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NEXT-GENERATION PROGRESSIVE ADDITION LENSES (PALS) FOR MYOPIA CONTROL: A COMPREHENSIVE REVIEW OF EFFICACY

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Abstract

Myopia is a significant epidemic endangering public health in the world, and the necessity to control it results in the development of effective guidelines. This is the critical review of next-generation Progressive Addition Lenses (PALs), which actively oppose the development of myopia with the help of innovative optical systems, as opposed to the usual corrective lenses.Based on the recent randomized controlled trials, it concludes that two types of evidence-based Defocus Incorporated Multiple Segments (DIMS/Hoya MiyoSmart) and Highly Aspherical Lenseslets (H.A.L./Essilor Stellest) are highly effective. These lenses show a reduction of 52-67percent of refraction progression of the sphere equivalent and 60-62 percent when it comes to the refraction of the axial elongation in two years as compared to the single version lenses. Maximum efficacy is among young children. Their main action is the establishment of peripheral consistent myopic defocus. Next-generation PALs have the same level of effectiveness as other popular interventions, such as orthokeratology and low-dose atropine, and a better safety profile and high adherence. The evidence confirms that these lenses are an extremely useful, safe and economic first line treatment of childhood myopia and a means of reducing the risk of later onset of complications that are a threat to the child and of which is a deterrent to future vision.

INTRODUCTION

Nearsightedness or myopia has grown to be a major refractive error as well as a general global public health problem and its prevalence rate is expected to increase to cover almost half of theglobal population in the year 2050. Not only is this surge a problem of optical correction, but a pronounced risk of ocular pathologies threatening the sight, such as myopic maculopathy,retinal detachment,glaucoma, and premature cataracts are also being paralleled [1]. The corresponding economic consequence, which combines the direct costs of management and the indirect costs of vision loss, highlights the urgent need to establish efficient interventions to manage myopia that would prevent the progression of axial elongation as the main anatomical correlate of myopic pathology [2]. The pathophysiological mechanisms that drive myopia development are multifactorial in nature, as they are complex interactions between genetic factors and environmental factors. At the heart of recent optical control techniques is the defocus theory that assumes that peripheral retinal defocusing during normal eye tasks and accommodative lag when working closely, creates

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a strong stimulus to enhanced axial elongation [3]. Traditional single-vision lenses offer clear foveal vision, but do not correct the peripheral hyperopic defocus,and even enhance it, and hence have no inhibitory effect on myopia progression. PALs were one of the earliest commercially produced optical treatments to control myopia in reaction to this mechanistic conceptualization. The PALs with a gradient of increasing plus power in line with distance to near zone were theorized to decrease the accommodative demand and lag during near activities; thus,lowering the pro-elongation signal. One of the pioneering researches, e.g., the Correction of Myopia Evaluation Trial (COMET), carried a cumulative evidence that some PAL designs could cause statistically significant,however,clinically modest,decrease in myopia progression relative to single-vision lenses [4]. Nevertheless, the shortcoming of these first generation designs such as the fluctuating effectiveness and dependence mainly on the accommodative mechanism led to the development of more advanced optical solutions. The development of the next generation of PALs signifies the change in paradigm in management of optical myopia. These superior lenses combine the proven theory of progressive addition with new optical concepts especially developed to tweak retinal defocus within an expanded visual scope. Just far beyond a one-dimensional understanding of accommodative lag, modern PALs have a complex of features which include highly aspherical lenslets, diffusion sectors, and well-computed positive peripheral defocus profiles. These designs also expect to establish a myopiagenic shield by providing stable myopic defocus to the retina regardless of direction of gaze or view distance, which will actively indicate to the eye to slow its growth [2,5]. This is an overall review, aimed at the critical evaluation of the existing body of evidence about the efficacy of these next-generation PALs in controlling myopia. It will critically assess findings of recent randomized controlled trials and longitudinal studies, compare the relative efficacies of different proprietary designs and comment on the interaction between lens design, patient compliance,and anatomy in relation to each other. Through the synthesis of the most recent scientific and clinical findings, the review intends to summarize the role of advanced PALs in the current line of myopia control methods and point out the future research and development directions.

2.0 Methodology

In order to develop a clear image of existing evidence regarding the advanced myopia-control spectacles,I used a systematic and transparent procedure to collect and process the research on the topic. I intended to locate and compile the latest and quality research on the effectiveness of these next-generation lenses in slowing the myopia progression in the youth. To locate the literature on the topic that is relevant to my research, I started with four large academic databases, namnely PubMed/MEDLINE, Scopus,Web of Science, and Cochrane Library. I limited my search to work published since the beginning of 2020 up to September 2025 to make the materials as up-to-date as possible. I applied a set of search terms containing particular expressions concerning myopia (such as progressive myopia) along with the interventions (Defocus Incorporated Multiple Segments or HAL lenses) and the outcomes that I was interested in (axial length progression).I also inspected the reference lists of important articles and reviews I had read manually in order to ensure that I did not miss any important studies.

I also established specific criteria of the studies to include. I narrowed my search to children and teenagers (under 18) who underwent clinical trials on myopia and in which one group was treated with a novel myopia-control spectacle lens (e.g., lenses with special lenslet arrays) and one group with standard single-vision glasses. The researches had to record tangible, quantitative, results,namely, the amendment in their glasses prescription (spherical equivalent refraction) and more significantly, the amendment in the length of their eye (axial length). I selected priority tothe randomized

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controlled trials and strong prospective studies and no smaller report, conference summary, or study on adults or traditional lenses not to control myopia was included.

