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Review Article

A comprehensive review of binocular vision in myopia control

Namrata Srivastava[1]*, Deepak Gupta[2], Mahesh Chandra[3]

[1]Department of Optometry, ERA University of Allied Health Science, Lucknow, Uttar Pradesh, India
[2]Department of Paramedical, Technology NIMS University Rajasthan, Jaipur, India
[3]Dr. Shushila Tiwari Hospital and Government Medical College, Haldwani, Uttarakhand, India

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***Correspondence:**
Dr. Namrata Srivastava,
E-mail: nam.dropth@gmail.com

ABSTRACT

Myopia is a growing problem worldwide and is particularly common among young people. Myopia is a disease that affects the retina responsible for detail in the middle eye and can lead to permanent vision loss. Myopia, a prevalent refractive error causing distant objects to appear blurred, is increasingly affecting global populations, particularly children. By 2050, it's projected that half the world's population will be myopic, largely due to genetic predispositions and environmental factors like excessive near work and limited outdoor activities. A promising approach to managing myopia is binocular vision training, which involves using both eyes to create a single, clear image, potentially slowing myopia progression. Understanding the benefits of this method is critical as we move forward, especially considering the surge in myopia cases during the COVID-19 pandemic due to increased digital device use. Research underscores the importance of addressing lifestyle and promoting outdoor activities and mitigating the impact of near work can help manage myopia progression and associated binocular vision disorders. Binocular vision training shows promise for myopia control by enhancing eye coordination, potentially slowing progression. Key factors include accommodation, AC/A ratios, and phoria, which are essential for effective diagnostics and therapy. Recent research emphasizes a holistic assessment of these elements for precise management of myopia and related binocular vision disorders in children. Understanding the mechanisms and innovative approaches of binocular vision in controlling myopia, highlighting the significance of continuous research and patient education in improving eye health.

Keywords: Myopia, Accommodation, Phoria, AC/A ratio, COVID-19, Binocular vision

INTRODUCTION

Myopia is a growing concern worldwide, affecting millions of people each year. In the quest for effective solutions, a new method is gaining attention: binocular vision. This powerful approach could revolutionize myopia control, offering hope for better eye health.

UNDERSTANDING MYOPIA AND ITS PREVALENCE

Myopia, commonly known as near-sightedness, is a refractive error that causes distant objects to appear blurred while close objects remain clear. The prevalence of myopia has been steadily increasing worldwide, especially in younger populations. According to the world health organization, it is estimated that by 2050, half of the world's population will be myopic.

FACTORS CONTRIBUTING TO MYOPIA

Various factors contribute to the development and progression of myopia. Genetics play a significant role, with children having myopic parents being more likely to develop myopia themselves. Environmental factors such as limited time spent outdoors and excessive near work,

such as reading or screen time have also been linked to the onset of myopia. Lack of exposure to natural light and spending extended periods performing close-up tasks can contribute to elongation of the eyeball, leading to myopia.

But what exactly is binocular vision, and how can it help manage myopia? By using both eyes to create a single, clear image, binocular vision training may reduce the progression of myopia, especially in children.

As we move into 2024, it's crucial to explore these advancements. Understanding the benefits of binocular vision could help us tackle the myopia epidemic and improve the quality of life for many. Stay tuned to learn how this innovative method can make a difference.

Pediatric optometrists are seeing an increase in myopia development/progression and binocular vision disorders due to increased usage of digital devices during the COVID-19 pandemic.[1] patients developed acquired concomitant esotropia from excessive near device usage during the lockdown, and were myopia who were reported to intensively use the computer for more than eight hours per day. It is important to consider lifestyle and environmental factors when developing or progressing myopia. Increased time spent outdoors has been linked to a reduced risk of developing myopia. Take regular breaks when engaging in near work. Following the 20-20-20 rule can be beneficial-every 20 minutes, take a five-minute break to look away from close-up tasks. Maintain proper reading distance and taking breaks when reading and holding reading material at Harmon's distance are recommended.

