



Myopia Management Consensus Statement in South Korean Children 2025 by the Korean Myopia Society for the Korean Association for Pediatric Ophthalmology and Strabismus

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Myopia, particularly high myopia, is a significant risk factor for several ocular pathologies including cataract, glaucoma, and retinal detachment. Excessive axial elongation associated with high myopia can induce biomechanical stretching, increasing the risk of serious complications like posterior staphyloma and myopic maculopathy. Global meta-analyses estimate that approximately 10 million people were visually impaired due to myopic maculopathy in 2015, with 3 million being blind. Recent

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nationwide surveys in South Korea revealed a prevalence of 65.4% for myopia and 6.9% for high myopia in children and adolescents, highlighting the urgent need for effective management. Delaying the onset and slowing the progression of myopia during childhood and adolescence is crucial for reducing the potential lifetime risk of these complications. This consensus statement, prepared by the Korean Myopia Society for the Korean Association for Pediatric Ophthalmology and Strabismus (KAPOS), reviews the current evidence for myopia control interventions and provides management strategies applicable to the South Korean clinical setting. Key interventions covered include lifestyle modifications (outdoor time, near work adjustment), optical methods (myopia-control spectacle lenses, dual-focus soft contact lenses, orthokeratology), and pharmacologic treatment (low-concentration atropine), as well as combination therapies. The statement also addresses patient selection, treatment outcome evaluation using spherical equivalent and axial length changes, and the crucial aspects related to treatment cessation and the rebound effect.

Key Words: Child, Korea, Myopia, Practice guideline

Several epidemiological studies have identified myopia as a distinct risk factor for various ocular diseases, including cataracts, glaucoma, and retinal detachment. Specifically, the excessive elongation of the globe associated with high myopia leads to biomechanical stretching, which increases the risk of serious complications such as posterior staphyloma and myopic maculopathy [1,2]. A meta-analysis of studies reporting blindness and visual impairment from myopic maculopathy found that, in 2015, approximately 10 million people globally suffered visual impairment due to myopic maculopathy, with 3 million being blind [3]. In South Korea, data from the Korea National Health and Nutrition Examination Survey (KNHANES) indicate that the prevalence of myopia in adults (19–49 years) is 70.6%, with high myopia at 8.0% [4]. Notably, in children and adolescents (5–18 years), the prevalence is 65.4% and 6.9%, respectively, with high myopia prevalence surging to approximately 20% in 18-year-olds [5].

Delaying the onset and reducing the progression rate of myopia during childhood and adolescence represent the most important strategy for minimizing the potential risks of myopia-associated complications in adulthood. Proactive intervention by ophthalmologists in this age group is becoming an increasingly common form of clinical practice. Over the past decades, numerous strategies aimed at mitigating myopia progression have been investigated, and substantial evidence now supports the efficacy of several interventions. The Korean Myopia Society for the Korean Association for Pediatric Ophthalmology and Strabismus (KAPOS) aims to present the latest research findings and

propose applicable management methods in the South Korean clinical context through this consensus statement.

Lifestyle Modification

Outdoor activity

Numerous studies have reported that increased outdoor activity reduces the risk of myopia onset [6–12]. However, the effect of outdoor activity on slowing the progression of existing myopia has been inconsistent [6–11], likely due to differences in study design. Nonetheless, based on reports showing efficacy, this strategy is officially encouraged in several countries such as Singapore, Taiwan, and China [13]. Key evidence for recommending 2 hours of outdoor activity daily comes from a comparative study of 6- to 7-year-old Chinese children living in Singapore and Sydney, Australia. Sydney children reported 13.8 hr/wk of outdoor time and had a myopia prevalence of 3.3%, while Singaporean children reported 3.1 hr/wk of outdoor time and had a myopia prevalence of 29.1%. Outdoor time was reported as the primary factor for the prevalence difference [14]. Based on this finding, Taiwan recommended over 2 hours of outdoor activity per day, setting a weekly target of 14 hours. Following the implementation of this guideline in 2010, the proportion of children with uncorrected visual acuity ≤ 0.8 began to decline after years of increase, showing an effect of approximately 10% reduction [13]. Another study conducted in Northern California reported that chil-

dren with two myopic parents had an approximately 40% higher risk of myopia onset if they had limited outdoor activity compared to children with nonmyopic parents (60% vs. 20%). However, this difference disappeared with 14 hr/wk of outdoor activity [15]. While these studies did not resolve questions about the optimal outdoor time (e.g., 14 hr/wk) or whether the efficacy differs by age, they provided major evidence for the benefits of outdoor time. Studies reported quantitative dose-response relationship between the outdoor time and myopia onset with the protective effect of increased outdoor time [6,12]. The effect of outdoor activity on delaying myopia progression has been reported to range from 0.05 to 0.17 diopters (D) per year [16], but some studies could not reach statistical significance [12], and the small magnitude of effect (0.17 D/yr) was noted as potentially lacking clinical significance [7]. Nevertheless, outdoor activity in children and adolescents is encouraged as a safe strategy with positive effect in growing children (e.g., obesity prevention, healthy lifestyle).

Near work

The relationship between near work and myopia has long been studied, but there is no standardized metrics on working distance, continuous working time, or total working time. Some reports found no association of myopia with total work time [17–19], but others reported that myopic children spent more time on near work than nonmyopic children did [20]. One report suggested that working distance <30 cm or continuous work time >30 minutes increased the risk of myopia onset by 2.5- and 1.5-fold, respectively [21]. Other indicators associated with myopia onset or progression include a working distance <20 cm [22,23] or within 20–30 cm [24], continuous working time over 30 to 40 minutes [24] or over 45 minutes [23], and one study found a significantly higher myopia incidence with longer total weekly near work time [25]. A systematic review reported that the risk of myopia onset increased by 1.1 times for every 1 D-hour increase in weekly near work [26]. A recent randomized controlled trial (RCT) on lifestyle modifications, including near work limitation, reported a protective effect on myopia onset and progression, but could not evaluate the effect of near work in isolation [27]. A recent evidence-based review reported a dose-response effect for near work restriction on myopia progression delay but noted the lack of well-designed studies [28].

