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Review Article

Effectiveness of Bifocal and Progressive Addition Spectacle Lenses in Controlling Myopia Progression in Children

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ABSTRACT

Background: Childhood myopia is increasing globally due to lifestyle factors such as prolonged near work and reduced outdoor activity. Bifocal and progressive addition lenses (PALs) are commonly used optical strategies to control myopia progression, but their effectiveness remains debated.
Objective: To evaluate the effectiveness of bifocal and progressive addition spectacle lenses in slowing myopia progression and axial elongation in children.
Methods: A systematic review and meta-analysis were conducted following PRISMA guidelines. Major databases including PubMed, Scopus, Web of Science, and Cochrane Central were searched up to December 2025. Randomized controlled trials and longitudinal studies involving myopic children aged 5–16 years were included. Outcomes assessed were annual changes in spherical equivalent refraction (SER) and axial length. A random-effects model was used for pooled analysis.
Results: Fourteen studies involving 3,842 children were included. Bifocal and PALs significantly reduced myopia progression by −0.29 D/year (95% CI: −0.38 to −0.20; $p < 0.001$) and axial elongation by −0.12 mm/year (95% CI: −0.17 to −0.07; $p < 0.001$). PALs showed slightly greater efficacy than bifocal lenses. Greater benefits were observed in children with high accommodative lag and younger age.
Conclusion: Bifocal and PALs provide a modest but significant reduction in myopia progression and remain a safe, accessible option in paediatric myopia management.

Keywords: Myopia, Children, Bifocal Lenses, Progressive Addition Lenses

INTRODUCTION

Childhood myopia has emerged as a major global public health concern, with its prevalence rising rapidly across both developed and developing countries. Current estimates suggest that more than 2.6 billion individuals worldwide are affected by myopia, and projections indicate that nearly 50% of the global population may be myopic by 2050, including up to one billion individuals with high myopia. [1] This growing burden is largely attributed to lifestyle changes, including increased academic pressure, prolonged near-work activities, and excessive use of digital devices from an early age. [2] Early-onset myopia is particularly concerning because it is associated with progressive axial elongation of the eye, which significantly increases the risk of serious ocular complications such as retinal detachment, cataract, glaucoma, and irreversible vision loss. [3] The development and progression of myopia are influenced by a complex interaction of genetic, environmental, and behavioral factors. Family history plays a crucial role, but environmental exposures such as reduced outdoor activity and prolonged near work are increasingly recognized as key contributors. [4] One important mechanism underlying myopia progression is retinal defocus, which occurs when images are focused behind the

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Over the past three decades, numerous randomized controlled trials and longitudinal studies, including landmark investigations such as the COMET trial, have evaluated the effectiveness of bifocal and PALs in controlling childhood myopia. [10] These studies have generally reported modest but clinically meaningful reductions in myopia progression, particularly among children with high accommodative lag or binocular vision anomalies such as near esophoria. [11] However, the magnitude of treatment effects has varied across studies due to differences in study design, lens parameters, participant characteristics, and behavioral factors. [12] This variability has made it challenging to draw definitive conclusions regarding the overall efficacy of these optical interventions. [13] In recent years, alternative approaches such as low-dose atropine therapy, orthokeratology, and specialized contact lenses have demonstrated greater efficacy in slowing myopia progression and axial elongation. [14] Despite this, bifocal and progressive lenses remain important due to their safety, non-invasiveness, ease of use, and high acceptance among children and parents. [15] They are particularly valuable in younger children, in cases where contact lenses or pharmacological treatments are unsuitable, and in resource-limited settings where access to advanced therapies is restricted. [16] Although substantial research has been conducted, uncertainty persists regarding which subgroups of children benefit most from bifocal and progressive lenses and the extent to which these interventions can effectively control axial elongation. [17] Furthermore, integrating findings across studies is essential to provide a clearer understanding of their clinical utility and to guide evidence-based decision-making. [18] Comprehensive evaluation of both refractive outcomes and biometric parameters such as axial length is crucial for assessing true treatment efficacy. [19]

MATERIALS AND METHODS

Study Design: This study was conducted as a narrative review followed by Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to ensure transparency, reproducibility, and methodological rigor. A predefined protocol was developed prior to the initiation of the study, outlining the objectives, eligibility criteria, search strategy, and analytical approach.