Outdoor time may prevent or delay myopia onset, but it is less clear whether it is effective in slowing myopia progression in eyes that are already myopic. A symmetric head posture whiles sitting at a desk can lead to differences in accommodative demands between the two eyes, which can affect vergence postures, further disrupting binocularity.[2] the bottom line is to reduce accommodative and vergence demands, given that intensive near work has harmful effects on one of the eyes. Accommodation, binocular function, and myopia are the roles of accommodative amplitude, accuracy (lag of accommodation), eye alignment measures (phoria), and accommodative convergence to accommodation ratios (AC/A). Several studies have examined the relationship between accommodation and binocular vision. During the COVID-19 pandemic, pediatric optometrists have seen increased cases of myopia development/progression and binocular vision disorders, likely due to greater digital device usage. A case series reported patients developing acquired esotropia from excessive near work during lockdowns, some of whom were also myopic.[3]

Research indicates that while spending approximately two hours a day outdoors can prevent or delay the onset of myopia, its effectiveness in slowing the progression of myopia in already myopic eyes is less certain.[4] When children are outside, they typically look at objects farther away compared to when they are indoors, and the higher levels of illumination outdoors lead to greater pupil miosis. This increased pupil constriction results in a greater depth of focus and reduced accommodative demand.[5] An outdoor environment is, on average, 100 times brighter than indoors, and this brightness stimulates release of dopamine in outer retina. Dopamine acts as a strong inhibitor of axial elongation, key factor in myopia progression.[6] A prospective population study in Taiwan found that taking breaks from near work every 30 minutes and spending more time outdoors are protective behaviors against both the onset and progression of myopia.[7] Additionally, engaging in near work at distances closer than 40 cm increases demands on both accommodation and vergence, which can exacerbate binocular vision symptoms.[8] Asymmetric head posture while sitting at desk can also lead to different accommodative demands between the two eyes, affecting vergence postures and disrupting binocularity.[9] In summary, reducing accommodative and vergence demands is crucial, as intensive near work has detrimental effects on binocular vision. Therefore, promoting outdoor activities and implementing strategies to mitigate the impact of near work is essential for managing myopia progression and associated binocular vision disorders in children.

Figure 1: Myopia and its prevalence.

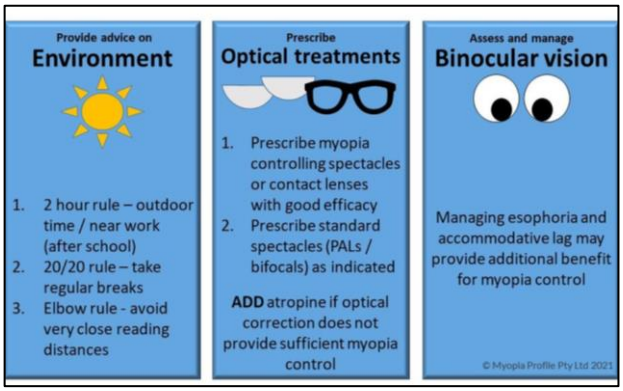

Figure 2: Clinical management for myopia control.

RISKS ASSOCIATED WITH HIGH MYOPIA

Individuals with high myopia face increased risks of severe eye conditions that can impact vision and overall eye health. One of the primary risks is retinal detachment, where the thin layer at the back of the eye pulls away from its normal position, causing vision loss. Myopic maculopathy, a condition affecting the central part of the retina responsible for detailed central vision, can lead to permanent vision impairment. Furthermore, high myopia is associated with an elevated risk of developing glaucoma, a group of eye conditions causing damage to the optic nerve.

Managing myopia through appropriate interventions and regular eye exams is crucial in minimizing the risks associated with high myopia. Implementing strategies such as myopia control treatments, lifestyle modifications, and protective eyewear can help in managing myopia progression and maintaining optimal eye health. It is essential to raise awareness about myopia and its potential consequences to encourage proactive measures for effective myopia management.