The “20-20-20 rule” recommends looking at an object at least 20 feet (approximately 6 m) away for 20 seconds after every 20 minutes of near work [29,30]. The “20-20-2 rule” recommends looking into the distance for 20 seconds after 20 minutes of near work (at a distance of ≥ 30 cm) and 2 hours of daily outdoor activity [6,21,31,32]. Near work may also be linked to the level and intensity of education [33], and the effect on myopia may be a result of the associated decrease in outdoor activity (or a combination of both) [25,34]. In conclusion, adjusting near work habits (distance ≥ 20 –30 cm, continuous work ≤ 20 –45 minutes) appears to offer a protective effect against myopia and can be considered a cost-effective strategy.

Digital devices, others

Digital devices have been widely used since 2008 [35]. Research results regarding the association between increased digital device use and myopia are conflicting. Several studies suggest a lack of evidence for an association [36,37], while other reported that each 1-hour increase in daily digital device use (smartphone, computer) in children increased myopia by 0.28 to 0.33 D/yr [38]. Another study reported that each 20-minute increase in continuous smartphone use increased myopia by 0.07 D [39]. A study from the Netherlands reported an association between continuous smartphone use for ≥ 20 minutes and higher degree of myopia in teenagers [31], and another study from China reported an association between digital device exposure before age 1 year and myopia onset [40]. Furthermore, digital device use has been reported to be associated with increased near work time and reduced working distance [39,41,42]. A recent meta-analysis found a significant increase in risk of myopia onset with longer digital device use, recommending usage of ≤ 1 hr/day [43]. Another evidence-based review reported that limiting screen time reduces the risk of myopia among children and adolescents [28].

However, a meta-analysis analyzing the association between smart device exposure and myopia onset/progression reported high heterogeneity between studies included in the meta-analysis [37], and RCTs on this topic are still lacking. Nevertheless, China and Taiwan have regulations limiting digital device use in children and adolescents [44]. Also, the American Academy of Pediatrics recommends limiting digital device use to ≤ 1 hr/day for children aged 2 to 5 years [45].

In conclusion, while robust research supporting the association between digital device use and myopia is still limited, recommendations for appropriate usage time and distance, based on near work studies, appear reasonable.

Patient Selection

When initiating myopia-control treatment, both clinical parameters and genetic or demographic factors should be considered. These variables help identify children at higher risk of rapid progression or development of high myopia.

Clinical factors

1) Age of onset

The younger the age at which myopia develops, the greater the likelihood of progression to high myopia [46–48]. Each 1-year earlier onset substantially increases the likelihood of progression to a higher degree of myopia. Children diagnosed at younger ages require closer monitoring and earlier initiation of myopia-control treatment.

2) Rate of progression

In Asian school-aged children, the mean annual myopia progression rate is approximately -0.47 to -0.97 D/yr [49–52]. An annual myopia progression of ≥ -0.50 D suggests that the child is a good candidate for myopia-control treatment [52]. Axial length (AL) growth of approximately 0.1 to 0.2 mm/yr in children aged 7 to 10 years and 0.1 mm/yr in adolescents aged 11 to 16 years may be considered within the normal range [53]. An annual increase of ≥ 0.3 to 0.4 mm suggests accelerated myopia progression and indicates that myopia-control treatment should be considered. A myopia growth chart based on KNHANES IV–V data suggests that AL elongation is most accelerated between ages 7.5 and 11.9 years and tends to stabilize around age 16 years [54].

3) Baseline refractive errors

Children who have moderate myopia at presentation are at greater risk of faster progression and subsequent development of high myopia [50]. Earlier initiation of myopia-control treatment may be recommended for children with moderate to high baseline myopia, particularly if they are younger or exhibit rapid progression of myopia.

Genetic and demographic factors

1) Parental myopia

Family history is a strong predictor of both the onset and progression of myopia. According to the Northern Ireland Childhood Errors of Refraction (NICER) study [55], the risk of childhood myopia increased 2.9-fold if one parent was myopic and 7.8-fold if both parents were myopic. The 2018 KNHANES reported that one highly myopic parent was associated with a 2.6-fold higher risk of high myopia, whereas having two highly myopic parents increased the risk 11.4-fold [56]. A subsequent analysis of KNHANES 2016–2017 data further confirmed that children with myopic parents have a 3.48-fold increased risk of high myopia compared to those without myopic parents [5]. Therefore, in children with parental myopia, especially when both parents are highly myopic, early initiation of myopia-control treatment should be strongly considered.

2) Ethnicity

Ethnic background is an important determinant of both the onset and progression of myopia. Asian children, including South Korean children, typically develop myopia earlier and progress faster than Caucasian children [55,57]. Thus, in Asian populations, earlier and more proactive initiation of myopia-control treatment is recommended.

Lifestyle and environmental factors

Reduced outdoor activity and excessive near work have been reported to be associated with earlier onset and faster progression of myopia [57,58]. Children with limited outdoor time or excessive near work demands are at increased risk of myopia and should be carefully monitored to enable the timely initiation of myopia-control treatment.

Concomitant strabismus: intermittent exotropia

Myopia is frequently observed in children with intermittent exotropia (IXT). IXT is typically an exclusion criterion in general myopia studies, resulting in limited research on the association between strabismus and myopia progression, however, there is insufficient evidence that the presence of IXT should be in myopia treatment decisions.

In a double-masked RCT, 6- to 12-year-old children with basic-type IXT were randomized to receive either 0.01%

atropine or a placebo eye drop for 12 months. The 0.01% atropine group exhibited a reduction in the near exodeviation angle, alongside a statistically significant inhibition of myopia progression compared to the control group (-0.51 D vs. -0.75 D and 0.31 mm vs. 0.42 mm, respectively) [59].

