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Research Progress on Defocus Spectacle Lenses for Myopia Control in Adolescents

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Abstract: ***Myopia has emerged as a global public health concern, with a particularly rising prevalence among children and adolescents in China. Based on the theory of peripheral retinal defocus, defocus spectacle lenses aim to correct central vision while simultaneously inducing myopic defocus in the peripheral retina to inhibit excessive axial elongation, thereby slowing myopia progression. This article reviews the theoretical foundation and clinical research progress of defocus spectacle lenses in juvenile myopia control, with a focus on analyzing the efficacy of three design types: DIMS, HAL, and CARE. Additionally, factors influencing treatment outcomes and standardized application are discussed to provide a reference for clinical practice.***

Keywords: Myopia control, Adolescents, Defocus spectacle lenses, Peripheral defocus**.**

1. Introduction

Myopia has become a global public health issue. According to statistics, approximately 2 billion people worldwide are affected by myopia, and it is estimated that by 2050, the prevalence of myopia will rise to 49.8% [1]. In China, the problem of myopia among children and adolescents is particularly severe, with data from the National Health Commission indicating that the overall prevalence of myopia in this population reached 53.6% in 2022 [2]. High myopia increases the risk of ocular complications such as cataracts, glaucoma, retinal detachment, and myopic maculopathy, which may have long-term effects on patients' visual health and impose a sustained burden on society and the healthcare system. To slow the progression of myopia, researchers have conducted extensive investigations encompassing various approaches, including optical interventions, pharmacological interventions, and behavioral interventions. Among these, optical interventions have garnered significant attention due to their non-invasive nature and favorable safety profile. As the most common method for correcting refractive errors, spectacles offer unique advantages in terms of safety, convenience, and patient compliance compared to other correction methods such as contact lenses [3].

In recent years, significant progress has been made in functional spectacle lenses based on the theory of peripheral retinal defocus [4]. From early designs such as bifocal lenses and progressive addition lenses to contemporary innovations like defocus incorporated multiple segments (DIMS) lenses and highly aspherical lenslets (HAL) technology, the efficacy of defocus spectacle lenses in controlling myopia has been continuously improving. This article aims to systematically review the research progress on defocus spectacle lenses for juvenile myopia control, elaborating on aspects including the optical theoretical foundation, main technological types, clinical efficacy evaluation, safety, and standardized application, so as to provide a reference for clinical practice.

2. Optical Theoretical Basis of Defocus Spectacle Lenses

2.1 Peripheral Retinal Defocus Theory

The peripheral retinal defocus theory posits that the refractive status of the peripheral retina plays a crucial regulatory role in the growth and development of the eye. When the peripheral retina experiences hyperopic defocus, where the focal point falls behind the retina, it induces compensatory axial elongation, thereby leading to or exacerbating myopia. Conversely, when the peripheral retina experiences myopic defocus, where the focal point falls in front of the retina, it may inhibit axial elongation [5]. Conventional single-vision spectacles, while correcting central vision, often result in peripheral light rays focusing behind the retina due to the curved spherical surface of the retina, thereby creating peripheral hyperopic defocus. This optical drawback may, to some extent, counteract the benefits of central vision correction and might even promote axial elongation. Therefore, how to eliminate or reverse peripheral hyperopic defocus while correcting central vision has become a core strategy in optical interventions for myopia control.

2.2 Principles of Optical Design Based on Peripheral Defocus

Defocus spectacle lenses are designed based on the principle of "simultaneous vision," incorporating two distinct optical zones on the same lens. The central optical zone corrects central vision to ensure daily visual quality, while the peripheral microstructured zone induces myopic defocus in the peripheral retinal region. When wearers view objects through the central zone of the lens, they achieve clear distance vision, whereas the microlens structures in the peripheral zone cause peripheral light rays to focus in front of the retina, generating a continuous myopic defocus signal that inhibits excessive axial elongation. Animal experimental studies have provided important support for this design principle. In chick and rhesus monkey models [6, 7], researchers observed corresponding changes in the direction of axial growth by inducing peripheral defocus using specialized optical lenses. These fundamental studies have established the scientific foundation for the clinical application of defocus spectacle lenses.