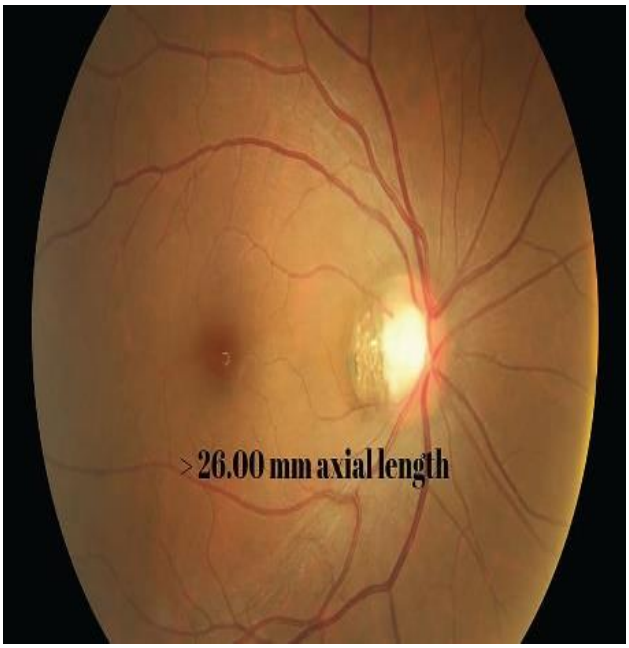

Figure 3: Axial length of 26.00 mm or greater in children greatly increases their risk of eye disease in adulthood.

BINOCULAR VISION AND MYOPIA CONTROL

Binocular vision plays a crucial role in our visual system, allowing us to perceive depth and distance accurately. When it comes to myopia control, understanding how binocular vision influences visual processing is key. The coordination between both eyes is vital for proper depth perception and focusing abilities. In myopia, where the eyeball is elongated, binocular vision can be harnessed as a tool to help manage its progression.

MECHANISMS OF BINOCULAR VISION IN MYOPIA MANAGEMENT

Binocular vision exercises or therapies aim to strengthen the coordination between the eyes, which can potentially slow down myopia progression. Studies have shown that interventions focusing on binocular vision can improve eye alignment and reduce the strain on the visual system. By incorporating exercises that promote proper binocular vision, individuals with myopia may experience better visual outcomes and reduced dependence on corrective lenses.

INNOVATIVE APPROACHES IN BINOCULAR VISION FOR MYOPIA CONTROL

In recent years, advancements in technology have opened up new possibilities for leveraging binocular vision in myopia control. Optometrists and ophthalmologists are exploring cutting-edge techniques to integrate binocular vision therapies into their practice. By incorporating innovative tools and methodologies, such as virtual reality-based exercises or personalized vision training programs, practitioners can provide tailored solutions for each individual's unique visual needs. By staying at the forefront of these developments, eye care professionals can offer more effective and personalized care for managing myopia through binocular vision interventions.

Understanding the binocular vision status in young myopes can help determine if a prescribed myopia management strategy will synergistically improve binocular vision or whether additional management is necessary. For example, take extra care of patients with an exophoria vergence presentation as they are more likely to become more exophoric with myopia defocus optical corrections.

Here are the four management options to consider:

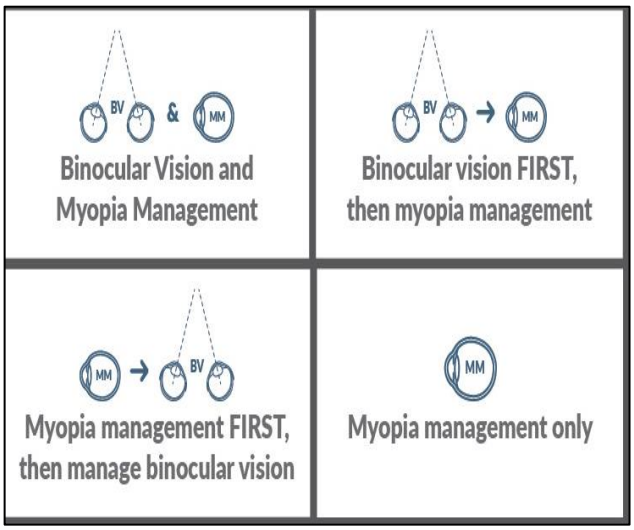

Figure 4: Innovative approaches in binocular vision for myopia control.

