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Review Article

Myopia: Current Concepts and Review of Literature

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Abstract

Myopia is the most common cause of refractive error in children. It is the most common ocular disorder worldwide. Apart from genetic factors, age and environmental factors have also been found to be closely associated as predictors of myopia. A comprehensive literature search was on online platforms using terms Myopia review, onset, progression, treatment, control, updates, bifocals, Atropine, and Orthokeratology. All the relevant articles published in English in last 10 years were analyzed and included. Excessive near work and prolonged screen usage have been proven as definite risk factors apart from genetics. Role of Vitamin D and outdoor activities are still having a controversial stand. Myopia treatment has come a long way from glasses/contact lenses to advanced minimally invasive refractive procedures such as femtosecond-assisted procedures and small incision lenticule extraction. With tremendous improvement in technology and increased dependence on digital devices, control of myopia progression remains a big challenge. Use of bifocals, progressive glasses, rigid contact lenses, and soft bifocals lenses have been studied widely. These all measures seem to do well in initial years, but long-standing results are not encouraging. The results with low-dose atropine have been convincing, but long-term follow-up results are still awaited.

Keywords: Atropine, myopia control, orthokeratology, progressive glasses

Introduction

Refractive error has been reported as the most common cause of reduced vision in children, affecting 2%–11% of the population below 16 years of age.[1,2] It is also responsible for 60%–80% of visual impairment in children.[3,4] As a single entity, myopia is the most common ocular disorder worldwide.[5] It has been well documented that development of myopia depends both on genetic and environmental factors. In general, myopia has the trait of familial clustering. A study among Singapore Chinese preschoolers showed that family history of myopia was the strongest risk factor for offspring's myopia.[6] Environmental risk factors such as prolonged near work, intensive education, and limited time spent outdoors are strongly supported.[7]

Children are easily exposed to screens for prolonged times from a very young age and are dependent on tablets, smart phones, televisions, laptops, or computers. This can be related to an easy access to gadgets in today's world. Thus, there is a strong need to understand the epidemiology, etiology, associations, changing concepts, and the management options of myopia.

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Methodology

In this article, we have comprehensively covered the basics as well discussed review articles published in the recent past. A thorough literature search was conducted for papers using the online search engines PubMed, Google Scholar, and Cochrane database. The following terms were used while searching articles: myopia AND (review) AND (onset OR progression OR treatment OR control OR updates OR bifocals) OR (Orthokeratology) OR (Atropine). All the relevant articles published in English language from 2010 onwards and the referenced articles were included in the study.

Myopia

Myopia is commonly referred to as short sightedness. The light rays that enter the eye are focused in front of the retina, rather than directly on it, so that distant objects appear blurred. This is illustrated in Figure 1.

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The evolving epidemic of myopia

Myopia is the leading cause of visual impairment worldwide. Myopia is like an epidemic that is occurring worldwide. According to researchers, the number of myopes is expected to increase up to more than 5000 million by 2050.[8] In the United States, the prevalence of myopia has increased from 25% to 44% between 1972 and 2004.[9-11] In urban communities in Asia, the prevalence is >80%.[12,13] The prevalence is much lower in underdeveloped areas of the world such as Sherpa in Nepal.[14]

Risk factors

Age

A less hyperopic refraction at a young baseline age has been considered as the most significant predictor of myopia.[15] In another study, it was found that for every year of delayed stabilization, there was an increase in the total amount of myopia (overall 0.27 diopters (D) more myopia per year of delay).[16]

Hereditary

Increased incidence of myopia has been noticed in children if parents are myopic. The risk seems to be still higher if both the parents are myopic. In such scenarios, a more than six-fold increased risk of juvenile onset myopia has been reported.[17] Parental myopia is also a risk factor for progressive myopia. Saw *et al.*[18] showed that children with even single myopic parent had increased rates of myopia progression compared to children with no myopic parent (0.63 D/year versus 0.42 D/year, respectively).

Urbanization and increased near work

Many studies have shown an association between increased myopia in urban areas as compared to rural areas. In 2008, a Polish study found that children living in the city had two-fold increase in the rate of myopia when compared to children living in rural areas.[19] Myopia is more common among professionals, educated patients, computer users, university students, and associated with increased intelligence. All these risk factors are associated with more near work.