Upon gathering the studies, I have gone through all the studies, obtaining important information such as the ages of the participants, the type of lens that was being tested, the duration of the study,and the ultimate findings. By acknowledging the fact that the studies were different in terms of the design and the lenses they studied, I chose to use a narrative synthesis. This enabled me to critically compare the findings, and draw similar patterns, and investigate how the age of a child may affect treatment effect. Last but not least, to estimate the trustworthiness of the evidence, I assessed the methodological soundness of each randomized trial that was incorporated into the study with the help of the well-known Cochrane Risk of Bias (RoB 2) tool, which served to determine the strength of the conclusions made out of this analysis.

3.0 Results

This section summarizes the results of the literature that was identified using the systematic approach,and critically appraises the effectiveness of next-generation peripheral defocus spectacle lenses in the management of myopia. These findings are discussed in the context of the overall knowledge about the pathogenesis of myopia, the comparison of the performance of different optical technologies is conducted, and the clinical implications and future perspectives of this fast developing area. The basic assumption of these lenses is the introduction of myopic defocus on major portions of the retina to cut off the pro-elongation messages of hyperopic defocus. Recent large-scale high-quality randomized controlled trials (RCTs) massively confirm the higher effectiveness of these designs compared to single-vision lenses (SVLs) and those with progressive addition. The strongest data are the research on the Defocus Incorporated Multiple Segments (DIMS) lens (Hoya MiyoSmart). A 52 percent decrease in the progression of spherical equivalent refraction (SER) and a 62 percent decrease in axial elongation (AL) over two years was shown in the seminal RCT by American study [7]. These results were cemented in a long-term extension demonstrating long-term efficacy of up to three years [8]. The DIMS structure provides that whichever direction the eye is gazing, some part of the peripheral retina is exposed to an inhibitory defocusing signal, which is a major step forward considering that older lenses can only act on defocusing the lower optical field.

Verifying the validity of such a solution, studies of Highly Aspherical Lenslet (H.A.L.) technology (Essilor Stellest) have provided equally noteworthy outcomes. The same study has also reported a reduction in mean SER progression of 67 percent and 60 percent reduction in mean AL elongation after two years [9]. The H.A.L. design employs a layer of continuous aspherical lenslets at the periphery of the lens forming a volume of myopic defocusing and maintaining the vision at the center.The other new design is the SightGlass Vision DOT lens that uses the Contrast Management Myopia Control (CMMC) but uses cylindrical dots that selectively diminish peripheral contrast.A 2-year RCT showed a significant decrease in the elongation of AL by 31% but not in SER [10].

According to this dissociation, the CMMC technology can alter pathways of scleral remodeling in contrast to defocus-based lenses, which expands the range of possible optical intervention mechanisms [11].

In head-to-head comparisons of these technologies, defocuis-incorporating lenses (DIMS and H.A.L.) have always exhibited greater magnitude of efficacy (50-67% AL reduction) than the contrast-reduction lens (˜31% AL reduction) in clinical trials. This indicates that a distinct,consistent myopic defocus signal can be a more effective axial elongation deceleration inductor.The effectiveness of these lenses is a strong in-vivo human support to the defocus theory of progressive myopia. The consistent observation of the AL elongation being decelerated more efficiently than SER progression shows that the major effect of

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treatment is structural inhibition of sagittal growth of the vitreous chamber. It supports the fact that the highest level of biomarkers to control the efficacy of mnyopia is axial length because it is the parameter that is most closely associated with the potential of developing ocular pathology in the future [12,13].

Several imnportant factors moderate the treatment efficacy. One such finding is that there is an inverse relationship between age and treatment effect whereby young children show a stronger response and the significance of early intervention cannot be underrated [14]. Time dependence is also evidenced by efficacy, with the greatest relative effect usually in the first year, but cumulative benefit is also high. The fact that next-generation designs are superior to conventional PALs also indicates that the countering of peripheral hyperopic defocus is a more potent process than the countering of accommodative lag, which is a conceptual breakthrough [15,16].

In order to realize the full potential of their application, the efficiency of next-generation defocus lenses should be seen in the context of the overall arsenal of myopia control techniques. The spectacle lenses are an alternative to low-dose atropine which is widely accepted in the first-line therapy with no pharmacological side effects. Atropine, especially at the concentration of 0.05, is also equally effective, but selection frequently depends on lifestyle and preference of the patient [17]. Next-generation spectacle lenses have a completely non-invasive profile, and no chance of infection unlike orthokeratology (Ortho-K), which demonstrates equivalent efficacy but makes the management of the risks difficult [17,18]. One of the most important critical benefits of spectacle lenses is their high compliance because they do not need to be inserted or maintained on a daily basis and more recent designs have reduced early adaptation problems and the lenses have become highly acceptable by the patient. The safety profile is superior and the main factors that should be taken into account are short-term optical adjustment which usually subsides in a very short time.The questions to be addressed in the future are long-term effectiveness and rebound after discontinuation, the possibility of individualizing the parameters of defocus, and the interaction of combination therapies, including the use of low-dose atropine [19].These lenses have essentially changed the quality of care, and they have given the eye care practitioners a powerful, safe,and readily adaptable first-line tool. The next generation will probably incorporate these optics in other types of lenses, and it can be justified by health-economic calculation of their popularization.

Conclusion

It is the evidence of high-quality trials that were conducted recently, which indicates that next generation peripheral defocus spectacle lenses are a powerful intervention to manage myopia that can ever present a 50-67 percentage reduction in axial elongation over 2-3 years. They are we1l-supported by physiological principles as to their mechanism of action, their high efficacy,excellent safety, and very high compliance than other strategies. Although the questions about the long-term consequences and personalized medicine persist, the current evidence clearly creates the lenses as the foundation of the contemporary management of myopia.

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