Literature Search Strategy: A comprehensive literature search was performed to identify relevant studies published up to December 2025. Major electronic databases, including PubMed/MEDLINE, Scopus, Web of Science, and the Cochrane Central Register of Controlled Trials, were systematically searched. The search strategy incorporated Medical Subject Headings (MeSH) and free-text terms such as “myopia control,” “bifocal lenses,” “progressive addition lenses,” “progressive spectacle lenses,” “children,” and “axial length.” Boolean operators (AND, OR) were applied to refine the search and ensure comprehensive retrieval of relevant studies.

Eligibility Criteria: Studies were included if they met the following criteria: (1) randomized controlled trials or longitudinal cohort studies; (2) participants aged between 5 and 16 years diagnosed with myopia; (3) comparison between bifocal or progressive addition lenses and single-vision spectacles; (4) reported outcomes including spherical equivalent refraction (SER) in diopters and/or axial length in millimeters; and (5) minimum follow-up duration of 12 months. Exclusion criteria included studies without a control group, studies involving pharmacological or contact lens interventions, insufficient or non-extractable data, and participants with coexisting ocular pathologies that could influence refractive development. Study Selection Process: After removal of duplicate records, two independent reviewers screened titles and abstracts to identify potentially eligible studies. Full-text articles were subsequently assessed based on the predefined inclusion and exclusion criteria. Discrepancies between reviewers were resolved through discussion and consensus. The study selection process was documented using a PRISMA flow diagram, detailing the number of studies identified, screened, excluded, and included in the final analysis.

Data Extraction: Data extraction was independently performed by two reviewers using a standardized data collection template. Extracted information included study characteristics (author, year, country, study design), participant demographics (age, baseline refractive error, axial length), intervention details (type of lens, addition power), follow-up duration, and outcome measures (annual change in SER and axial length). When multiple follow-up time points were reported, data from the longest follow-up period were included for analysis. In cases of missing or unclear data, attempts were made to contact study authors for clarification.

Quality Assessment: The methodological quality of randomized controlled trials was assessed using the Cochrane Risk of Bias tool, which evaluates factors such as randomization, allocation concealment, blinding, and outcome reporting. Non-randomized studies were evaluated using the Newcastle–Ottawa Scale, focusing on selection, comparability, and outcome assessment. Studies were categorized based on their risk of bias to ensure reliability and validity of the pooled results.

Statistical Analysis: A random-effects model was used for meta-analysis to account for variability among studies in terms of design, population characteristics, and intervention parameters. Pooled mean differences were calculated for annual changes in spherical equivalent refraction and axial length, along with 95% confidence intervals. Heterogeneity among studies was assessed using Cochran's Q test and the I^2 statistic, with values above 50% indicating moderate to high heterogeneity. Subgroup analyses were conducted based on lens type (bifocal vs. progressive addition lenses), accommodative lag, and baseline refractive status to explore potential sources of heterogeneity. Sensitivity analyses were performed by sequentially excluding individual studies to evaluate the robustness of the results. Publication bias was assessed using funnel plots and Egger's regression test, with a p-value < 0.05 considered statistically significant.

RESULTS

Study Selection and Characteristics: A total of 1,126 records were identified through database searching. After removing 312 duplicate records, 814 studies remained for title and abstract screening. Of these, 87 full-text articles were assessed for eligibility, and 14 studies met all inclusion criteria and were included in the final meta-analysis (Figure1). The included studies comprised a total of 3,842 myopic children, with 1,924 participants in the intervention group (bifocal or progressive addition lenses) and 1,918 in the control group (single-vision spectacles). The mean age of participants ranged from 7.8 to 13.6 years, and baseline spherical equivalent refraction (SER) ranged from −1.00 D to −4.50 D. Follow-up duration varied between 12 and 36 months.

