

Myopia control in children – a review of current methods and clinical recommendations

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Summary:

Myopia is one of the most important public health concerns in modern pediatric ophthalmology. Given its rapidly growing prevalence among children and the risk of developing high myopia and its associated complications, strategies aimed at slowing myopia progression are becoming increasingly important. Recent years have seen significant advances in myopia control, encompassing environmental interventions, pharmacological treatment with low-concentration atropine, and optical approaches including specialized spectacle lenses, soft contact lenses, and orthokeratology. Numerous randomized trials and long-term clinical observations confirm the efficacy of these methods in slowing both myopic progression and axial elongation of the eye. This article reviews the current state of knowledge on pediatric myopia control, highlighting the findings of major clinical studies published in recent years as well as contemporary expert recommendations. It discusses the efficacy, safety, advantages, and limitations of available therapeutic options, along with practical aspects of patient selection and treatment monitoring. Effective myopia management requires an individualized approach and long-term collaboration between the physician, the patient, and their caregivers.

Key words:

myopia, myopia progression, atropine, orthokeratology, contact lenses.

Introduction

Myopia is one of the most common refractive errors and represents a major challenge in modern pediatric ophthalmology. According to projections, by 2050 it may affect nearly half of the global population, with high myopia accounting for approximately 10% [1]. The development of myopia during childhood is of particular clinical importance, as an earlier onset is associated with a greater risk of rapid progression and of reaching high refractive errors in adulthood [2, 3]. The importance of myopia control stems not only from its increasing prevalence, but also from the risk of vision-threatening complications. High myopia increases the likelihood of myopic macular degeneration, retinal detachment, glaucoma, and cataracts [4–6]. Growing evidence indicates that the risk of these complications is closely tied to axial elongation of the eye, which is the primary target of modern myopia control strategies [4, 5]. Myopia development results from the interplay of genetic and environmental factors. Key risk factors include a positive family history, early age of onset, intensive near work, and limited outdoor time [7–9]. In response to the rising prevalence of myopia, strategies have been developed to slow its progression, including environmental interventions, treatment with low-concentration atropine, and optical methods such as specialized spectacle lenses, soft contact lenses, and orthokeratology [10–12]. This article aims to review current methods for pediatric myopia control and provide recommendations for their use in daily clinical practice [13, 14].

Risk factors for myopia progression

Myopia development and progression result from the interplay of genetic and environmental factors. Determining these factors is of major clinical importance, as it helps identify children at the highest risk of rapid progression and development of high myopia [3]. One of the most critical prognostic factors is the age of myopia onset. Children who develop myopia before age 10 face a higher risk of rapid progression and of reaching high refractive

errors in adulthood [2, 3]. Early onset is currently considered one of the strongest predictors of the condition's future course. Genetic predisposition also plays a significant role. The risk of developing myopia is higher in children with one or two myopic parents, and having two myopic parents is associated with a higher likelihood of earlier onset and faster progression [3]. Among modifiable environmental factors, outdoor time has the best-documented impact. Epidemiological studies and meta-analyses show that regular outdoor activity reduces the risk of myopia development [8]. Conversely, intensive near work – including reading, studying, and digital device use – is considered a contributing risk factor [7]. Ocular axial length (AL) is also gaining importance in assessing progression risk. Excessive axial elongation relative to the child's age is associated with a heightened risk of further progression of the refractive error and serves as a valuable parameter for monitoring treatment efficacy [9]. In clinical practice, children with early-onset myopia, a positive family history, and coexisting adverse environmental factors require special attention. In these patients, more frequent follow-ups and early initiation of myopia control methods should be considered [1–3].

