power in the periphery of the lens. The study lasted 2 years and the participants were monitored along the way. At the end of the two years, the results showed that MF lenses slowed myopia progression by 50%. This treatment also slowed axial elongation as well. These results show both statistically and clinically significant results making MF contact lenses an effective and safe option for myopia control (Walline et al, 2013).

Another study conducted by Lam et al. also reviewed the efficacy of multifocal contact lens treatments. This 2-year study enrolled 128 children that were randomly assigned either MF or SV contact lenses. The subjects with the MF contact lenses were given a +2.50 D additional power. Their results showed that the MF group progressed about 25% slower than the SV group (Lam et al 2013). Holden et al. had a similar design that utilized participants with MF contact lenses and SV contact lenses. These MF contacts had the near prescription on the periphery of the lenses of +1.50 D. The results of the study revealed that the MF lenses slowed myopia progression by 39% (Holden et al, 2012).

Orthokeratology

Another approach to slow myopia progression is through the use of orthokeratology. These lenses, also known as corneal reshaping contacts, are rigid contacts that are specially designed to correct refractive errors by altering the shape of the cornea. These orthokeratology (OK) contacts have been used since the early 1960's to correct refractive errors (Sun et al, 2015). The patient wears OK contact lenses while they sleep and removes them during the day. These lenses are gas-permeable in order for oxygen to diffuse through the lens to prevent the eye from becoming hypoxic. OK contacts, as seen in Figure 6, flatten and thin the center of the cornea and thicken the mid-peripheral cornea (Lin et al, 2014). This flattening of the front surface of the cornea reduces myopia up to -6.00 D. These lenses act by creating peripheral myopic blur by focusing light slightly in front of the retina to slow myopia progression (Smith and Walline 2015).

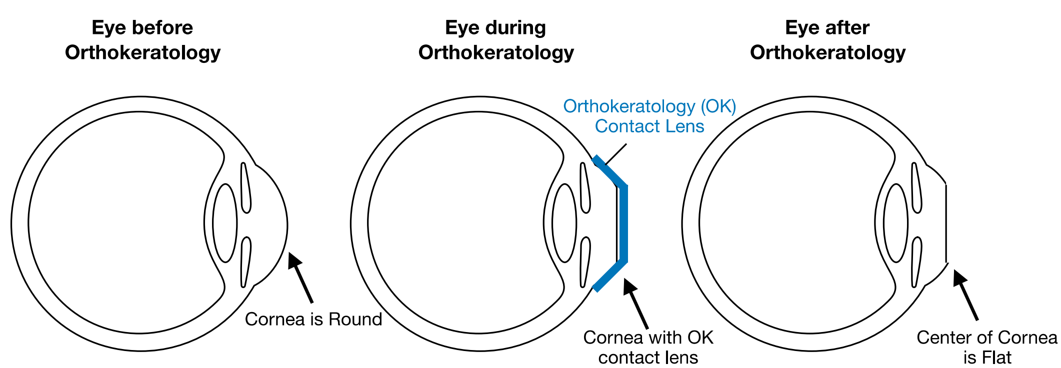

Figure 6: This diagram shows the eye before, during, and after the orthokeratology (OK). Before orthokeratology, the cornea is rounded. When a patient wakes up and removes these OK lenses, the front of their cornea is flat and their vision is temporarily corrected.

One study conducted by Cho et al., "The longitudinal orthokeratology research in children (LORIC)" tested the effectiveness of orthokeratology contacts in children in Hong Kong (2005). This study lasted two years and enrolled 35 individuals. Their results showed over a 50% reduction in axial elongation and myopia progression. Unfortunately this treatment has also led to many severe cases of microbial keratitis, which is inflammation of the cornea that is caused by microbial organisms (Leo and Young 2011).

Walline et al. also conducted a similar two-year study with OK contact lenses in 2009. They reported an average increase in axial elongation of 0.25 mm in the OK group and 0.57 mm in the control group. This shows over a 50% decrease in axial elongation and myopia progression when compared to the control group (Walline et al, 2009).

Other Myopia Control Interventions

Atropine drops have also been used to treat myopia progression. Atropine is a nonselective muscarinic acetylcholine receptor antagonist. The drug blocks the neurotransmitter acetylcholine from binding to these receptors and prevents smooth muscle contraction from occurring. When atropine is administered to the eyes as an eye drop, it causes the pupils to dilate and prevents accommodation (Lin et al, 2014). Many animal studies have shown the efficacy of atropine in slowing myopia progression (Leo and Young, 2017). Although several studies have indicated atropine as an effective treatment method, it is not used ubiquitously due to its many side effects. Atropine leads to increased intraocular pressure in the eye, which can lead to glaucoma. It also causes sensitivity to light and poor near vision as accommodation is inhibited. Even low doses of atropine can also cause damage to the crystalline lens and retina. This is caused by the dilated pupils allowing an abundance of harmful light to reach the retina and lens of the eye. Although atropine is one of the most effective interventions for slowing myopia progression, it is often not used for these reasons (Lin et al, 2014). Pirenzipene, which is also a muscarinic blocker, has been suggested as a safer substitute for atropine in myopia treatment. However, few long-term studies have been conducted to test its safety and efficacy in humans (Ganesan and Wildsoet, 2010).