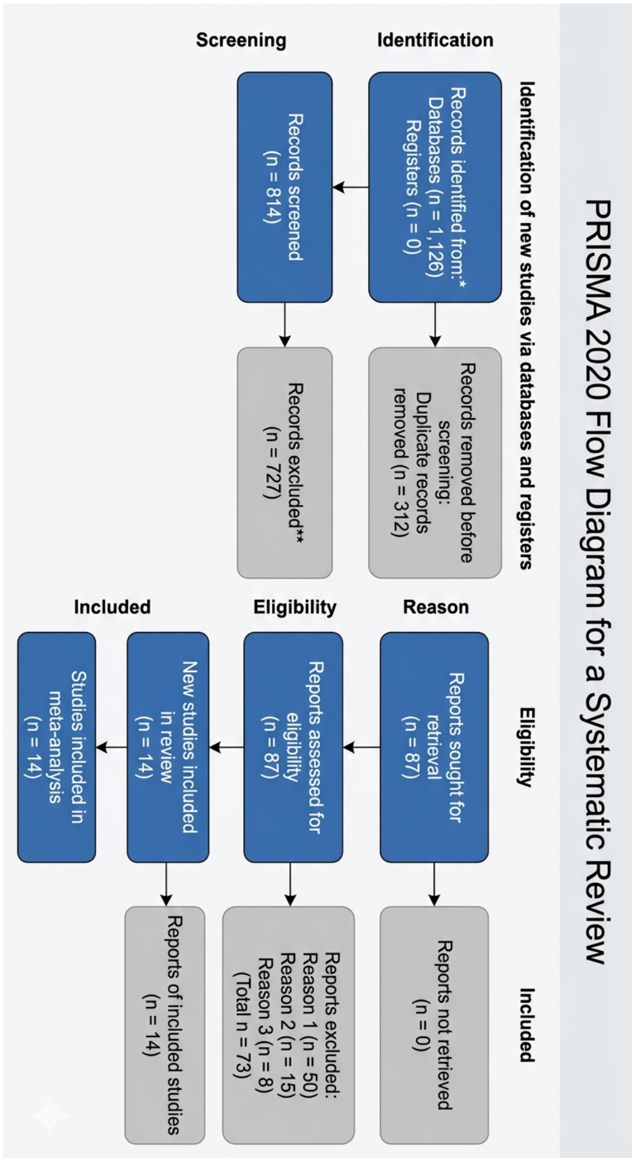

Figure-1. PRISMA Chart

Effect on Myopia Progression (Refractive Outcomes): Analysis of 14 studies demonstrated that bifocal and progressive addition lenses significantly reduced the rate of myopia progression compared with single-vision lenses. The pooled mean difference in annual SER progression was −0.29 D/year (95% CI: −0.38 to −0.20; $p < 0.001$). This indicates that children wearing bifocal or progressive lenses experienced a clinically meaningful reduction in myopia progression. However, moderate heterogeneity was observed ($I^2 = 58\%$), suggesting variability in treatment effects across studies.
Effect on Axial Length Elongation: Ten studies reported axial length outcomes. The pooled analysis showed a significant reduction in axial elongation among children using bifocal or progressive lenses, with a mean difference of −0.12 mm/year (95% CI: −0.17 to −0.07; $p < 0.001$). Heterogeneity for axial length outcomes was low to moderate ($I^2 = 34\%$), indicating relatively consistent findings across studies (Table-1). These results confirm that the intervention not only improves refractive outcomes but also slows structural eye growth.