Theories of myopia progression

Several theories have been proposed to explain the etiology behind myopia progression. These include:

1. Lag of accommodation
2. Mechanical tension
3. Peripheral refraction.

Lag of accommodation

The theory is based on the hypothesis that high lag of accommodation that occurs during near work in myopic eyes causes foveal hyperopic retinal blur.[20,21] This induces an abnormal axial growth of the eye, leading to myopia as illustrated in Figure 2.

Mechanical tension

The mechanical tension theory is based on response of the eye to transient changes in axial length following short periods of accommodation.[22] This theory suggests that there is a forward and inward pulling of the choroid secondary to contraction of the ciliary muscle following accommodation. Such ciliary-choroidal tension restricts the equatorial growth of the eye, thus decreasing the circumference of the sclera. This leads to a more prolate shape of the eye[22,23] and ultimately an elongation of theaxial length of the eye, resulting in myopia as illustrated in Figure 3.

Peripheral refraction

Previous studies have shown that chronic exposure to lens-induced hyperopic defocus accelerates the axial growth of

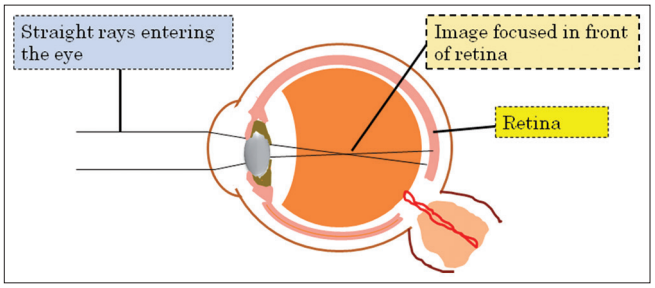

Figure 1: Parallel rays of light focus in front of the retina, simulating a myopic eye

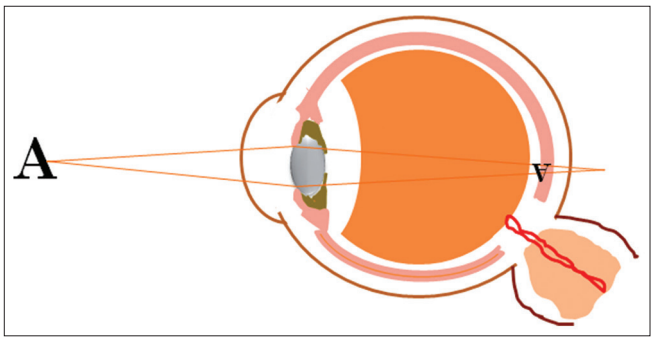

Figure 2: Foveal hyperopic retinal blur resulting from reduced accommodative response at near

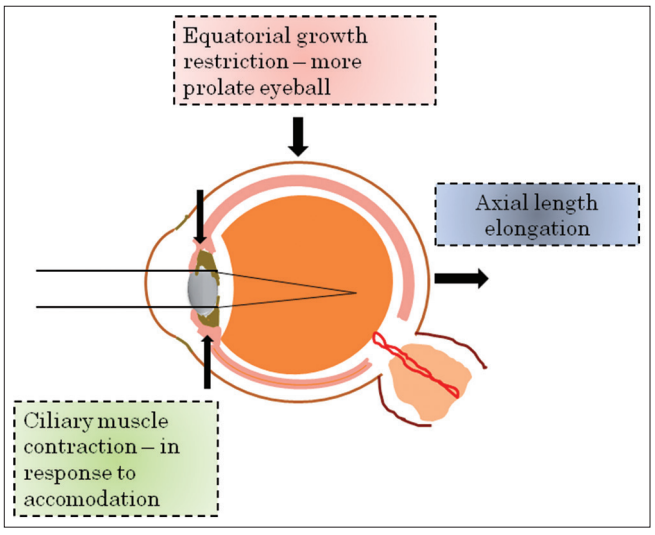

Figure 3: Schematic representation of the mechanical tension theory

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the eye. Thus, it was believed that foveal defocus influences the eye growth.[24,25] However, recent investigations on the effect of hyperopic defocus on ocular growth have highlighted the role of peripheral image formation in the etiology and progression of myopia. The peripheral refraction theory[26,27] indicates that peripheral hyperopic defocus plays a significant role in the development of myopia as illustrated in Figure 4.