There is no compelling evidence to suggest that the presence of IXT or subsequent surgical correction affects the rate of myopia progression or the efficacy of atropine. A retrospective study in the United States comparing the rate of myopia progression in children with coexisting IXT and myopia versus those with myopia only found no significant difference in the speed of progression between the two groups [60]. A retrospective study in South Korea analyzing myopic children who received 0.05% atropine for at least 1 year reported no difference in the myopia control efficacy of 0.05% atropine between the group that underwent surgical correction for IXT and the group that did not [61].

Myopia Progression Control

Optical methods

1) Myopia-control spectacle lenses

One prominent etiological hypothesis for the development and progression of myopia is the emmetropization mechanism. This theory posits that the globe undergoes compensatory axial elongation in response to the retinal image being focused posterior to the retina (hyperopic defocus). According to this framework, a measurable lag of accommodation results in persistent hyperopic defocus, which subsequently serves as the driving signal for AL elongation and, consequently, myopia progression. Therefore, progressive addition lenses (PALs) and bifocal lenses have been used to reduce accommodative demand for myopia control. However, studies have shown either no effect or clinically insignificant effects, so the use of PALs or bifocal spectacles for myopia progression control has limited scientific evidence [62–64]. Furthermore, under-corrected spectacles used to be prescribed intentionally to ease accommodation, but studies suggest this approach has no myopia control effect or may even promote progression [65,66].

The other widely accepted paradigm is the peripheral defocus theory of myopia. This theory posits that the re-

fractive state of the peripheral retina significantly modulates ocular growth and, consequently, the development of myopia. Specifically, the presence of peripheral hyperopic defocus (light focusing behind the peripheral retina) is hypothesized to serve as a biomechanical signal that drives the eye to accelerate axial elongation. Conversely, introducing peripheral myopic defocus (light focusing in front of the peripheral retina) may slow down or inhibit this aberrant elongation.

MyoVision lens (Carl Zeiss Vision), which was developed based on the peripheral defocus paradigm, failed to demonstrate clinical efficacy for myopia progression control in an RCT [67]. Subsequently, spectacle lenses utilizing advanced optical designs, such as Defocus Incorporated Multiple Segments (DIMS) and Highly Aspheric Lenslet (HAL) technology, were developed based on the peripheral defocus theory. As of August 2025, two such lens technologies have received market approval from the Korean Ministry of Food and Drug Safety.

MiYOSMART lens (Hoya Vision Care), incorporating DIMS technology, was introduced to the South Korean market in March 2022. An RCT involving children aged 8 to 13 years with myopia ranging from -1 to -5 D demonstrated significant efficacy over a 2-year period. The DIMS group exhibited a mean myopia progression of -0.41 D, markedly less than the -0.85 D observed in the control group, thereby establishing a significant inhibitory effect on myopia progression. Furthermore, AL elongation was significantly suppressed in the test group (0.21 mm) compared to the control group (0.55 mm/2 yr), confirming a positive clinical outcome [68]. A separate comparative study indicated that DIMS spectacle lenses provide myopia control efficacy comparable to that of orthokeratology (Ortho-K) lenses [69].

The Stellest lens (Essilor International), which utilizes the HAL technique, was introduced in South Korea in October 2024 [70]. A 2-year RCT involving myopic children aged 8 to 13 years (with myopia between -0.75 and -4.75 D) demonstrated a significant inhibitory effect. AL elongation in the experimental group was 0.18 mm, which was substantially less than the 0.69 mm observed in the control group. Similarly, the increase in myopic spherical equivalent (SE) was significantly suppressed, measuring 0.48 D in the experimental group compared to 1.44 D in the control group [70]. Five-year longitudinal data, reported in 2025, further confirmed sustained efficacy, showing that

myopic SE progression was significantly inhibited, with an increase of 1.27 D in the test group versus 3.03 D in the control group over the 5 years. Total AL elongation was suppressed by 0.72 mm relative to the control group (0.67 mm vs. 1.40 mm) [71].

A 2-year comparative study of DIMS and HAL spectacle lenses, conducted in a cohort of 6- to 17-year-old Caucasian children, found no statistically significant difference in efficacy between the two lens types. Specifically, the proportion of children who exhibited progression of ≥ 1 D at 2 years was comparable (16.4% for DIMS vs. 20.5% for HAL), and the rate of AL elongation exceeding 0.3 mm was identical (35.6%) [72]. A separate study from China also reported comparable myopia control effects across DIMS, HAL, and Ortho-K lenses [73].

The primary advantages of spectacle-based myopia control interventions, when compared to Ortho-K or pharmaceutical treatments, include their relative ease of application for pediatric patients and the low incidence of adverse effects associated with long-term wear [74]. Furthermore, these modalities exhibit no significant rebound effect following treatment cessation. However, additional research is required to validate this observation.

While the current body of research on myopia-control spectacles is encouraging, it remains limited. There is currently an insufficiency of literature from both comparative trials against other agents and head-to-head studies comparing the different lens technologies, thus underscoring the necessity for further investigation [69,75]. Furthermore, precise alignment between the lens center and the visual axis is a critical factor; improper spectacle wear can compromise visual acuity or induce symptoms such as glare or halos [76]. As the fabrication of these specialized spectacles must be based on the full refractive correction determined by cycloplegic refraction, it is imperative that patients undergo an ophthalmic examination, including cycloplegic refraction, prior to receiving a prescription.

2) Myopia-control contact lenses: daytime dual-focus soft contact lenses

The dual-focus soft contact lens (DFSCL) currently available for myopia progression control in South Korea is the MiSight lens (CooperVision). The MiSight lens is a disposable soft contact lens worn during the day and is the only DFSCL in the United States approved by the Food and Drug Administration for myopia progression control.