RESEARCH ON ACCOMMODATION, BINOCULAR FUNCTION, AND MYOPIA

Recent research has delved into intricate relationship between accommodation, binocular function, and development and progression of myopia. Key areas of focus include accommodative amplitude, accuracy (lag of accommodation), eye alignment measures (phoria) and AC/A.

Lag of accommodation and myopia

A lag of accommodation occurs when the eye focuses farther than the stimulus, resulting in hyperopic defocus. Mutti and colleagues conducted a large longitudinal study in 2006, which revealed that children who developed myopia exhibited a greater lag of accommodation compared to those who remained emmetropic, even four years before myopia onset. Interestingly, this increased lag was not significantly elevated during the first year of myopia onset.[10] Other studies have also confirmed that myopes generally have a higher lag of accommodation than emmetropes.[11] The concept of hyperopic defocus in the peripheral retina contributing to myopia progression is supported by animal studies, where form deprivation and diffuse blur, simulating a high lag of accommodation, induced hyperopic defocus. This suggests that relative hyperopic blur coupled with an increased lag of accommodation could stimulate myopia development.

AC/A ratios and myopia

The AC/A ratio represent the relationship between the amount of convergence induced by accommodation and the amount of accommodation itself. Research indicates that children with higher AC/A ratios are at an increased risk of developing myopia. Myopic children typically show higher AC/A ratios compared to their emmetropic peers, marking it as a potential risk factor for rapid myopia onset.[12] Mutti and colleagues also found a correlation between higher AC/A ratios and greater accommodative lag, though they did not establish a direct association with a faster rate of myopia progression.[13]

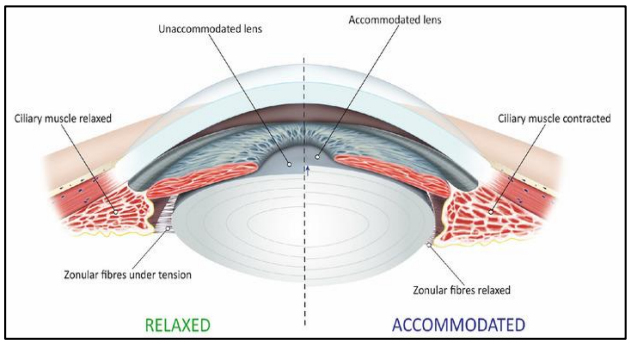

Figure 5: Accommodated lens unaccommodated lens ciliary muscle relaxed ciliary muscle contracted zonular fibres under tension zonular fibre relaxed accommodation.

Phoria and myopia

Phoria, particularly near phoria, has been studied for its predictive value in myopia development. Drobe and de-Saint-Andre in 1995 reported that pre-myopes tended to exhibit esophoria compared to emmetropes. Gross and Jackson in 1996 conducted a three-year study on 87 children and observed that near phoria outside the range of 1 esophoria to 3 exophoria was a risk factor for myopia development. They found that near phorias were more convergent in the group that became myopic compared to those who remained emmetropic.[14] Despite these studies being nearly three decades old, their findings remain relevant: atypical near phoria is a reliable predictor of myopia onset and progression. Clinically, if a child's near phoria deviates from the expected 2-6 diopters of exophoria and they exhibit symptoms of a binocular vision disorder, a comprehensive binocular vision evaluation is warranted.

MYOPIA MANAGEMENT STRATEGIES

The four primary strategies for managing myopia are topical low-dose atropine, orthokeratology (OrthoK), dual-focus soft contact lenses/center-distance multifocal contact lenses, and bifocal or multifocal glasses. Each of these strategies has distinct effects on binocular vision and accommodation, which must be considered to optimize treatment outcomes.

Topical low-dose atropine

Low-dose atropine (0.01%, 0.025%, 0.05%) is effective in slowing myopia progression. The LAMP study (2019) found 0.05% atropine to be the most effective at controlling spherical equivalent progression and axial length elongation over two years.[15] However, even at low concentrations, atropine can impair accommodation and increase the tendency towards esophoria. A notable case report described children developing convergence excess esotropia (CEET) after using 0.01% atropine.[16] I encountered a patient who developed acquired esotropia after being mistakenly given 1% atropine. This child's sudden-onset esotropia, with no neurological cause found, was attributed to atropine-induced accommodative paralysis and excessive accommodative convergence, resulting in a high AC/A ratio.