3. Efficacy of Different Types of Defocus Spectacle Lenses in Myopia Control

3.1 Defocus Incorporated Multiple Segments (DIMS) Design

The core of DIMS lenses lies in utilizing the principle of "peripheral defocus" to control myopia. This is achieved through the precise arrangement of 396 microscopic lenslets within the optical zone of the lens. These microlenses are specifically designed to generate myopic defocus that inhibits axial elongation, while the central region of the lens and the gaps between the microlenses fulfill the function of correcting the refractive error. Through this structural design, DIMS lenses are able to maintain clear daily vision while simultaneously establishing a continuous "myopic defocus" protective zone in the peripheral retina. This mechanism helps interrupt the driving factors behind abnormal axial elongation, ultimately achieving effective control over the rate of myopia progression. Research has shown [8] that children wearing DIMS lenses daily exhibited a more pronounced slowing trend in both myopia progression and axial elongation compared to the control group. Specifically, the mean annual change in spherical equivalent refraction decreased by 52%, while the annual axial elongation was reduced by 62%. Notably, throughout the two-year observation period, approximately 21.5% of the participating children showed no significant myopia progression. Study findings indicate [9] that compared to children wearing conventional single-vision spectacles, those wearing DIMS lenses experienced a 59% reduction in the rate of myopia progression and a 60% slowdown in the rate of axial elongation, demonstrating a relatively significant delaying effect. Research by Hao Jingjing et al. [10] showed that when compared to other commercially available lenses with specialized peripheral defocus designs, DIMS lenses exhibited more advantageous clinical efficacy in slowing myopia progression in children.

3.2 Highly Aspherical Lenslets (HAL) DesignHAL

This technology employs concentrically arranged aspherical lenslet structures, with hundreds of microlenses distributed across the lens surface in a honeycomb pattern. Unlike DIMS, the microlenses in HAL lenses feature a highly aspherical design, with the defocus amount exhibiting a gradient change from the center to the periphery, creating multi-level defocus signals. Benefiting from this unique lens design, regardless of how the eye rotates or in which direction the gaze is directed, a continuous "myopic defocus" signal is formed in front of the retina, thereby achieving inhibition of myopia progression and axial elongation [11]. A clinical study conducted on pre-myopic children aged 6 to 10 years found that wearing plano HAL lenses effectively slowed the rate of axial elongation. The study also indicated that children who wore the lenses for longer durations each day experienced more significant control effects [12]. Research has also shown [13] that the myopia control effect of HAL lenses exhibits a clear "dose-dependent" relationship. Specifically, the lower the refractive power of the lens itself, the stronger its effect in slowing myopia progression. A three-year follow-up study compared the impact of different wearing regimens on myopia control efficacy [14]. The results indicated that children who continuously wore HAL lenses for the full three years experienced significantly slower myopia progression compared to those who wore SAL or SVL lenses for the first two years and only switched to HAL lenses in the third year. However, the study also found that even after wearing SVL or SAL lenses for the first two years, switching to HAL lenses in the third year still resulted in a significant slowdown in both myopic progression and axial elongation.

3.3 Concentric Annular Ring Epithelium (CARE) DesignCARE

This technology employs a concentric annular ring with micro-cylindrical lens structures, where rings with cylindrical lens effects and transparent zones are alternately arranged on the lens surface. The micro-cylindrical lenses on each annular ring produce a defocus effect, creating myopic defocus in the peripheral retina. The unique aspect of this design lies in its incorporation of cylindrical elements rather than simple spherical additions. Due to the relatively recent market introduction of CARE lenses, there are currently fewer clinical studies and published literature available regarding them. A study by Liu et al. comparing children wearing CARE lenses and those wearing conventional single-vision spectacles [15] showed a difference of 0.14 D in myopia progression and 0.09 mm in axial elongation between the two groups, suggesting that CARE lenses possess certain clinical efficacy in slowing myopia progression.

4. Factors Influencing Control Efficacy

The control efficacy of defocus spectacle lenses is influenced by multiple factors [16]. Age is one of the important influencing factors [17]; younger children (aged 6-10 years) typically experience faster myopia progression, and while the absolute intervention effect may be more pronounced, the relative control ratio might be lower compared to older children. Baseline refraction also affects intervention outcomes, with children having low to moderate myopia often showing better control effects than those with high myopia [18]. Wearing time is a critical variable determining efficacy. Defocus lenses require sufficient daily wear time, with a recommendation of more than 8 hours per day, to achieve stable effects. Some children wear them only during class or for distance vision, using single-vision lenses or no glasses during leisure time, which may weaken the defocus intervention effect. Additionally, factors such as anterior chamber depth, corneal curvature, and lens thickness may also influence the actual distribution of peripheral defocus on the retina, leading to inter-individual differences in efficacy [19].