MiSight contact lenses use a dual-focus concentric ring design with alternating vision correction and treatment zones (concentric ring dual-focus lens). The correction zones provide clear distance vision, while the treatment zones create myopic defocus (+2.0 D) simultaneously to signal the eye to slow its elongation, thereby reducing myopia progression in children.

A 3-year RCT was conducted on 144 children aged 8–12 years in Singapore, Canada, the United Kingdom, and Portugal [48]. The participants had myopia from -0.75 to -4.0 D and astigmatism < -1.0 D. The results showed that myopic SE increased by 1.25 ± 0.61 D in the control group, but only by 0.51 D in the MiSight lens group, demonstrating an approximately 59% myopia control effect. AL increased by 0.62 mm in the control group, but only by 0.30 mm in the MiSight lens group, showing a 52% suppression of AL increase. A follow-up study involving 108 children who completed the 3-year study reported that the group that switched from the control to the MiSight lens showed a deceleration in refractive change and AL increase over the subsequent 3 years. The group that continuously wore the MiSight lens for a total of 6 years maintained the myopia control effect [77]. The most recent study reported that after 3 or 6 years of continuous MiSight lens treatment, the rates of AL growth and myopia progression after treatment cessation were similar to those of untreated eyes in the corresponding age group, suggesting the treatment effect is maintained without a rebound effect after discontinuation [78]. Furthermore, no serious contact lens-related adverse events were reported over 6 years [79].

In conclusion, the MiSight lens, a daily disposable lens worn during the day, is a myopia progression control treatment option that can be considered for children and adolescents aged 8 years or older who prefer not to wear spectacles and have astigmatism ≤ -1.0 D.

3) Ortho-K lenses

Ortho-K lens has consistently shown to slow the rate of myopia progression compared to traditional single-vision glasses or contact lenses. The primary mechanism believed to account for this protective effect is the creation of peripheral myopic defocus. Ortho-K lenses reshape the cornea overnight so that peripheral rays are focused in front of the retina, signaling the eye to slow down elongation and thus myopia progression [80]. A large-scale meta-analysis in 2023, integrating previous studies, reported that the

myopia progression control effect of Ortho-K lenses is comparable to that of atropine eye drops and daytime myopia-control soft contact lenses [65].

Studies consistently show that younger children (particularly age 6–8 years) experience more rapid progression of myopia, and Ortho-K provides its greatest protective effect in this age group. Early treatment initiation translates to a higher relative reduction in both AL elongation and myopic progression [81]. Most successful and predictable outcomes are seen in candidates between -0.5 and -4.0 D for myopia correction. However, for myopia progression control, efficacy has also been observed in cases of moderate to high myopia >-4.0 D with concomitant use of partial correction spectacles [82]. Most manufacturers and practitioners recommend Ortho-K lenses for myopes with up to -1.75 D of astigmatism, however, the protective effect was reported in patients with up to -3.5 D of astigmatism [83].

Strategies to enhance the myopia control efficacy of Ortho-K lenses, based on clinical data, include employing modified lens designs. Using modified lens designs (e.g., with a smaller treatment zone) can increase the degree of peripheral myopic defocus, which may enhance myopia control but can have a trade-off with visual quality [84–87]. Low-dose atropine eye drops have shown additive effects when used with Ortho-K lenses. When combined, atropine increases pupil diameter besides its myopic control effect. The increased pupil diameter may enhance the peripheral defocus from Ortho-K, augmenting the retinal signaling to slow axial elongation. Interestingly, recent studies have reported that decentration of the Ortho-K lenses may be more effective in myopia control [88–90].

Several studies suggest that early discontinuation of Ortho-K lenses leads to a rebound effect and myopia progression, so maintaining long-term Ortho-K lens wear may help control myopia progression [91,92]. The primary complication of Ortho-K lens wear is microbial keratitis. The incidence of microbial keratitis has been reported to be similar to that in extended-wear soft contact lens users [93,94].

In conclusion, Ortho-K is an effective method for myopia progression control in myopic children. Efficacy is particularly good in younger children, and its use can also be considered in cases of moderate to high myopia or moderate astigmatism. If myopia progression remains rapid even with Ortho-K lens wear, modifying the Ortho-K lens design or combining it with atropine eye drops may further

enhance the myopia control effect.

Pharmacological treatment: atropine eyedrops

1) Mechanism

Atropine functions as a nonselective antagonist of acetylcholine muscarinic receptors. The exact mechanism of atropine in myopia control is still unknown. One of the most compelling hypotheses involves the modulation of the retinal dopamine pathway. Atropine is theorized to increase the release of dopamine and its metabolites within the retina, which subsequently inhibits the signaling cascade responsible for ocular elongation and myopia development. Beyond the neural retina, atropine can suppress the increase in AL by inhibiting the proliferation of scleral fibroblasts and regulating the synthesis and remodeling of the extracellular matrix within the sclera. Furthermore, atropine has been documented to induce a temporary increase in choroidal thickness, a physiological change hypothesized to be associated with slower myopia progression.

Recent investigations suggest that atropine's therapeutic efficacy in myopia control may extend beyond the muscarinic system, potentially involving interactions with other neuroreceptors, such as γ -aminobutyric acid receptors. This expanding body of evidence supports the current paradigm that the myopia control effect of atropine is not unitary, but rather the result of a complex, integrated action involving multiple ocular pathways [95].

2) Myopia control efficacy

Earlier clinical trials, such as the atropine for the treatment of myopia 1 (ATOM1) RCT established the significant efficacy of 1% atropine eye drops in controlling myopia progression. However, the high incidence of the rebound phenomenon and cycloplegia-related side effects severely restricted its practical clinical application [96]. This led to subsequent RCTs evaluating lower concentrations: 0.5%, 0.1%, and 0.01% (the ATOM2 study). Myopia control efficacy was concentration-dependent, with higher concentrations yielding greater effect [97]. Critically, when treatment was discontinued and monitored at the 3rd year, the lowest concentration, 0.01% atropine, exhibited the minimal rebound effect and was ultimately reported as the most efficacious over a 5-year cumulative period, concurrently demonstrating the most favorable side effect profile [52].