Following atropine discontinuation and vision therapy, his binocular function improved significantly, reducing his need for prism correction. Given these observations, low-dose atropine should be cautiously used in children with esophoria. Some retrospective, population-based observational study was to describe the long-term refractive error changes in children diagnosed with intermittent exotropia (IXT) in a defined population while progressive addition lens (PALs) and photochromic lenses can help manage accommodative and photophobic effects in these patients.[17]

Orthokeratology (OrthoK)

OrthoK manages myopia by inducing peripheral myopic defocus. Studies indicate that children with lower baseline accommodative amplitudes respond better to OrthoK, showing a 56% improved control of myopia progression over two years.[18] OrthoK also tends to increase exophoria in young adult myopes, making it a suitable option for children with esophoria.[19] However, patients with IXT or high exophoria may not be ideal candidates. Evaluating near base-out vergence ranges during initial follow-ups ensures Sheard's criterion is met, optimizing treatment outcomes.

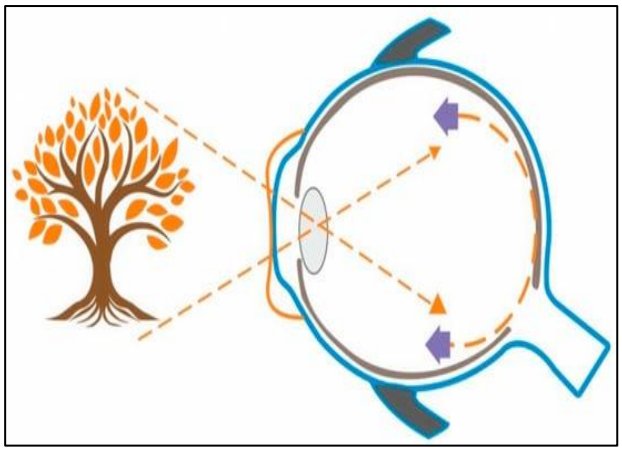

Figure 6: Depicts the mechanism of action of orthokeratology lens.

The cornea reshaped by the orthokeratology lens bends peripheral light to impose myopic defocus in the peripheral retina.

Center-distance multifocal and dual-focus soft lenses

These lenses are effective in reducing peripheral hyperopic defocus. Some studies show that children wearing multifocal contact lenses exhibit reduced accommodative responses and increased exophoria compared to those in single-vision lenses.[20] However, other studies report no significant differences in binocular or accommodative function between children wearing dual-focus lenses and those wearing single-vision lenses. Interestingly, an abstract from the International Myopia Conference noted more regressive saccades during reading in subjects wearing extended depth of focus lenses compared to dual-focus or single-vision lenses.[20,21]

The studies also explored the initial experience of participants wearing two different daily disposable myopia management (MM) contact lenses. These lenses are designed to slow myopia progression and axial elongation. The study assessed various factors associated with successful lens wear, including visual acuity, contrast sensitivity, accommodation, comfort, and vision quality and the purpose of some study was to evaluate the binocular and accommodative function in children wearing dual focus (DF) MiSight® contact lenses for myopia control, compared to children wearing single-vision (SV) spectacles.[22,23]

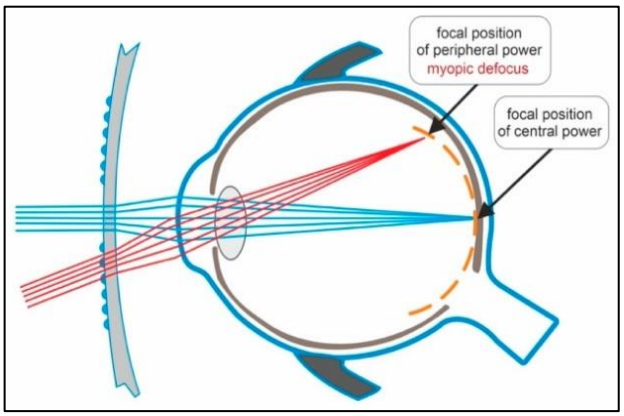

Figure 7: Depicts the mechanism of action of defocus-incorporated multiple-segments spectacle lens.