Conclusion

There have been many studies testing for the safety, efficacy, and practicality of various methods to slow the progression of myopia in children. However, few have shown promising results beyond the first two years of treatment. Many studies did not track myopia progression in myopia patients beyond three years. Undercorrection of myopia should never be used because it either increases myopia progression or has no effect (Vasudevan et al, 2014). Recent studies with bifocal eyeglasses lenses have shown that they are more effective when prism is added to the lenses (Cheng et al, 2014). Future studies with bifocals should evaluate the long-term effects of these lenses and their effect on the patient's vision. Progressive lenses have been effective in some studies but not in others (Gwiazda et al, 2003). When the COMET study was repeated in COMET2, the results showed that the PALs were not as effective in slowing myopia progression (COMET2, 2011). Orthokeratology is not commercially available and has been shown to increase the risk of many eye infections and other ocular diseases (Leo and Young 2011; Walline et al, 2009). Although OK contacts are very effective during the first few years of treatment, further research should be done on long-term efficacy and safety. Atropine and pirenzepine are not widely used due to their side effects. Safer drugs need to be developed and tested to slow progression with less harmful side effects (Lin et al, 2014).

Multifocal contact lenses appear to be the safest and most effective in slowing myopia progression. The ongoing BLINK study will show the long-term effects and safety of multifocal contact lenses on myopia progression (Walline et al, 2017). As with all contacts, multifocal contact lenses do come with the risk of infection. Corneal neovascularization, or blood vessel growth on the cornea, can occur if contact lenses are over worn or not cleaned properly (Cogan, 1962). Children are highly adaptable to contact lenses and can learn to safely and effectively utilize these multifocal lenses with the guidance of their parents and optometric/ophthalmic professionals (Walline et al, 2013). These lenses also do not compromise the vision of the children as they still have their full myopia correction in these lenses for their distance vision (Holden et al, 2012). These multifocal lenses also may help reduce eyestrain from over-accommodation as well as creating a beneficial myopic blur from the additional power on the periphery of the lenses. Peripheral myopic blur has been shown to slow axial elongation in both animal and human studies (Ticak and Walline 2013). Multifocal contact lenses are fairly inexpensive when compared to other myopia treatments and may also be covered by some insurance (Smith et al, 2014). These contact lenses are also commercially available from optical shops, online distributors, and other pharmacies.

Children with parents who have high myopia should have more frequent eye exams, spend more time outdoors, get more light exposure, and reduce their near work activities. These preventative measures have been shown to help mitigate children’s risk of developing myopia and may help to slow its progression. Future studies should look into safer, more effective, and more accessible treatments to slow childhood myopia. Multifocal contact lenses have been shown to be the most effective, current treatment for slowing myopia progression in children.

References Cited

Adler D, Millodot M. 2006. The possible effect of undercorrection on myopic progression in children. Clinical and Experimental Optometry 89(5):315-321.

American Optometric Association (AOA). 2018. Strabismus (Crossed Eyes). American Optometric Association. Available from: https://www.aoa.org/patients-and-public/eye-and-vision-problems/glossary-of-eye-and-vision-conditions/strabismus

Asbury T, Augsburger J, Biswell R, Chan T, Chang D, Charles S, Chong N.H. V, Colenbrander A, Correa Z, Cunningham E, Faye E, Flach A, Fletcher E, Fraunfelder F, Fredrick D, Garcia-Ferrera F, Graham E, Harper R, Hodge W, Hoyt W, Kent S, Motley W, Nijm L, Pavesio C, Pirbhai A, Pringle E, Riordan-Eva P, Salmon J, Schwab I, Shock J, Sterns G, Sullivan J, Vagefi M. 2011. Vaughan and Asbury's General Ophthalmology. 18. McGraw Hill.

Berntsen D, Sinnott L, Mutti D, Zadnik K. 2012. A Randomized Trial Using Progressive Addition Lenses to Evaluate Theories of Myopia Progression in Children with a High Lag of Accommodation. Investigative Ophthalmology and Visual Science 53(2): 640-649.

Burton T. 1989. The influence of refractive error and lattice degeneration on the incidence of retinal detachment. Transactions of the American Ophthalmological Society 87: 143-157.