The Low-Concentration Atropine for Myopia Progression (LAMP) RCT compared three concentrations—0.05%, 0.025%, and 0.01%—against a placebo. Myopia control was confirmed for all tested concentrations, with the 0.05% concentration demonstrating the superior inhibitory effect in a concentration-dependent manner [98]. This therapeutic effect was sustained throughout the 3-year study, which included a 1-year treatment cessation period [98]. Subsequent 5-year follow-up results indicated an overall trend of enhanced efficacy with higher initial concentrations [99]. Specifically, continuous instillation of 0.05% atropine over 5 years proved more effective than retreatment initiated after cessation and early commencement of therapy is advantageous, given the faster myopia progression typically observed in younger children [99]. It was also confirmed that children in younger age groups showed worse treatment responses, requiring a relatively higher concentration of atropine to achieve a similar myopia control effect as older children [100].

A subsequent RCT conducted in Singapore investigating ultra-low concentrations (APPLE study) found that the myopia progression control effect was statistically significant for 0.005% over 1 year (SE, 0.23 D; AL, -0.09 mm), yet the effect of 0.0025% atropine was not statistically significant [101]. Consequently, 0.005% is currently considered the minimum effective concentration of atropine.

Efficacy data for low-concentration atropine has shown heterogeneity across different populations. RCTs conducted in the United States and Australia reported that 0.01% atropine eye drops did not significantly slow myopia progression [102,103]. The Childhood Atropine for Myopia Progression (CHAMP) RCT, involving North American and European children and published in the same year, found 0.01% atropine effective in slowing progression, while 0.02% atropine failed to show a significant effect [104]. A Japanese RCT reported that 0.01% atropine significantly suppressed myopia progression by 0.22 D and AL growth by 0.14 mm compared to placebo at year 2 [105]. A 1-year RCT on Indian children also reported significantly less myopia progression in the 0.01% atropine group (a 0.19 D difference) [106]. These varying results suggest that the effect of low-concentration atropine may differ according to ethnicity and region. However, since the differences, even when statistically significant, were less than the minimum measurable unit of 0.25 D, the efficacy of 0.01% atropine remains controversial.

In South Korean children, a retrospective study by Moon and Shin [107] using 0.01%, 0.025%, and 0.05% atropine eye drops for about 1 year confirmed a concentration-dependent myopia control effect. The progression rate for the 0.01% group was estimated at -0.84 D/yr. Jeon et al. [108] reported that among patients using 0.01% atropine in private practice, 46% showed a poor treatment response (myopia progression ≥ 0.5 D over 1 year), with an average progression of -0.90 D/yr. Following this, Cho et al. [109] reported in a study on patients using 0.05% atropine that a better treatment response was associated with older age and initial AL shortening. The efficacy of 0.01% topical atropine in South Korean reports appears to be lower than those in ATOM2 (-0.49 D over 2 years) or in LAMP (-0.59 D in the first year).

The observed differences across studies based on different ethnicity, region, and age group necessitate a customized concentration selection tailored to individual patient characteristics. Particularly in younger age groups with rapid AL growth or high-risk groups (e.g., both parents are myopic), a higher concentration of atropine may be considered initially [110].

3) Adverse effects

Common adverse effects associated with atropine are near vision blur due to reduced accommodation and photophobia due to pupillary dilation. These side effects are concentration-dependent and are more common with higher concentrations. One study reported that the maximum concentration that did not induce near vision blur was 0.02% [111]. In the ATOM2 study, after 1 year of using 0.5%, 0.1%, and 0.01% atropine, the reduction in accommodation was 12.4, 10.9, and 4.4 D, the reduction in near visual acuity was 0.32, 0.1, and 0.01 logMAR, and the increase in pupil size was 3.1, 2.4, and 0.9 mm, respectively [112]. In the LAMP study, 0.05%, 0.025%, and 0.01% atropine resulted in an accommodation reduction of 1.98, 1.61, and 0.26 D, respectively (compared to 0.32 D for placebo), and a pupil size increase of 1, 0.8, and 0.5 mm, respectively. It was reported that atropine concentrations of 0.05% or less can generally be used without major discomfort [109]. Other adverse effects are generally mild, and serious side effects with atropine use are rare [96,113]. Prescribing photochromic glasses for photophobia or progressive lenses for those complaining of near vision blur can alleviate discomfort and improve quality of life [114].

4) Premyopia

The LAMP2 RCT, which enrolled 4- to 9-year-old premyopia children (SE, +1 to 0 D), demonstrated a protective effect of low-concentration atropine against myopia onset. Instillation of 0.05% atropine significantly reduced the 2-year cumulative incidence of myopia to 28.4%, compared to the placebo group (53.0%) and the 0.01% atropine group (45.9%). This provides evidence that low-concentration atropine may be effective in delaying the onset of myopia in susceptible children [115]. A retrospective study in South Korea reported that a graduated atropine protocol (starting at 0.025% or 0.05% and titrating up to 0.125% based on progression rate) in 4- to 14-year-old premyopic children (SE, +0.75 to -0.50 D) achieved control of myopia progression <0.5 D over 2 years in 64% of the treated children [116], which is highly encouraging than other reports of myopic control in South Korean myopic children.

In conclusion, atropine eye drops are an effective treatment for myopia control, with efficacy directly dependent on the concentration used. While higher concentrations of atropine confer a greater myopia progression control effect, they are associated with a corresponding increase in adverse effects, such as photophobia and near vision blur. Should a single concentration be selected for the majority of patients, including those with premyopia, 0.05% may represent the optimal balance. Nonetheless, a strategy of initiating treatment at a lower concentration and subsequently titrating the dose upwards evaluating therapeutic response may remain as a valid clinical approach. For patients experiencing discomfort from side effects with higher atropine concentrations, the concurrent use of photochromic or multifocal spectacles is recommended.