Light passing through the central zone of the DIMS creates a clear image on the retina. Light passing through the peripheral part of the DIMS creates myopic defocus on the peripheral retina.

Bifocal or multifocal glasses

Prescribing a near addition lens reduces accommodative response and results in an exophoric shift. This approach aims to improve accommodative accuracy and minimize retinal blur. Studies indicate that myopic children with near esophoria progress faster in single-vision lenses than those in PALs, with a higher lag of accommodation in the PALs group showing a greater treatment effect.[24,25] For myopia management, executive bifocals are preferable because they allow more plus lens power to affect a larger retinal area. However, due to cosmetic considerations, PALs are often chosen. When prescribing PALs, setting the segment height 1 mm above pupil center provides wider access to near plus power, minimizing retinal blur and stabilizing accommodative response.

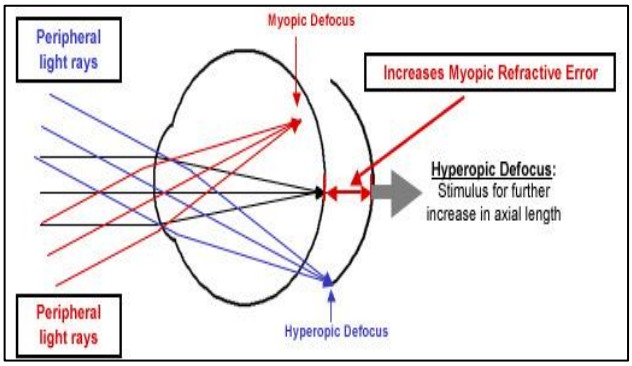

Figure 8: Peripheral hyperopic defocus simulates eye growing longer to focus peripheral light rays onto retina.