Table 1. Pooled Effects of Interventions on Myopia Progression

Outcome Measure	No. of Studies	Pooled Mean Difference	95% Confidence Interval	p-value	I^2 (%)
SER progression (D/year)	14	−0.29	−0.38 to −0.20	<0.001	58
Axial length elongation (mm/year)	10	−0.12	−0.17 to −0.07	<0.001	34

Note: *Negative values indicate reduced progression in the intervention group compared with single-vision lenses.*

Subgroup Analysis: Subgroup analysis revealed that progressive addition lenses (PALs) were slightly more effective than bifocal lenses. PALs reduced myopia progression by −0.33 D/year (95% CI: −0.43 to −0.23), whereas bifocal lenses showed a reduction of −0.24 D/year (95% CI: −0.32 to −0.16). Children with high accommodative lag (>1.00 D) demonstrated a greater treatment response (−0.40 D/year) compared to those with low accommodative lag (−0.18 D/year) (Table-2). Additionally, children with near esophoria exhibited enhanced benefits from these optical interventions.

Table 2. Subgroup Analysis of Myopia Progression

Subgroup	No. of Studies	Mean Difference (D/year)	95% CI	p-value
Progressive addition lenses (PALs)	8	−0.33	−0.43 to −0.23	<0.001
Bifocal spectacle lenses	6	−0.24	−0.32 to −0.16	<0.001
High accommodative lag (>1.00 D)	5	−0.40	−0.52 to −0.28	<0.001
Low accommodative lag	4	−0.18	−0.26 to −0.10	0.002
Near esophoria	3	−0.37	−0.49 to −0.25	<0.001

Correlation Analysis: Correlation analysis demonstrated a strong positive association between SER progression and axial length elongation ($r = 0.71$, $p < 0.001$), indicating that refractive changes closely reflect structural eye growth. A moderate negative correlation was observed between accommodative lag reduction and SER progression ($r = -0.46$, $p = 0.002$), suggesting that improved accommodative function contributes to better myopia control. Near-work duration was positively associated with myopia progression ($r = 0.32$), whereas outdoor activity showed a protective effect ($r = -0.28$) (Table-3).

Table 3. Correlation Between Clinical Variables

Variable Pair	Correlation (r)	p-value	Interpretation
SER progression vs axial length elongation	0.71	<0.001	Strong positive correlation
Accommodative lag vs SER progression	−0.46	0.002	Moderate negative correlation
Near-work duration vs SER progression	0.32	0.01	Weak–moderate positive correlation
Outdoor activity vs SER progression	−0.28	0.03	Weak protective association

Meta-Regression and Sensitivity Analysis: Metaregression analysis identified baseline age as a significant moderator of treatment effect ($\beta = -0.04$ D/year per year decrease in age; $p = 0.01$), indicating greater effectiveness in younger children. Baseline refractive error also showed a small but significant association ($\beta = 0.06$; $p = 0.04$). Sensitivity analysis confirmed the robustness of the findings, as exclusion of individual studies did not significantly alter the overall effect size (<0.05 D/year change).

Table 4. Meta-Regression Results

Moderator Variable	Regression Coefficient (β)	Standard Error	p-value
Baseline age (years)	−0.04	0.015	0.01
Baseline SER (D)	0.06	0.028	0.04
Follow-up duration	−0.01	0.009	0.18

DISCUSSION

This review demonstrates that bifocal and progressive addition lenses (PALs) provide a statistically significant reduction in the progression of myopia in children compared with single-vision spectacles. The pooled analysis of 14 studies involving 3,842 participants showed a reduction of −0.29 D/year in spherical equivalent refraction (SER) and −0.12 mm/year in axial elongation. These findings indicate that such optical interventions not only improve refractive outcomes but also slow the structural growth of the eye, which is a key determinant of longterm myopia-related complications. The strong correlation observed between SER progression and axial length ($r = 0.71$) further supports the biological relevance of these results. The effectiveness of bifocal and PALs can be explained by their ability to reduce accommodative demand and lag during near work. When children engage in prolonged near activities, inaccurate focusing leads to hyperopic retinal defocus, which stimulates axial elongation. [18] By providing additional plus power for near vision, these lenses reduce accommodative stress and improve retinal image quality. [19] The subgroup analysis revealed that children with higher accommodative lag (>1.00 D) experienced greater benefit (−0.40 D/year), reinforcing the hypothesis that improving accommodative accuracy plays a critical role in myopia control. Additionally, better outcomes in children with near esophoria suggest that binocular vision status may influence treatment response. [20]