Callier V, Balintfy J. 2017. Myopia: A close look at efforts to turn back a growing problem. National Eye Institute

Cheng D, Woo G, Drobe B, Schmid K. 2014. Effect of bifocal and prismatic bifocal spectacles on myopia progression in children. Three-year results of a randomized clinical trial. JAMA Ophthalmol 132(3):258-264.

Cho P, Cheung SW, Edwards M. 2005. The Longitudinal orthokeratology research in children (LORIC) in Hong Kong: a pilot study on refractive changes and myopic control. Curr Eye Research 30(1):71-80.

Chung K, Mohidin N, O'Leary D. 2002. Undercorrection of myopia enhances rather than inhibits myopia progression. Vision Research 42:2555-2559.

Cogan D. 1962. Corneal Vascularization. Investigative Ophthalmology 1(2):253-261.

Correction of Myopia Evaluation Trial 2 Study group for the Pediatric Eye Disease Investigator Group. 2011. Progressive-addition lenses versus single-vision lenses for slowing progression of myopia in children with high accommodative lag and near esophoria. Investigative Ophthalmology and Visual Science 52(5):2757-2759.

Edwards M, Li R, Lam C, Lew J, Yu B. 2002. The Hong Kong progressive lens myopia control study: study design and main findings. Investigative Ophthalmology and Visual Science 43(9):2852-2858.

Ganesan P, Wildsoet C. 2010. Pharmaceutical intervention for myopia control. Expert Rev Ophthalmol 5(6): 757-787.

Ghosh A, Collins M, Read S, Davis B, Chatterjee P. 2014. Axial elongation associated with biomechanical factors during near work. Optometry and Vision Science 91 (3): 322-329.

Gwiazda J, Deng L, Manny, R, Norton T. 2014. Seasonal Variations in the progression of myopia in children enrolled in the Correction of Myopia Evaluation Trial. Investigative Ophthalmology and Visual Science 55:752-758.

Gwiazda J, Hyman L, Hussein M, Everett D, Norton T, Kurtz D, Leske M, Manny R, Marsh-Tootle W, Scheiman M, COMET Group. 2003. A randomized clinical trial of progressive addition lenses versus single vision lenses on the progression of myopia in children. Investigative Ophthalmology and Visual Science 44(4): 1492-1500.

Hecht E. 1998. Geometrical optics. In: Optics. Berrisford J, editor. 3rd ed. Addison Wesley.

Holden B, Fricke T, Wilson D, Jong M, Naidoo K, Sankaridurg P, Wong T, Naduvilath T, Resnikoff S. 2016. Global Prevalence of Myopia and High Myopia and Temporal Trends from 2000 through 2050. Ophthalmology 123(5): 1036-1042.

Holden B, Sankaridurg P, De La Jara P, Naduvilath T, Ho A, Sweeney D, Markoulli M, Smith E, Ge J. 2012. Decreasing peripheral hyperopia with distance-centre relatively-plus powered periphery contact lenses reduced the rate of progress of myopia: a 5 year vision Crc study. Investigative Ophthalmology and Visual Science 53(6300).

Jones-Jordan L, Sinnott L, Manny R, Cotter S, Kleinstein R, Mutti D, Twelker D, Zadnik K, and the Collaborative Longitudinal Evaluation of Ethnicity and Refractive Error (CLEERE) study group. Investigative Ophthalmology and Visual Science 51:115-121.

Joo W, Jung M. 2012. A Study of Optical Proterties of intraocular lenses and of Measurement of index of Reflection for an Unknown Liquid. Journal of the Optical Society of Korea 16(3):236-242. DOI: 10.3807/JOSK.2012.16.3.236

Kowalski P, Wang Y, Owens R, Bolden J, Smith J, Hyman L. 2005. Adaptability of Myopic Children to Progressive Addition Lenses with a Modified fitting Protocol in the Correction of Myopia Evaluation Trial (COMET). Optometry and Vision Science 82(4):328-337.

Lam C, Tang W, Tse D, Tang Y, To C. 2013. Defocus incorporated soft contact (DISC) lens slows myopia progression in Hong Kong Chinese schoolchildren: a 2-year randomised clinical trial. British Journal of Ophthalmology 98:40-45.

Leo S, Young T. 2011. An evidence-based update on myopia and interventions to retard its progression. American Association for Pediatric Ophthalmology and Strabismus 15(2): 181-189.

Lin H, Wan L, Tsai F, Tsai Y, Chen L, Tsai A, Huang Y. 2014. Overnight orthokeratology is comparable with atropine in controlling myopia. BMC Ophthalmology 14:40.