Clinical classification of myopia

Various forms of myopia have been described as:

- Congenital Myopia: It is associated with an increase in axial length and overall globe size. This is seen more frequently in children born prematurely or with birth defects, such as Marfan's or Homocystinuria
- Simple myopia: Also known as "school myopia". Myopia usually begins between 8 and 12 years of age. It is typically <4.00–6.00 diopters.[28] This is the most common form of myopia
- Degenerative myopia: Also known as "pathological", or "progressive myopia". It is characterized by marked fundus changes, such as posterior staphyloma, and associated with a high refractive error and subnormal visual acuity after correction.[29] This form of myopia gets progressively worse over time. This starts in childhood around 5–10 years of age and results in high myopia (>6 diopters)
- Acquired myopia: Pseudomyopia is the blurring of distance vision brought about by spasm of the accommodation system[30]
- Nocturnal myopia: The shift from photopic to scotopic vision at twilight is associated with sensitivity to the shorter wavelengths of light. The emmetropic thus becomes slightly myopic for the shorter wavelengths[28]
- Near work-induced transient myopia (NITM): short-term myopic far point shift immediately following a sustained near visual task.[31] Some authors argue for a link between NITM and the development of permanent myopia[32]
- Drug-induced myopia: It results from various medications, increases in glucose levels, oxygen toxicity (e. g., from diving or from oxygen and hyperbaric therapy) or other anomalous conditions.[28] Sulfonamide therapy can cause ciliary body edema, resulting in anterior displacement of the lens, pushing the eye out of focus.[33] Cholinergic drugs such as pilocarpine and echothiophate cause accommodative spasm responsible for myopia. Elevation of blood-glucose levels can also cause edema (swelling) of the crystalline lens as a result of sorbitol accumulating in the lens. This edema often causes temporary myopia
- Iatrogenic myopia: Scleral buckles, used in the repair of retinal detachments may induce myopia by increasing the axial length of the eye[34]
- Index myopia: It is attributed to variation in the index of refraction of one or more of the ocular media.[25] Cataracts may lead to index myopia.[35]

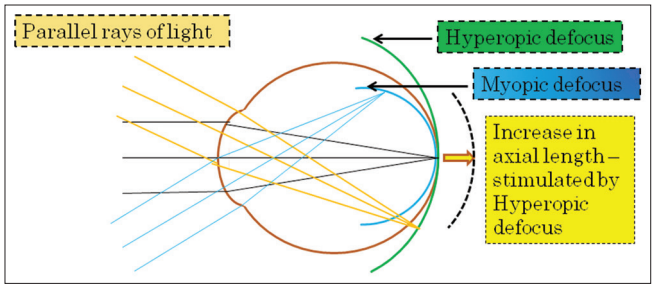

Figure 4: Schematic representation of the peripheral theory

Syndromic associations

The syndromic associations with myopia are listed in Table 1.

Treatment of myopia

Myopia treatment can be broadly divided in to 2 subheadings as shown in Figure 5.

General Treatment

Optical treatment

Glasses or contact lenses

An appropriate power concave lens based on cycloplegic refraction is advised. The concave lenses diverge the light rays entering the eye and form a focused image accurately onto the retina. More severe the myopia, more stronger (more negative power) lenses are required. Basic rule while prescribing correction in myopia is minimum acceptance providing maximum vision.

However, strong eyeglass prescriptions create distortions such as prismatic movement and chromatic aberrations. Contact lens wearers do not experience these distortions because the lens moves with the cornea, keeping the optic axis in line with the visual axis. Furthermore, the vertex distance is reduced to zero with contact lenses.

Surgical treatment

The surgical management options for myopia have gained lot of importance in recent past. It is being opted by patients not only for cosmetic purpose to be able to avoid glasses but also as a means of matching the occupation vision standards. Various options for refractive surgeries for myopia are enlisted in Table 2.