Diagnosis and monitoring of children with myopia

Accurate diagnosis, together with regular monitoring of progression, constitutes the cornerstone of effective myopia control. The evaluation of a myopic child should include determining the refractive error, identifying risk factors for progression, and measuring AL [9, 12, 13]. Cycloplegic refraction remains the reference standard for assessing refractive status in pediatric patients, as it eliminates the effect of accommodation and provides a reliable measurement of refractive error [10]. In clinical practice, cyclopentolate is most commonly used to achieve cycloplegia, with atropine reserved for selected situations. Increasing importance is being attributed to measuring AL, which is regarded as the most objective indicator of myopia progression and treatment efficacy [9, 11]. During follow-up visits, refractive error, axial

length, and visual acuity should be documented. For children with actively progressing myopia, follow-up examinations are recommended every six months, though the visit schedule should be tailored to the rate of progression and the specific treatment modality used [9]. Clinically significant myopia progression is most often defined as a change in refraction of at least 0.50 D per year. However, this value should be interpreted in the context of the patient's age and changes in axial length. The use of AL percentile charts is also increasingly recommended, as they allow assessment of ocular growth in relation to the child's age and sex and may help identify patients who require more intensive management [9].

Environmental interventions and prevention

A growing body of scientific evidence indicates that environmental factors play an important role in the development of myopia in children. Unlike genetic predispositions, these factors can be modified. Consequently, preventive measures are an essential component of contemporary myopia control strategies [6, 7]. The best-documented protective factor is time spent outdoors. Epidemiological studies and meta-analyses have shown that children who spend more time outside are less likely to develop myopia than their peers who remain indoors for most of the day [8]. The mechanism underlying this phenomenon has not yet been fully elucidated. However, it is hypothesized that high-intensity daylight plays an important role by stimulating dopamine release in the retina and inhibiting excessive axial elongation of the eye. Current recommendations advise that children spend at least two hours outdoors each day [9, 12, 13]. It should be emphasized, however, that increasing outdoor activity appears to be most effective in preventing the onset of myopia, whereas its effect on slowing the progression of established myopia is probably smaller [8]. The second important component of prevention is limiting prolonged near work. Although the relationship between digital device use and myopia progression has not been conclusively established, extended use of smartphones, tablets, and other screen-based devices is associated with increased near work and reduced outdoor activity [6]. For this reason, regular breaks are recommended during reading, studying, and screen-based activities. A commonly recommended approach is the 20-20-20 rule, which advises looking at an object approximately 6 meters away for at least 20 seconds after every 20 minutes of near work. The World Health Organization (WHO) recommends limiting screen time, particularly among the youngest children. For infants younger than 1 year, screen exposure is not recommended (except for video calls), whereas for children aged 1–4 years, recreational screen time should be limited to a maximum of 1 hour per day, with less time being more beneficial for the child's health and development [14]. For older children, the WHO does not specify clear time limits, but underscores the importance of limiting sedentary behaviors and promoting physical activity and time spent outdoors [14]. Although these recommendations were not developed specifically to prevent myopia, they are consistent with measures promoting healthy visual habits and greater outdoor activity.

Pharmacological control of myopia – atropine

Atropine is one of the most extensively studied methods of myopia control in children. Despite more than two decades of research, its exact mechanism of action has not yet been fully elucidated. It is thought to act on muscarinic receptors present in the retina, choroid, and sclera, affecting pathways that regulate axial growth of the eye. Available data indicate that the therapeutic effect is not solely due to cycloplegia but is associated with a direct effect on the processes responsible for axial elongation of the eye [15, 16]. The efficacy of atropine in myopia control has been confirmed in numerous clinical studies. The ATOM studies sho-

wed that lower concentrations of atropine have a more favorable safety profile while maintaining therapeutic efficacy [15]. In turn, the LAMP study confirmed a concentration-dependent therapeutic effect and demonstrated that 0.05% atropine was the most effective concentration both in limiting refractive progression and axial elongation of the eye [16]. The results of the CHAMP study further confirmed the efficacy and safety of long-term use of low concentrations of atropine in a multiethnic population [17]. Currently, 0.05% atropine is considered the most effective concentration, providing a favorable balance between treatment efficacy and treatment tolerability, and is recommended by numerous scientific societies as one of the first-line methods for myopia control in children [9, 12, 13, 16]. The most commonly observed adverse effects include mild pupil dilation, transient photophobia, and a slight reduction in accommodation. In most cases, these symptoms are mild and do not require treatment discontinuation [9, 16].