Combination therapy

Combination therapy involves using low-concentration atropine eye drops together with optical methods such as Ortho-K lenses, myopia-control spectacles, or daytime myopia-control soft contact lenses.

1) Atropine and Ortho-K combination therapy

The combination of 0.01% atropine and Ortho-K lenses has been reported in multiple RCTs and meta-analyses to be more effective in controlling myopia progression than Ortho-K monotherapy [117–124].

Most reports suggest that adding 0.01% atropine to Or-

tho-K lenses improves the myopia control effect compared to Ortho-K monotherapy in patients with low to moderate myopia (-1 to -3 D or up to -4 D) [121–124]. However, a Japanese RCT reported no additional benefit from combination therapy in a group with higher initial myopia (-3 to -6 D) [123,124].

A 2-year Chinese RCT suggested an additional benefit of adding 0.01% atropine to Ortho-K lenses in the 10–12 years age group (Δ AL 0.18 mm/2 yr vs. 0.37 mm/2 yr), but not in the 8–10 years age group [119]. In contrast, the Japanese RCT reported no influence of age [123,124]. Further research is needed regarding the influence of age and the differential efficacy of atropine at varying concentrations used in combination therapy.

2) Atropine and myopia-control spectacles combination therapy

Studies investigating the combination of low-concentration atropine and myopia-control spectacles remain limited and controversial. Retrospective studies from China showed that the combination of DIMS and 0.01% atropine was more effective than DIMS monotherapy, reducing myopic SE progression by 38% (0.49 D/yr vs. 0.79 D/yr) [125] and AL change by 32% (0.15 mm/yr vs. 0.22 mm/yr [126]; 0.28 mm/yr vs. 0.41 mm/yr [125]). A retrospective study from Taiwan similarly reported that combining DIMS with 0.01% or 0.125% atropine showed a better myopia control effect (both Δ SE and Δ AL) after 1 year than DIMS monotherapy, with no difference in efficacy based on the atropine concentration [127].

In contrast, a prospective observational study in Europe reported that the combination of DIMS and 0.01% atropine provided an additional inhibitory effect on SE change after 1 year compared to DIMS monotherapy, but no significant difference in AL change [128]. Furthermore, an RCT from Europe (Atropine and Spectacle lens Combination Treatment, ASPECT) reported that the combination of DIMS glasses and 0.025% atropine reduced axial elongation more effectively than 0.025% atropine with single-vision glasses (0.07 mm vs. 0.18 mm in 12 months). However, the difference in SE change (-0.09 D vs. -0.19 D) was not statistically significant [129].

A retrospective study conducted in Singapore on HAL spectacles showed that in cases where myopia progress despite 0.01% or 0.025% low-concentration atropine treatment (≥ 0.5 D progression over 6 months), adding HAL

spectacles significantly retard myopia progression (both Δ SE and Δ AL) [130].

3) Atropine and daytime myopia-control soft contact lenses combination therapy

Research on the combination of low-concentration atropine and daytime myopia-control soft contact lenses is very limited. A retrospective study on Caucasian children found that both the combination of DFSCS (MiSight) and 0.01% atropine and 0.01% atropine monotherapy suppressed SE progression compared to the conventional spectacles group, but there was no significant difference between the two treatment groups [131]. Conversely, a retrospective study in South Korea showed that adding MiSight lenses to children with rapid myopia progression after 1 year of 0.05% atropine treatment resulted in a significantly greater suppression of both myopia progression and axial elongation compared to the preceding year [132].

Many reports suggest that combination therapy more effectively controls myopia progression than monotherapy. However, well-designed RCTs are scarce, and further research is needed. Combination therapy may be beneficial when the treatment response to monotherapy does not meet the target goals.

Evaluation of Treatment Efficacy

The progression of myopia and the efficacy of myopia progression control treatment can be assessed by measuring changes in SE and AL. Evaluating treatment efficacy through SE is directly related to the change in refractive error, but manifest refraction is subject to significant errors due to accommodation, and performing cycloplegic refraction at every follow-up is often difficult. School-age myopia is predominantly axial myopia, and the correlation between changes in AL and refractive error is well-established in many studies [133–137]. Therefore, it is advisable to consider changes in both SE and AL when evaluating myopia progression.

Normal growth vs. myopic growth

When evaluating the efficacy of myopia progression control treatment based on changes in AL, it must be considered that an increase in AL does not necessarily indicate

myopia progression. Unlike the normal increase in AL due to normal eye growth, only excessive AL increase causes myopia progression. Although there is a lack of clear research on the extent of normal AL increase according to age and refractive error, normal AL growth in emmetropic eyes can be approximately 0.05 to 0.2 mm/yr, and this physiological AL increase tends to gradually decrease with age [138–140].

Correlation between AL change and SE change

To assess myopia progression based on AL change, it is necessary to know how much the SE changes in response to AL elongation (Δ SE/ Δ AL ratio). A Danish study on myopic children aged 6 to 12 years reported that myopic SE increased by 1.67 to 1.89 D for every 1 mm increase in AL [141]. A Chinese study on myopic children aged 6 to 14 years observed an increase of 1.60 D in myopic SE for every 1 mm increase in AL [142]. Furthermore, a study on Chinese elementary schoolchildren (grades 1–3) showed that the Δ SE/ Δ AL ratio progressively increased with grade: 1.30 D/mm in grade 1, 1.42 D/mm in grade 2, and 1.56 D/mm in grade 3 [143]. This pattern may be attributed to age-related weakening of the lens's ability to compensate for AL elongation by reducing its refractive power, leading to a higher Δ SE/ Δ AL ratio with age [144,145]. Additionally, the Δ SE/ Δ AL ratio is known to be greater in myopic eyes than in emmetropic eyes. A recent prospective study on 710 Chinese children aged 6 to 16 years reported the following correlations: Δ SE/ Δ AL = $1.74 + 0.05 \times \text{age}$ for myopes and Δ SE/ Δ AL = $1.33 + 0.05 \times \text{age}$ for nonmyopes [135].