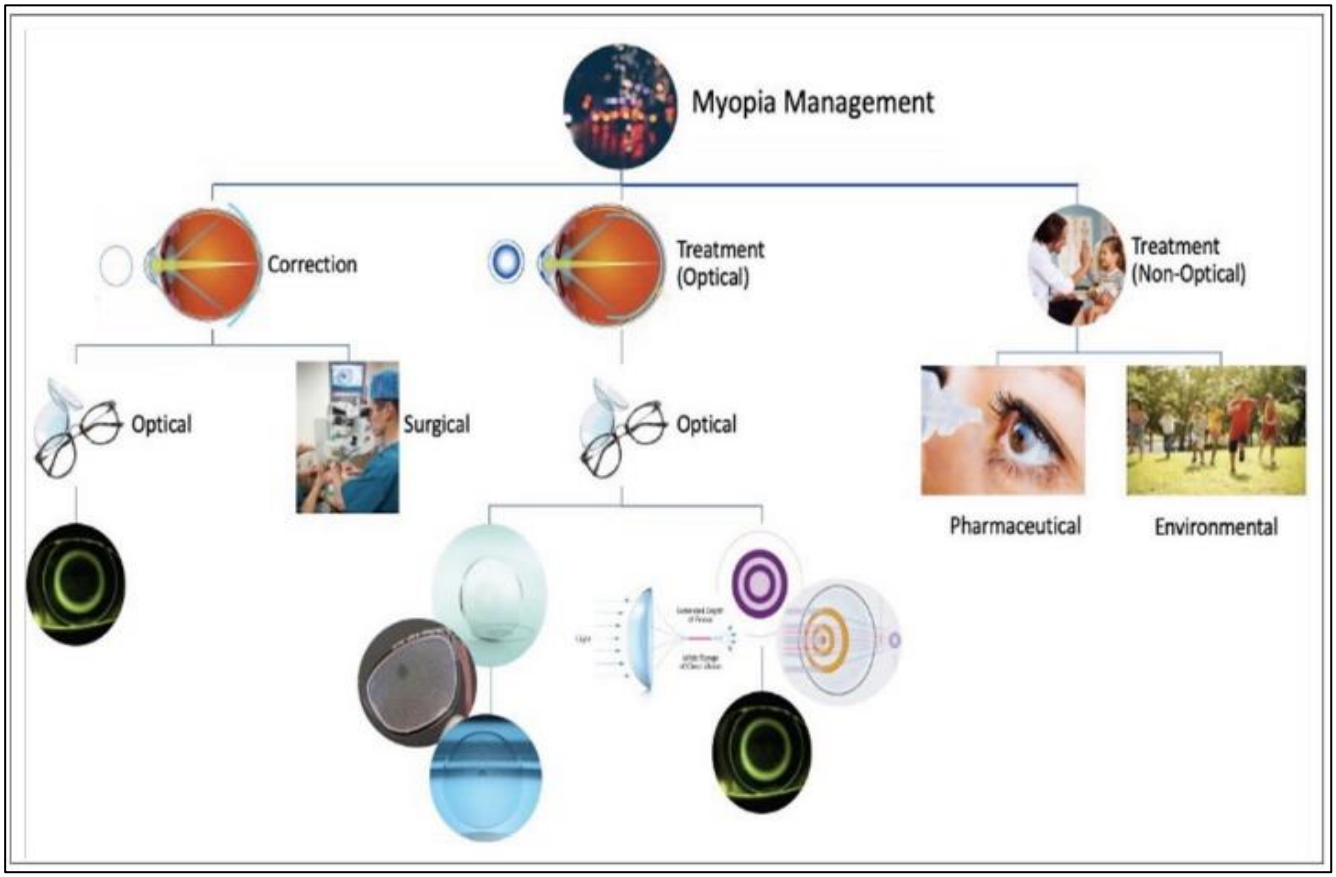

Figure 9: This flowchart of possibilities for myopia management can help parents appreciate what options are available for each route.

ADDITIONAL TESTS BEFORE COMMENCING MYOPIA MANAGEMENT

When beginning myopia management, it is crucial to conduct a comprehensive assessment of a patient's binocular vision and accommodative function. This involves more than just a standard refraction; a thorough evaluation of various visual functions and symptoms is necessary to ensure effective treatment. Here are the essential tests and considerations:

Binocularly balanced refraction

Ensures accurate correction of refractive errors while considering both eyes' contributions to binocular vision.

Cover test at distance and near

Identifies the presence and extent of phorias or tropias, providing insight into the patient's binocular alignment.

Accommodative amplitudes

Measures the maximum accommodative ability of the eyes, helping to detect any accommodative insufficiency or excess.

Retinoscopy at near point

Assesses the refractive status at near working distances, identifying any accommodative anomalies such as lead or lag of accommodation.

Near point of convergence

Evaluates the closest point at which the eyes can maintain binocular single vision, indicating the strength and flexibility of the convergence system.

Additional tests (if needed)

Accommodative facility: Measures the speed and accuracy of accommodative changes in response to varying focal distances.

Subjective distance/near phorias: Determines the alignment of the eyes in different gaze positions, aiding in diagnosing esophoria or exophoria.

UNDERSTANDING THE RELATIONSHIP BETWEEN ACCOMMODATION AND VERGENCE

It is essential to understand that accommodation and vergence are interrelated processes that significantly

impact myopia development and control. For this reason, evaluating these functions comprehensively is necessary.

VISUAL SYMPTOMS

Apart from individual test results, it is crucial to inquire about any visual symptoms the patient may be experiencing. Symptoms such as focusing problems, double vision, skipping lines when reading, headaches, or eye fatigue can indicate underlying accommodative or vergence issues.