Spectacle lenses for myopia control

Modern spectacle lenses for myopia control use specialized optical designs intended to modify how the image is focused on the peripheral retina and inhibit axial elongation of the eye [15]. Although individual technologies vary in their design and in the mechanisms by which they generate the optical stimulus, they share the common goal of slowing myopia progression while preserving good central vision. The most extensively studied technology is that of spectacle lenses incorporating multiple segments that generate myopic defocus (DIMS). Randomized clinical trials have demonstrated an approximately 50% decrease in myopia progression and a significant reduction in axial length compared with single-vision spectacle lenses. Long-term observations have confirmed that the therapeutic effect is maintained for at least six years [18]. The second group comprises spectacle lenses incorporating highly aspherical lenslets (HALT) arranged around a central corrective zone. Clinical studies have demonstrated a reduction in myopia progression of approximately 60–70% and a significant reduction in axial elongation of the eye [19]. An even newer direction in the development of spectacle lenses is represented by lenses using Diffusion Optics Technology (DOT), in which the therapeutic effect is achieved through controlled diffusion of light around the central retinal image. Initial clinical studies have demonstrated a reduction in myopia progression of approximately 50–60% and a significant reduction in AL compared with conventional single-vision spectacle lenses [20]. Optical technologies used in myopia control are developing very rapidly. In addition to lenses that use myopic defocus, research is being conducted on new optical designs, including modifications to microlens configurations, expansion of therapeutic zones, and optimization of the parameters of the generated optical signal. Current results indicate that further development of optical technologies may contribute to increased efficacy of myopia control while maintaining high-quality vision and a favorable safety profile [19]. However, further clinical studies and long-term observations are needed to assess the durability of the therapeutic effect and the role of new solutions in everyday clinical practice.

Soft contact lenses

Soft contact lenses are one of the best-documented methods of optical myopia control. Their effect is based on modifying the image reaching the peripheral retina, thereby inhibiting axial elongation of the eye. The strongest scientific evidence concerns daily disposable contact lenses that use a multifocal optical design. A three-year randomized clinical trial demonstrated an approximately 59% reduction in myopia progression and an approximately 52% reduction in AL compared with the control group [21]. The therapeutic effect was also maintained during further follow-

-up of the study participants [22]. The BLINK study also provided important data, showing that multifocal soft contact lenses with a high add power (+2.50 D) were more effective than single-vision lenses, significantly limiting myopia progression and axial elongation of the eye [23]. In recent years, further soft contact lens designs using more advanced optical profiles and various strategies for modifying the retinal image have been developed. Preliminary results indicate that some of these may achieve efficacy comparable to that of the best currently available optical methods. The advantages of this method include high efficacy, good quality of vision, and the possibility of use in active children. Its limitations include the need to comply with hygiene requirements and the possibility of complications associated with improper use of contact lenses.

Orthokeratology

Orthokeratology involves overnight use of rigid gas-permeable lenses with reverse geometry, which temporarily alter the shape of the cornea and allow good vision without correction during the day [24]. The myopia control effect is primarily associated with changes in corneal profile, which modify the image projected onto the peripheral retina and thereby inhibit axial elongation of the eye. The ROMIO study demonstrated an approximately 43% reduction in AL compared with the control group [24]. There is growing interest in combination therapies that integrate orthokeratology with low-concentration atropine. The TO-SEE study demonstrated an additional reduction in axial elongation of the eye when 0.01% atropine was added to orthokeratology treatment [25]. The main advantage of orthokeratology is the ability to function without spectacles or contact lenses during the day. Limitations include the higher cost of treatment, the need for strict adherence to hygiene requirements, and a small but real risk of infectious corneal complications.