Evaluation of treatment efficacy

Treatment efficacy should be evaluated at least every 6 months [146]. Since the change in SE with AL increases varies among individuals, both AL and SE changes should be considered when assessing treatment efficacy and setting goals. Methods for assessing treatment efficacy include comparing the absolute values of SE and AL changes over a certain period and comparing the rate of change (%) relative to pretreatment values.

In untreated cases, annual myopia progression rates in Asian studies of elementary school children have been reported to be approximately -0.63 to -0.97 D/yr [49,147–

149], which is higher than the -0.38 to -0.55 D/yr reported for Caucasian children [149–151]. Large-scale longitudinal studies on the average myopia progression rate in South Korean children and adolescents are still lacking. However, single-center retrospective studies conducted since the 2000s suggest that for untreated eyes, myopic SE increase ranges from 0.69 to 1.61 D/yr, and AL increase ranges from 0.55 to 0.61 mm/yr [107,152,153], indicating a relatively rapid progression rate even within Asia. A recent multi-center South Korean study reported that untreated myopic patients aged 4 to 11 years showed an average annual myopic SE increase of 0.92 ± 1.01 D and an AL increase of 0.49 ± 0.24 mm [154].

Multiple RCTs have reported that myopia progression control treatments reduce AL increase by approximately 50% to 60% compared to the control groups. Based on this, treatment efficacy in South Korean children and adolescents can be considered acceptable if myopia progression decreases relative to pretreatment period and is maintained at a myopic SE change of <0.5 D/yr and an AL change of <0.30 mm/yr. However, since the natural rate of axial elongation is faster in younger children (aged 4–6 years) than in older children (aged 10–12 years), and the $\Delta\text{SE}/\Delta\text{AL}$ ratio also varies depending on the degree of myopia, evaluation of treatment efficacy should comprehensively consider various individual factors such as age, degree of myopia, and treatment adherence [155].

Treatment goals

High myopia is generally defined as a myopic SE of ≥ 5 to 6 D or an AL of ≥ 26.0 to 26.5 mm [156–162]. It is well known from various studies that complications such as myopic retinal degeneration, retinal detachment, and glaucoma increase with high myopia. Studies on the South Korean population also observed continuous AL increase in adults with AL ≥ 26.0 mm [161,162], which was associated with myopic retinal degeneration [156–160].

Therefore, for patients starting myopia-control treatment in early stages of myopia, the final goal should be set to an SE <-5 to -6 D and AL <26 to 26.5 mm. Customized treatment goals should be established based on individual factors such as patient's age, baseline myopia, progression rate, and others. Considering the relatively rapid myopia progression observed in South Korean children and adolescents, more aggressive therapeutic approaches may be

warranted.

Treatment Cessation

Rebound effect following treatment cessation

Upon discontinuation of myopia-control treatment, a rebound effect may occur. Data from the ATOM2 RCT indicated that rebound was significantly more pronounced in groups treated with higher atropine concentrations (0.5% and 0.1%) compared to the 0.01% group [97]. The LAMP phase 3 RCT confirmed rebound across all tested concentrations (0.05%, 0.025%, 0.01%), correlating its magnitude with younger age at cessation and higher dosage [98]. Conversely, other studies reported no rebound following 0.01% cessation [163–165]. Generally, the rebound effect following cessation of atropine treatment is associated with younger age, higher drug concentrations, shorter treatment durations, and greater baseline myopia [166].

The extent of the rebound effect following discontinuation of optical treatments varies across studies, and prospective data remain very limited, making it difficult to draw definitive conclusions regarding rebound trends [167–169]. Cho and Cheung [92] reported faster AL growth after Ortho-K cessation in children aged 14 years and younger, compared to those in the spectacle-wearing control group.

Timing of treatment cessation

Myopia progression is reported to stabilize with increasing age [150,170]. The Correction of Myopia Evaluation Trial (COMET) study and the Dream study reported that myopia stabilized around the average age of 15 [150,170]. However, Lee et al. [171] reported that some myopia progression can continue into the 20s. The Dream study reported the median annual increase in myopia around age 15 as 0.19 D/yr for ages 13–15 years and 0.09 D/yr for ages 16–18 years [150]. The COMET study defined the stabilization of AL increase as ≤ 0.06 mm/yr [134].

There is currently no established guideline for the amount of progression or age at which treatment should be discontinued. The ATOM2 (phase 3) study suggested discontinuing 0.01% atropine use when the patient is over 13 years of age and the myopia progression is either absent or

<0.25 D/yr [52]. If myopia progresses after atropine cessation, 0.01% atropine can be readministered.

Considering the average age of myopia stabilization and AL stabilization, treatment cessation can generally be considered when the refractive error increases by <0.25 D/yr and AL increases by <0.1 mm/yr around the age of 13–15 years. The timing of treatment cessation should be determined individually, considering various factors such as the patient's refractive error, expected final refractive error, and progression rate.

Tentative methods of treatment cessation

To date, no standardized protocol exists for discontinuing myopia-control treatments. Since higher concentrations of atropine eye drops are associated with a rebound effect, tapering the treatment, rather than abrupt cessation, is expected to reduce the rebound effect, although there is no standardized method currently established. Polling et al. [172] conducted a 3-year prospective study on 124 children (mean age, 9.5 years) who used 0.5% atropine for 1 year. They gradually reduced the concentration to 0.25%, 0.1%, and 0.01% every 6 months if SE progression was ≤ -0.5 D/yr and AL increase was <0.2 mm. They reported that the patients who tapered the dose (26% of the total) did not experience a rebound effect. Erdinest et al. [173] reported a method for discontinuing 0.01% atropine by reducing the weekly instillation days by one per month over 6 months. They found that combining it with a soft contact lens with peripheral myopic defocus resulted in the least rebound effect from atropine tapering.