5. Standardized Application of Defocus Spectacle Lenses

Defocus spectacle lenses are primarily indicated for children and adolescents with progressive myopia, generally recommended for those under 18 years of age [20]. For children who are not yet myopic but have a high risk of developing myopia, some researchers suggest considering plano or positive power defocus lenses as a preventive intervention to delay axial elongation and postpone the age of myopia onset [21]. However, defocus spectacle lenses are not suitable for all populations. Patients with severe strabismus, significant anisometropia, or amblyopia are typically not

appropriate candidates. Children with allergies to lens materials, those unable to cooperate with the fitting process, or those who cannot ensure sufficient wearing time should also not arbitrarily choose defocus spectacle lenses. A standardized fitting procedure is a prerequisite for ensuring the efficacy and safety of defocus spectacle lenses. Before fitting, a comprehensive ocular health examination should be completed, including assessments of uncorrected visual acuity, refractive error, axial length, corneal curvature, intraocular pressure, and fundus examination, and a complete refractive record should be established [22]. The fitting process requires standardized medical refraction, binocular vision function evaluation, and frame adaptation. Follow-up is a crucial component in the application of defocus spectacle lenses. It is recommended to conduct the initial efficacy evaluation at 6 months and 1 year after wearing, followed by regular follow-up examinations every 6 to 12 months. Follow-up assessments should include refractive error, axial length, uncorrected and corrected visual acuity, wearing conditions, and adverse reactions [23]. If the control effect is unsatisfactory, the reasons should be promptly analyzed, and the intervention plan should be adjusted accordingly.

6. Challenges and Prospects

Although defocus spectacle lenses have shown broad application potential in the field of juvenile myopia control, there is significant individual variability in their myopia control efficacy. While axial elongation nearly ceases in some children after wearing them, other “low responders” achieve unsatisfactory control effects. A randomized controlled trial in India comparing different peripheral defocus designs showed [24] that although DIMS, HAL, and CARE lenses slowed myopia progression by 56.7%, 58.1%, and 47% respectively over one year, the inter-individual standard deviation reached 0.12-0.15 D, indicating considerable dispersion in efficacy. Secondly, long-term clinical evidence still needs to be enriched. Existing studies have relatively short follow-up periods [8, 25], and there is still a lack of sufficient high-quality, long-term evidence-based medical evidence to support questions regarding the long-term effects of defocus intervention continuing until ocular development stabilizes, as well as the long-term stability of myopia progression after discontinuation.

Future research can explore several directions in depth. The first is optimizing personalized fitting protocols, selecting the most appropriate defocus amount, microlens distribution, and design type based on individual factors such as refractive status, axial length, corneal morphology, and age. The second is exploring combined intervention strategies. Research indicates [25] that combining optical interventions with low-concentration atropine may produce synergistic effects. More evidence-based medical evidence is needed to determine the indications, timing, dosage, and risk-benefit ratio of combined interventions. The third is deepening research on the mechanism of action. How peripheral defocus signals are perceived by the retina, how they are transmitted to the choroid and sclera, and how they regulate axial growth — answers to these fundamental scientific questions will provide theoretical guidance for the next generation of defocus intervention technologies.

7. Conclusion

Based on the peripheral retinal defocus theory, defocus spectacle lenses effectively slow myopia progression in children and adolescents by inducing peripheral myopic defocus while correcting central vision. Clinical studies on microlens design technologies such as DIMS, HAL, and CARE have confirmed their favorable control efficacy and good safety profiles. However, issues such as significant individual variability in efficacy, uneven market quality, and limited long-term data still require continued attention. In the future, through deepening research on mechanisms, optimizing personalized protocols, exploring combined interventions, and improving industry standards, defocus spectacle lenses are expected to play a greater role in juvenile myopia control, providing higher quality and more precise solutions for the visual health of children and adolescents in China.

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