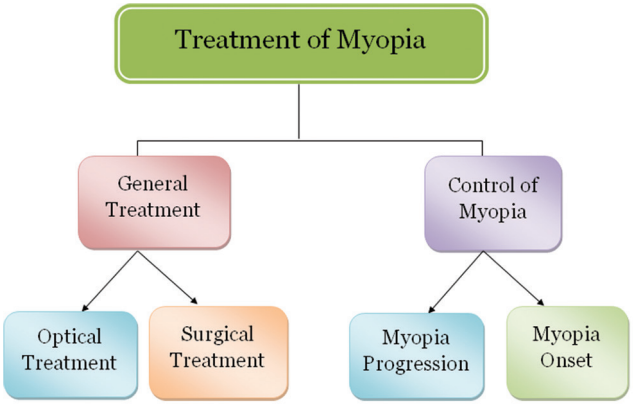

Figure 5: Diagram depicting outline of myopia management

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Control of myopia

1. Control of myopia progression
2. Control of myopia onset.

Control of myopia progression

Spectacles

Historically, undercorrection of myopia was believed to slow down the progression of myopia as a result of reduced accommodation. However, with today's knowledge that blur affects the ability of the eye to become emmetropic, this has been rejected. Two recent studies have demonstrated that undercorrection actually results in mild acceleration of myopia progression.[36,37] Thus, undercorrection should not be used to slow myopic progression.

Bifocal/multifocal glasses

Bifocal or multifocal spectacles are the most investigated for myopia control. The treatment with these glasses is based on the assumption that myopia is a response to prolonged accommodation.[38,39] Bifocal or multifocal spectacles would reduce the accommodative effort and thus slow the progression of myopia. Cheng *et al*.[40] studied the effect of high fitting bifocals and base in prismatic bifocal spectacles compared to single vision (SV) glasses in myopia progression. They reported that these glasses slowed the myopia progression by 40%.

Table 1: The common underlying ocular and syndromic associations

Syndromic associations with myopia	
Ocular diseases	**Multisystem diseases**
Congenital glaucoma	Stickler syndrome
Retinopathy of prematurity	Diabetes mellitus (uncontrolled)
Retinitis pigmentosa	Marfan's syndrome
Cataract	Weil-Marchesani
Congenital stationary night blindness	Knobloch
Keratoconus	Ehler danlos
Gyrate atrophy	
Albinism	

Progressive glasses

The Correction of Myopia Evaluation Trial study determined if a +2.00 D progressive additional lenses (PAL) slowed the progression of myopia as compared to SV full correcting lens.[41] This prospective, multicenter study demonstrated that in the 1st year, PALs slowed the progression of myopia by 20%. The net reduction was 0.2 D, which was statistically significant. The PALs were most effective; when both the parents were myopic, there was a large lag of accommodation or the child had esophoria at near.[18]

Contact lenses

For years, it was believed that gas permeable contact lenses slowed the progression of myopia. However, gas permeable contact lenses are typically prescribed when myopia begins to slow down (≥12 of age). It has been shown in a number of well-controlled clinical trials that neither conventional soft nor gas permeable contact lenses alter the myopia progression.[42,43]

Soft bifocal contact lenses

The center distance (add power in the peripheral part) contact lenses have been tested for myopia control. On an average, these contact lenses slow myopia progression by 46%.[44-47]

Lam *et al*.[45] conducted a randomized controlled trial on 8–13 years old children with myopia between −1.00 and −5.00 spherical equivalent. Over 2 years, the myopia progressed by an average of −0.59 ± 0.49 D for the bifocal contact lens wearers and −0.79 ± 0.56 D for the SV contact lens wearers ($P = 0.03$), showing a 25% slowing of progression of myopia. Axial length elongation was also slower for the soft bifocal contact lens wearers (0.25 ± 0.23 mm) than for the SV contact lens wearers (0.37 ± 0.24 mm, $P = 0.009$).

Table 2: Various surgical treatment modalities for myopia

Keratorefractive procedures		Lens-based procedures	Combined lens and cornea based refractive procedures
Incisional procedures	Radial keratotomy	Phakic refractive lenses	Bioptics
Lamellar corneal refractive procedures	Nonfreeze keratomileusis	Refractive lens exchange	Trioptics
	Keratomileusis *in situ*		
	Automated lamellar keratoplasty		
	Small incision keratoplasty		
	Corneoplastique		
Laser ablation corneal refractive procedures	PRK		
	LASEK		
	Epi-LASIK		
	LASIK		
	C-LASIK		
Intracorneal implants	Intracorneal lenses		
	Intrastromal corneal ring segments		
	Gel injectable adjustable keratoplast		

PRK: Photorefractive keratectomy, LASEK: Laser subepithelial keratomileusis, Epi-LASIK: Epithelial laser *in situ* keratomileusis, C-LASIK: Custom laser *in situ* keratomileusis