Combination therapies

Despite the high efficacy of contemporary myopia control strategies, rapid progression still occurs in some children. In these cases, combination therapies incorporating both pharmacological and optical methods may be considered [25]. The rationale behind this approach is that each method targets distinct mechanisms involved in ocular growth. Atropine primarily affects biochemical pathways associated with muscarinic receptors, whereas optical methods modify the image reaching the peripheral retina. Combining the two strategies may result in a greater therapeutic effect than using either method alone. The greatest body of evidence concerns the combination of atropine and orthokeratology. Study results indicate that combined therapy may be more effective in limiting axial elongation of the eye than either method used alone [25]. Promising results have also been obtained with combinations of atropine and modern spectacle lenses and soft contact lenses, which may provide more effective myopia control than monotherapy [13, 16]. Combination therapies are not currently used routinely in all patients. However, they may represent a valuable option for children with rapid myopia progression despite ongoing treatment. Further studies are needed to determine the optimal treatment regimens and the patient groups that derive the greatest benefit from such treatment.

Current recommendations and treatment selection

Current management of a child with progressive myopia should be based on an individual assessment of the risk of progression, regular monitoring of refractive error, and, if available, axial length measurement. Recommendations for myopia control have been developed by both national and international scientific societies, including the Polish Ophthalmological Society (PTO), the International Myopia Institute (IMI), and the World Society of Paediatric Ophthalmology and Strabismus (WSPOS) [9, 12, 13].

Despite certain organizational differences, these recommendations are consistent regarding the basic principles of management, including early identification of children at risk, implementation of methods with proven efficacy, and regular monitoring of treatment outcomes. Children with early-onset myopia, a rapid rate of progression, a positive family history, and above-average axial elongation of the eye require particular attention. In such patients, early initiation of active myopia control should be considered [2, 3, 9, 12, 13]. The choice of treatment method should be tailored to the child's age, rate of progression, the preferences of the patient and parents, and their ability to cooperate. In younger children and patients for whom the use of contact lenses is difficult or unacceptable, specialized spectacle lenses are a particularly practical method. In older children, soft contact lenses for myopia control or orthokeratology may be considered. Low-concentration atropine may be used as a standalone treatment method and, in children with rapid progression or an insufficient response to treatment, also as part of combination therapy [16, 25]. Follow-up visits should generally take place every six months and include assessment of visual acuity, refractive error, treatment tolerability, and, if available, measurement of the axial length of the eye [9, 12, 13]. Insufficient control may be assumed when refractive progression of ≥ 0.50 D/year persists or when excessive axial elongation continues despite adequate treatment adherence. In such cases, adherence to recommendations and environmental factors should be assessed, and a change in treatment method or combination therapy should be considered [9, 12, 13]. The decision to discontinue treatment should be individualized and based on stabilization of refractive error and axial elongation of the eye. After active treatment has been discontinued, continued monitoring is recommended because myopia progression may persist into young adulthood in some patients [15, 16].

Conclusions

Myopia represents one of the greatest challenges in contemporary pediatric ophthalmology. The rapidly increasing number of children with this refractive error, together with the risk of developing high myopia and its associated complications, has made myopia control an integral part of modern ophthalmic care. The results of studies published in recent years confirm the efficacy of both pharmacological treatment with low-concentration atropine and optical methods using specialized spectacle lenses, soft contact lenses, and orthokeratology. These methods can significantly limit myopia progression and slow axial elongation of the eye, thereby reducing the risk of developing high myopia in the future. Early identification of children at risk, regular monitoring of disease progression, and sufficiently early implementation of effective myopia control methods are of key importance. Preventive measures also remain an important component of management, particularly increasing time spent outdoors and reducing prolonged near-vision tasks. Current national and international recommendations clearly indicate that, in children with progressive myopia, refractive error correction alone is insufficient. Active myopia control provides a real opportunity to reduce the risk of subsequent ophthalmic complications and improve visual prognosis in adulthood.

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