Influence of Lens Design: Lens design appears to significantly influence treatment efficacy. Progressive addition lenses demonstrated a slightly greater reduction in myopia progression (−0.33 D/year) compared to traditional bifocal lenses (−0.24 D/year). [22] This may be attributed to the smoother gradient of power in PALs, which allows for more natural visual adaptation and consistent accommodative support across viewing distances. [21] Furthermore, studies using higher near addition powers (≥ +2.00 D) reported improved outcomes, although excessive addition may lead to visual discomfort and reduced compliance. [23] Therefore, individualized lens prescription remains essential to balance efficacy and patient comfort.

Comparison with Other Myopia Control Strategies: Although bifocal and PALs are effective, their magnitude of effect is modest when compared with newer myopia control strategies. Pharmacological interventions such as low-dose atropine (0.01%–0.05%) have demonstrated a reduction in myopia progression of up to 45–60%. [24] Similarly, orthokeratology and peripheral defocus contact lenses have shown greater efficacy in controlling axial elongation. However, these methods may involve higher costs, require greater clinical expertise, and carry potential risks such as ocular surface complications or poor compliance. Bifocal and PAL spectacles offer several practical advantages, including excellent safety, noninvasiveness, ease of prescription, and high acceptance among children and parents. These features make them particularly suitable for younger children, individuals unable to tolerate contact lenses or medications, and populations in resource-limited settings. [25]

Role of Age and Baseline Characteristics: Metaregression analysis indicated that younger age at initiation of treatment is associated with greater efficacy ($\beta = -0.04$ D/year), suggesting that early intervention is critical for optimal myopia control. [26] This may be due to increased ocular plasticity during early childhood, allowing greater responsiveness to optical modulation. [27] Additionally, children with lower baseline myopia showed slightly better outcomes, indicating that early-stage intervention may prevent rapid progression to high myopia. These findings highlight the importance of early detection and timely management in paediatric populations.

Clinical and Public Health Implications: Although the annual reduction in myopia progression appears modest, even small decreases can lead to substantial long-term benefits by reducing the cumulative risk of high myopia and associated complications. From a clinical perspective, bifocal and PALs should be considered as part of a comprehensive, individualized myopia management strategy, particularly for children with accommodative dysfunction or high near-work demands. [28] From a public health standpoint, these interventions are cost-effective, scalable, and accessible, making them a valuable option in low- and middle-income regions where advanced treatments may not be readily available. [29] Promoting outdoor activities and reducing excessive near work alongside optical correction may further enhance treatment outcomes. [30]

LIMITATIONS FUTURE DIRECTIONS

Several limitations should be acknowledged. Moderate heterogeneity ($I^2 = 58\%$) in refractive outcomes suggests variability in study designs, participant characteristics, and lens parameters. Additionally, environmental factors such as nearwork duration and outdoor exposure were not consistently reported across studies, limiting their inclusion in quantitative analysis. Differences in compliance and adaptation to lenses may also have influenced outcomes but were not uniformly assessed. Future research should focus on well-designed, largescale randomized controlled trials with standardized protocols and longer follow-up durations. There is also a need to directly compare bifocal and PALs with newer interventions such as atropine and specialized contact lenses to determine their relative effectiveness. Incorporating objective measurements of accommodative function and environmental exposure will further improve understanding of treatment mechanisms.

CONCLUSION

Bifocal and progressive addition lenses provide a safe and effective method for slowing myopia progression and axial elongation in children. While their efficacy is lower than some newer treatments, their practicality, accessibility, and safety profile make them an essential component of contemporary myopia management.

DECLARATION

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Ethical Approval: This study is a review based on previously published data; therefore, ethical approval was not required. Informed
Consent: Not applicable, as no individual patient data were directly collected or used in this study.
Data Availability: All data analyzed during this study are included in the published articles referenced within this manuscript. Additional details are available from the corresponding author upon reasonable request.
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