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Orthokeratology lenses

Orthokeratology (OK) lenses have been a boon for myopes. It provides patients with a "wow" factor and eliminates the need of daily wearing of contact lenses or glasses. This is particularly beneficial for athletes. Majority achieve the visual acuity of 20/20 and over 90% achieve 20/30.[48]

OK lenses change the curvature of the cornea by mechanical flattening of the cornea as shown in Figure 6. However, there is a strong evidence that the change in refraction is achieved by horizontal movement of epithelial cells secondary to reverse pressure made from the seal created in the mid-periphery bearing area of the lens.[49,50]

Reim *et al*.[51] performed a retrospective study of 253 children (ages 6–18) on the ability of OK to slow the progression of myopia. They reported that the rate of progression was slowed from 0.5 to 0.13 D/year. Subsequently, there have been a number of prospective clinical trials, which have demonstrated that OK lenses slows the progression of myopia by 40% using axial length measurements and wash-out cycloplegic measurements.[52-60]

Pharmaceutical agents- Antimuscarinic agents

Atropine was first used by Wells in 1900 to stop the progression of myopia by "paralyzing" accommodation. Analysis of a number of retrospective studies using atropine has shown that 1% atropine tends to slow the progression of myopia by almost 80%.

Atropine is a nonspecific muscarinic receptor antagonist that causes cycloplegia and mydriasis, and pirenzepine is a M1-specific muscarinic receptor antagonist. M1 receptors are highly concentrated in the retina and found rarely on the ciliary body or iris, so they cause far fewer cycloplegic and mydriasis-related symptoms. Both pirenzepine[61,62] and atropine[63-65] have been shown to slow myopia progression. The exact mechanism by which atropine inhibits myopia progression is unknown. Multiple studies indicate that atropine has an effect altering the sclera.[66-68] It has also been suggested that ultraviolet light (secondary to pupil dilation) may increase collagen cross-linking within the sclera, thereby slowing down the scleral growth.

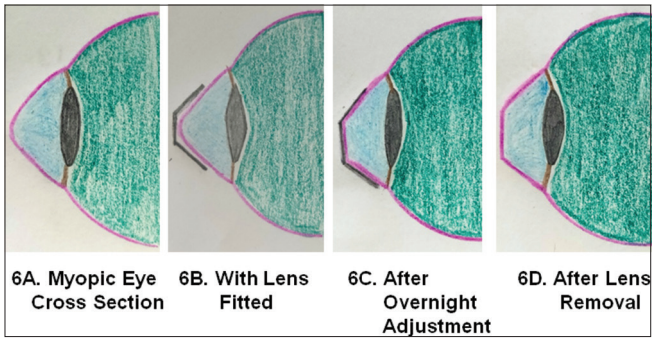

Figure 6: Schematic diagram showing effect of overnight Orthokeratology lenses

Chua *et al*.[64] (ATOM 1) studied the effect of 1% atropine in a group of 400 children (13.5% dropout rate). One group received atropine, whereas the other group received a placebo. Only one eye of each child was chosen for treatment. The mean progression in the control eye after 2 years was 0.6 D/year and in the atropine-treated eye was 0.14 D/year. This represents a 77% reduction in the progression of myopia. Furthermore, the axial length measurements in the eyes, which received atropine, remained almost unchanged (0.02 mm over 2 years). There were no serious adverse events and the atropine was well tolerated.

Chia *et al*.[69] (ATOM 2) studied the effect of 0.5%, 0.1%, and 0.01% concentrations of atropine in a group of 200 children. After 2 years, all 3 concentrations slowed myopia progression. Mean progression with each concentration (spherical equivalent) was 0.15 D/year (0.5% atropine), 0.19 D/year (0.1% atropine), and 0.25 D/year (0.01% atropine). ATOM 2 study suggests that myopic progression was slowed with all concentrations, with similar effects between moderate and low concentrations.