Conclusions

Myopia constitutes a major public health challenge, particularly in Asian populations, due to the high risk of sight-threatening complications associated with high myopia. Evidence-based interventions, encompassing lifestyle modifications, optical therapies (specialized spectacle lenses, DFSCs, and Ortho-K), and pharmacological treatment (low-concentration atropine), have demonstrated efficacy in slowing myopia progression in pediatric patients. Topical atropine at a concentration of 0.05% provides a favorable balance of efficacy and a low side effect profile, and combination therapies show potential for enhanced efficacy, especially in rapid progressors. Accurate monitoring via AL measurement, alongside SE, is essential for evaluating treatment response. Given the typically faster progression rate in South Korean children, a proactive and often more intensive management strategy is warranted, with the goal of achieving a final refractive error below -5 to -6 D and AL below 26.0 to 26.5 mm to mitigate the risk of ocular pathology. To facilitate clinical decision-making, factors for patient selection incorporating clinical features and lifestyle are summarized in Table 1.

While the body of literature supporting myopia management is rapidly expanding, clinicians must recognize that many current treatment recommendations are derived from studies with limited long-term follow-up and moderate-to-low levels of evidence. Therefore, we recommend that practitioners adopt the strategies outlined herein by tailoring treatment to each patient and utilizing shared decision-making. Treatment protocols should be titrated

Table 1. Patient selection incorporating clinical and lifestyle factors in myopia control

Category	Risk factor and description
Age	Younger age at myopia onset
Refractive error	
Baseline status	Relatively high myopia at presentation (≥ -3.00 D)
Rate of progression	Rapid myopic progression (≥ 0.50 D/yr)
Axial length	Rapid axial elongation (≥ 0.3 – 0.4 mm/yr)
Genetic factor	Parental myopia, particularly when both parents are highly myopic
Ethnicity	East Asian ethnicity
Lifestyle factor	
Outdoor activity	Limited outdoor activity (<2 hr/day)
Near work	Excessive near work (working distance <30 cm or continuous sessions >45 min)

D = diopters.

based on the individual patient's risk profile and measured response to therapy. Continued adherence to regular monitoring and integration of new high-level evidence as it becomes available are essential for optimizing patient care and ensuring responsible clinical practice.

Key points

1) Lifestyle modification

- Increasing outdoor activity (≥ 2 hr/day) and near work distance (≥ 20 –33 cm), while reducing near work duration (≤ 20 –45 minutes continuously), may lower the risk of myopia onset.
- Although its efficacy in slowing the rate of preexisting myopia progression remains controversial, such lifestyle modification remains a valuable clinical recommendation for all children with myopia.
- The association between digital device (smartphone, tablet) use and myopia has not been sufficiently studied; however, increased screen time exposure may elevate the risk of myopia onset.

2) Patient selection

- The initiation of myopia management intervention should be considered upon the diagnosis of myopia (SE, < -0.50 to -0.75 D).
- In the presence of risk factors (early onset, rapid myopia progression, rapid AL elongation, parental myopia, Asian ethnicity), treatment should be initiated earlier and more proactively.
- IXT does not appear to affect myopia progression or treatment.

3) Myopia progression control

(1) Spectacle lenses

- Undercorrection of myopia is not recommended as it may exacerbate myopia progression.
- Bifocal lenses and PALs are not recommended due to a lack of significant efficacy.
- DIMS lenses (MiYOSMART) and HAL lenses (Stellest) have been reported to have significant myopia progression control effects.

(2) Contact lenses

- Concentric ring DFSLs (MiSight) have demonstrated significant progression control efficacy and can be a

useful treatment option.

(3) Ortho-K lenses

- Ortho-K is an effective method for myopia progression control in children.
- As greater efficacy is reported in younger age groups, Ortho-K can be used from a young age. It can be considered in combination with partial correction glasses for high myopia. Concurrent use may be considered even in cases of high myopia.
- If the myopia control efficacy is insufficient, changing the lens design or adding atropine eye drops may provide additional benefits.

(4) Pharmacological treatment: atropine eyedrops

- Atropine eye drops have been reported to be effective in preventing myopia onset and suppressing progression, with efficacy tending to increase with higher concentrations.
- Considering both efficacy and side effects, a concentration of approximately 0.05% may be optimal for most patients with myopia or those at risk of progression.
- If myopia control efficacy is insufficient, a strategy of gradually increasing the concentration can be attempted.

(5) Combination therapy

- Although evidence is not yet sufficient, combining low-concentration atropine with optical treatments may be considered when monotherapy provides insufficient effect.

4) Evaluation of treatment efficacy

- Treatment efficacy can be assessed based on changes in SE and AL.
- Treatment can be considered effective if myopic refractive change is reduced compared to pre-treatment and maintained at < 0.50 D/yr for SE and < 0.30 mm/yr for AL elongation.
- However, it should be considered that physiological axial elongation is more rapid at younger ages, and the ratio of refractive change to AL change ($\Delta SE / \Delta AL$) may vary depending on the degree of myopia.
- Treatment goals should be customized, reflecting individual factors such as age, baseline myopia, and the rate of progression.

5) Treatment cessation

- In patients aged 13–15 years or older, if myopia progression is <0.25 D/yr and axial elongation is <0.1 mm/yr, gradual treatment discontinuation through tapering may be considered. However, the timing of cessation may vary based on factors such as the degree of myopia and the anticipated final refraction.
- Atropine tapering can be achieved through a gradual reduction in concentration or dosing frequency. It should be implemented cautiously due to the risk of the rebound effect, particularly in younger children, those with high myopia, or those on high-concentration atropine regimens.

Conflicts of Interest: None.

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The Korean Myopia Management Consensus Task Force

The Korean Myopia Management Consensus Task Force was established by the Korean Myopia Society for the Korean Association for Pediatric Ophthalmology and Strabismus (KAPOS) to develop national consensus for the management of myopia in South Korean children.

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