COVID QUALITY OF LIFE QUESTIONNAIRE

To streamline the examination and ensure no binocular vision concerns are missed, I use the covid quality of life questionnaire. This tool helps in identifying symptoms that might not be immediately evident through testing alone. The COVID-19 pandemic had significant adverse effects on the health and social outcomes of children and adolescents, who spent more time using technological devices like smartphones. The studies aimed to evaluate the patterns, purposes, and potential addiction associated with smartphone use among Italian youth during the pandemic, compared to the pre-pandemic period.[3-5,7,9,10,22,24,26]

REFERRAL TO VISION THERAPY

In cases where significant accommodative or vergence abnormalities are detected, it may be necessary to refer the patient to a vision therapy optometrist before starting myopia management strategies. The study aimed to evaluate accommodative lag before, during the year of, and after the onset of myopia in children who became myopic, compared to emmetropic children and vision therapy is effective in treating accommodative and vergence disorders by improving accommodative control, binocularity, depth perception, and ocular motor movements.[10]

HOLISTIC APPROACH TO MYOPIA MANAGEMENT

Myopia management should not be isolated from other aspects of visual health. Often, patients with myopia also experience multiple visual development problems. Addressing these binocular vision issues holistically can provide comprehensive care and may be the missing piece in effective myopia management.

2024: THE FUTURE OF MYOPIA CONTROL

Collaborative efforts in myopia research

In the dynamic landscape of myopia control, collaborative efforts play a pivotal role in driving research and innovation towards effective management strategies. Various organizations and initiatives are actively engaged in interdisciplinary cooperation to push boundaries and amplify advancements in myopia control. The synergy between optometrists, ophthalmologists, researchers, and industry experts fosters a comprehensive approach that integrates diverse perspectives and expertise.

Key players such as the international myopia institute (IMI), the myopia education program, and the world council of optometry (WCO) are at the forefront of spearheading collaborative initiatives aimed at enhancing the understanding of myopia progression and developing cutting-edge interventions. By sharing knowledge, resources, and best practices, these entities collectively contribute to shaping the future trajectory of myopia control, paving the way for ground-breaking discoveries that hold the promise of transforming the field by 2024.

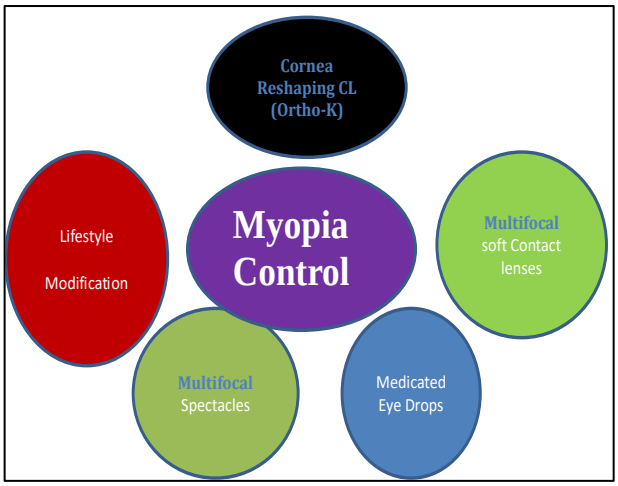

Figure 10: Myopia management strategies.

Patient education and awareness

Educating patients and increasing public awareness are vital components in the realm of myopia management. Empowering individuals with knowledge about myopia, its associated risks, and the available control methodologies is crucial in promoting proactive eye health practices and fostering informed decision-making. Optometrists and eye care professionals, as primary educators, play a pivotal role in disseminating essential information to patients and the wider community.

Through personalized consultations, informative campaigns, and engaging educational materials, optometry professionals are instrumental in raising awareness about the impact of myopia on visual health and overall well-being. By advocating for early intervention, promoting lifestyle modifications, and highlighting the benefits of myopia control interventions, optometrists champion a comprehensive approach to combating the global myopia epidemic. By amplifying patient education efforts and enhancing public awareness, the vision care community collectively contributes to

mitigating the progression of myopia and safeguarding ocular health for future generations.

CONCLUSION

Emphasizing preventive measures can mitigate the impact of pandemic-induced lifestyle changes and manage myopia progression in children. Reducing near work and promoting outdoor activities are essential. Understanding accommodation, AC/A ratios, and phoria is crucial for precise myopia management. Optometrists must conduct thorough assessments of binocular vision and accommodation. Each treatment, from atropine to multifocal glasses, affects binocular vision differently and requires careful consideration. Continuous research and innovation in myopia management will enhance strategies and improve overall visual health. By leveraging binocular vision, we can develop effective treatments and ensure better vision health for future generations.

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