In contrast to the benefits, the primary ocular side effects of topical atropine include mydriasis leading to photophobia, loss of accommodation resulting in blurred near vision, and local allergic responses. In addition to the side effects, high concentration atropine leads to a significant rebound following cessation of eye drops.[70]

Prevention of myopia onset

Limit screen time

The increased screen exposure could be associated with a higher risk of preschool myopia. It is proposed that the closer the viewing distance, more the focusing errors[71,72] and higher the lag of accommodation.[71,73]

Studies concerning screen exposure and myopia have been conducted worldwide. A study involving primary and middle school students in six provinces of China showed that children had a higher risk of myopia whose parents did not limit their offspring's screen time;[74] Harrington et al. reported that using screens >3 h/day was associated with a higher risk of myopia among schoolchildren in Ireland.[75] Similarly, a study from North India found screen viewing was a significant risk factor for myopia progression amongst children aged 5–15 years.[76]

The current American Academy of Pediatrics guidelines recommend that children under 2 years of age should not spend any time using electronic media, while children over 2 years of age should be restricted to <2 h/day.[77,78]

Increased outdoor time

Jones *et al*.[79] first reported the association between outdoor time and likelihood of developing myopic refractive error. This similar effect has been reported in several subsequent studies.[80-85]

The indoor activities create more hyperopic defocus (causing myopia) across the entire surface of the retina than any

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outdoors activities. Outdoor activities essentially eliminate any defocus across the entire visual field that serves as a stop signal for the eye growth (thus inhibiting development of myopia). Brighter light intensity also leads to pupil constriction and increased depth of focus, which reduces optical blur and increases contrast. Change in contrast, in turn, would affect the function of amacrine cells, which might explain the role of dopamine in myopia development in animal models. Few studies have tried to find an association between levels of Vitamin D, time spent outdoors, and myopia. The results have not been consistent, with some favoring and disapproving this association.[86,87] Spending more time outdoors clearly has a substantial therapeutic effect on myopia onset and possibly progression. Therefore, it should be recommended that children, especially those who have two myopic parents or show signs of myopia development or progression, spend more time outdoors as preventive measure of developing myopia.

Low concentration atropine

Chia *et al*.[88] conducted a study in which children between the ages of 6 and 12 years with +1.00 D and −1.00 D spherical equivalent, cycloplegic refractive error were followed for at least 12 months and included in a retrospective comparison of children who received 0.025% atropine and those who did not. Only 21% of the children receiving atropine became myopic, compared with 54% of the children not receiving atropine ($P = 0.016$). Refractive error progression was also less for those on atropine (−0.14 ± 0.24 D/year) than for those not on atropine (−0.58 ± 0.34 D/year, $P = 0.0001$). No children in either group complained of blurry vision at near, and there was no difference in reports of photophobia for those on atropine (16%) and those not on atropine (8%, $P = 0.41$).

For clinical practice, it should be remembered that atropine 0.01% eye drops are probably the most useful current way to reduce progression, but that this is a non-reimbursable, off-label treatment in Germany. The age up to which atropine eye drop treatment should be continued, the optimal length of treatment, and the nature of progression after the end of treatment are unknown. It also remains unproven whether atropine treatment may be useful as a prophylactic measure to prevent subsequent myopia, as has been shown for exposure to daylight.

Future prospects

The prevalence of myopia worldwide is increasing exponentially. The epidemic waves are seen in developing counties like India as well. Also, there is markedly increased rates of progression to pathological myopia. There is a need to understand the factors responsible for myopic waves in each country individually. Clinical trials to control myopia progression are needed on large scale. A comprehensive analysis of risk factors, lifestyle modifications to prevent myopia, and analysis of different modalities to prevent progression to pathological myopia once it sets in will help in better understanding the disease. These will also help lawmakers to ensure that school curriculums and teachings are modified in a way to control the myopia explosion. Family-based approach needs to adapted as it would be ideal to understand the individual risk factors. A proactive approach prior to onset of myopia will be beneficial. Earlier implementation of interventions will also help significantly reduce the chance of progression to pathological myopia.

Conclusion

Excessive near work and prolonged screen usage have been proven as definite risk factors apart from genetics. Role of Vitamin D and outdoor activities are still having a controversial stand. Myopia treatment has come a long way from glasses/contact lenses to advanced minimally invasive refractive procedures such as femtosecond assisted procedures and small incision lenticule extraction.

With tremendous improvement in technology and increased dependence on digital devices, control on progression of myopia remains a big challenge. Use of bifocals, progressive glasses, rigid contact lenses, and soft bifocals lenses have been studied widely. These all measures seem to do well in initial years, but long-standing results are not encouraging. Use of low-dose atropine has been approved, but long-term results are still awaited.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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