Li S.M., Li S.Y., Liu L.R. 2012. Full correction and undercorrection of myopia evaluation trial (FUMET): design and baseline data and baseline date. Clin Exp Ophthalmol 41:329-338.

Maheshwari R, Sukul R, Gupta Y, Gupta M, Phougar A, Dey M, Jain R, Srivastava G, Bhardwaj U, Dikshit S. 2011. Accomodation: It's relation to refractive errors, amblyopia, and biometric parameters. Nepal J Ophthalmol 3 (6):146-150.

McDougal D, Gamlin P. 2015. Autonomic control of the eye. Comprehensive Physiology 5(1): 439-473. DOI: 10.1002/cphy.c140014

Mitchell P, Hourihan F, Sandbach J, Wang J. 1999. The relationship between glaucoma and myopia. Ophthalmology 106 (10): 2010-2015. DOI: 10.1016/S0161-6420(99)90416-5

Morgan I, French A, Ashby R, Guo X, Ding X, He M, Rose K. 2018. The epidemics of myopia: aetiology and prevention. Progress in Retinal and Eye Research 62:134-149.

NEI (National Eye Institute). 2017. Facts about Myopia [Internet]. National Institute of Health; [cited 2018 April 3]. Available from https://nei.nih.gov/health/errors/myopia

NEI (National Eye Institute). 2012. Drawing of the Eye [Internet]. National Institute of Health; [cited 2018 April 3]. Available from: https://www.flickr.com/photos/nationaleyeinstitute/7544457228/in/photostream/

Read S, Collins M, Vincent S. 2015. Light exposure and eye growth in children. Investigative Ophthalmology and Visual Science 56:6779-6787.

Saw S, Chua W, Hong C, Wu H, Chan W, Chia K, Stone R, Tan D. 2002. Investigative Ophthalmology in Vision Science 43:332-339.

Smith E, Hung L, Huang J, Arumugam B. 2014. Effects of Local Myopic Defocus on refractive development in Monkeys. Optom Vis Sci 90(11): 1176-1186.

Smith M, Walline J. 2015. Controlling myopia progression in children and adolescents. Adolescent Health, Medicine and Therapeutics 6: 133-140.

Sun Y, Xu F, Zhang T, Liu M, Wang D, Chen Y, Liu Q. 2015. Orthokeratology to control myopia progression: a meta-analysis. PloS ONE 10(4):e0124535. Doi: 10.137/journal.pone.0124535

Ticak A, Walline J. 2013. Peripheraloptics with bifocal soft and corneal reshaping contact lenses. Optom Vis Sci 90(1):3-8.

Vasudevan B, Esposito C, Peterson C, Coronado C, Ciuffreda KJ. 2014. Under-correction of human myopia – is it myopigenic? A retrospective analysis of clinical refraction data. J Optom 7:147-152.

Vitale S, Sperduto R, Ferris F. 2009. Increased Prevalence of Myopia in the United States Between 1971-1972 and 1999-2004. Arch Ophthalmology 127(12):1632-1639.

Walline J, Greiner K, McVey M, Jones-Jordan L. 2013. Multifocal Contact Lens Myopia Control. Optometry and Vision Science 90(11):1207-1214.

Walline J, Jones L, Sinnott LT. 2009. Corneal reshaping and myopia progression. British Journal of Ophthalmology 93:1181-1185.

Walline J, Gaume G, Sinnott LT, Chandler MA, Huang J, Mutti DO, Jones-Jordan LA, Berntsen DA, BLINK Study Group. 2017. A randomized trial of soft multifocal contact lenses for myopia control: baseline data and methods. Optom Vis Sci 94(9): 856-866.

Whatham A, Judge S. 2001. Compensatory changes in eye growth and refraction induced by daily wear of soft lenses in young marmosets. Vision Res 41:267-273

WHO (World Health Organization), WHO. 2015. The impact of myopia and high myopia [Internet]. [Cited 26 April 2018.] Available from http://www.who.int/blindness/causes/MyopiaReportforWeb.pdf

Woodman E, Read S, Collins M, Hegarty K, Priddle S, Smith J, Perro J. 2011. Axial elongation following prolonged near work in myopes and emmetropes. British Journal of Ophthalmology 95: 652-656. DOI: 10.1136/bjo.2010.180323.

Younan C, Mitchell P, Cumming R, Rochtchina E, Wang J. 2002. Myopia and Incident Cataract and Cataract Surgery: The Blue Mountain Eye Study. Investigative Ophthalmology & Visual Science 43(12): 3625-3632.

Zhong Lin, Balamurali V, Jhanji V, Mao G, Gao T, Wang F, Rong S, Ciuffreda K, Liang Y. 2014. Near work, outdoor activity, and their association with refractive error. Optometry and Vision Science 91(4):376-382.