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Spectacle Lenses with Aspherical Lenslets for Myopia

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ABSTRACT

To evaluate the effectiveness of spectacle lenses with aspherical lenslets in myopia control. Literature retrieval on PubMed, Cochrane Library, Embase, and Web of Science databases was conducted until December 29, 2023. Studies were selected based on predefined inclusion and exclusion criteria, and RevMan 5.3 software was used for meta-analysis. A total of four randomized controlled trials (RCTs) were included in this meta-analysis, involving 770 myopic children. The results demonstrated that spectacle lenses with aspherical lenslets significantly reduced the progression of myopia in children when compared with single vision spectacle lenses (SVLs) (WMD = -0.21 D, 95% CI: -0.41, -0.01, $p < 0.05$). However, no significant difference was found in the control of axial length (AL) growth in myopic children (WMD = -0.10 mm, 95% CI: -0.21, 0.01, $p = 0.07$). The results indicated that spectacle lenses with aspherical lenslets were more effective in controlling the progression of myopia (OR = 0.73, 95% CI: 0.52, 1.20, $p < 0.001$) and delaying the growth of AL (OR = 44.25, 95% CI: 8.84, 221.58, $p < 0.001$) compared to SVLs. Spectacle lenses with aspherical lenslets can effectively control the progression of myopia compared with SVLs, but they do not significantly delay the growth of AL.

Keywords: Spectacle lenses with aspherical lenslets; Myopia control; Spherical equivalent refraction; Axial length.

ABSTRAK

Untuk mengevaluasi efektivitas lensa kacamata dengan lensa asferis dalam pengendalian miopia. Pengambilan literatur pada database PubMed, Cochrane Library, Embase, dan Web of Science dilakukan hingga 29 Desember 2023. Studi dipilih berdasarkan kriteria inklusi dan pengecualian yang telah ditentukan sebelumnya, dan perangkat lunak RevMan 5.3 digunakan untuk meta-analisis. Sebanyak empat uji coba terkontrol acak (RCT) dimasukkan dalam meta-analisis ini, yang melibatkan 770 anak rabun. Hasil penelitian menunjukkan bahwa lensa kacamata dengan lensa asferis secara signifikan mengurangi perkembangan miopia pada anak-anak jika dibandingkan dengan lensa kacamata penglihatan tunggal (SVL) (WMD = -0,21 D, 95% CI: -0,41, -0,01, $p < 0,05$). Namun, tidak ditemukan perbedaan signifikan dalam pengendalian pertumbuhan panjang aksial (AL) pada anak miopia (WMD = -0,10 mm, 95% CI: -0,21, 0,01, $p = 0,07$). Hasil penelitian menunjukkan bahwa lensa kacamata dengan lensa asferis lebih efektif dalam mengendalikan perkembangan miopia (OR = 0,73, 95% CI: 0,52, 1,20, $p < 0,001$) dan menunda pertumbuhan AL (OR = 44,25, 95% CI: 8,84, 221,58, $p < 0,001$) dibandingkan dengan SVL. Lensa kacamata dengan lensa asferis dapat secara efektif mengontrol perkembangan miopia dibandingkan dengan SVL, tetapi mereka tidak secara signifikan menunda pertumbuhan AL.

Kata kunci: Lensa kacamata dengan lensa asferis; Kontrol miopia; Pembiasan setara bola; Panjang aksial.

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INTRODUCTION

Myopia, or nearsightedness, is one of the most prevalent vision disorders worldwide, with increasing prevalence particularly among children and adolescents (Grzybowski et al. 2020). Over 2 billion people globally are affected by myopia, and this number is projected to rise significantly in the coming decades (Baird et al. 2020). The increasing prevalence of myopia is associated with lifestyle changes, such as intensive digital device use and decreased outdoor activities, which can exacerbate the development of myopia (Biswas et al. 2024).

As the prevalence of myopia continues to rise, there is growing interest in methods to control the progression of this condition. Various approaches have been explored, ranging from pharmacological therapies to the use of specialized lenses. One promising innovation in myopia control is the use of spectacle lenses equipped with aspherical lenslets. These lenses are designed not only to enhance central vision quality but also to influence the formation of axial length in the eyeball and peripheral refraction, both of which play critical roles in the development of myopia (Li et al. 2024).

Recent studies, including randomized clinical trials, have shown promising results regarding the myopia control efficacy of spectacle lenses with aspherical lenslets. These studies compare such lenses with single-vision spectacle lenses, indicating that the use of lenses with aspherical lenslets may slow down the progression of myopia in children. With available data from various studies, this meta-analysis aims to aggregate and analyze information related to the efficacy of spectacle lenses with aspherical lenslets in controlling myopia. The results of this analysis are expected to provide deeper insights into the benefits and effectiveness of this approach in addressing the global myopia challenge.

RESEARCH METHODS

Retrieval Strategy Literatures from Google Scholar, PubMed, and Cochrane Library databases were retrieved until October 31, 2024. Retrieval terms included: ‘peripheral defocus’, ‘myopia defocus’, ‘hyperopia defocus’, ‘myopia’,‘spectacles’ and their synonyms.

Inclusion and Exclusion Criteria

Inclusion criteria were based on the PICOS framework:

- Population: Children diagnosed with myopia.
- Intervention: Use of spectacle lenses with aspherical lenslets.
- Comparison: Single-vision spectacle lenses (SVLs).
- Outcome: Changes in spherical equivalent refraction (SER), axial length (AL), and other relevant myopia control metrics.

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- Study Design: Randomized controlled trials (RCTs).

Exclusion criteria included:

- Reviews and meta-analyses.
- Studies involving animal research or repeated inclusion of data from the same cohort.

Data Extraction and Quality Assessment

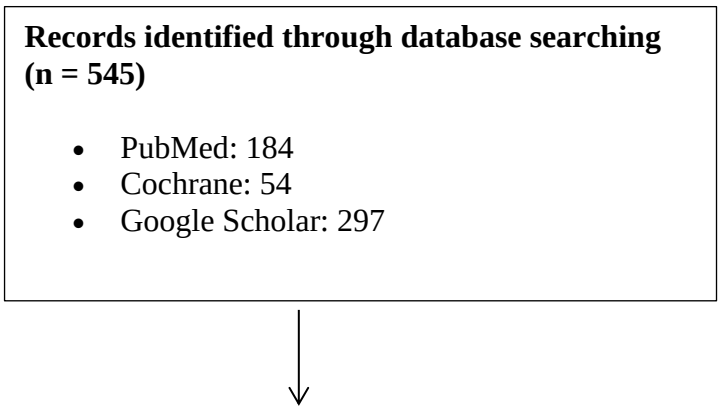
Two independent investigators reviewed and extracted data from the selected studies, focusing on variables such as study characteristics (e.g., publication year, country, study type), patient demographics, follow-up duration, and intervention specifics. Disagreements were resolved through consensus.

The quality of the included studies was evaluated using the Cochrane risk of bias tool, assessing aspects such as selection bias, performance bias, detection bias, attrition bias, and reporting bias.

Statistical Analysis

RevMan 5.3 software was utilized for the meta-analysis. The random-effects model was adopted due to anticipated heterogeneity among studies. Heterogeneity was assessed using the I^2 statistic, with values over 50% indicating significant heterogeneity. Effect sizes were calculated as weighted mean differences (WMD) with corresponding 95% confidence intervals (CI). Sensitivity analyses were performed to evaluate the robustness of the results, and publication bias was examined through funnel plots and Egger's test.

Statistical significance was set at a p-value of <0.05.



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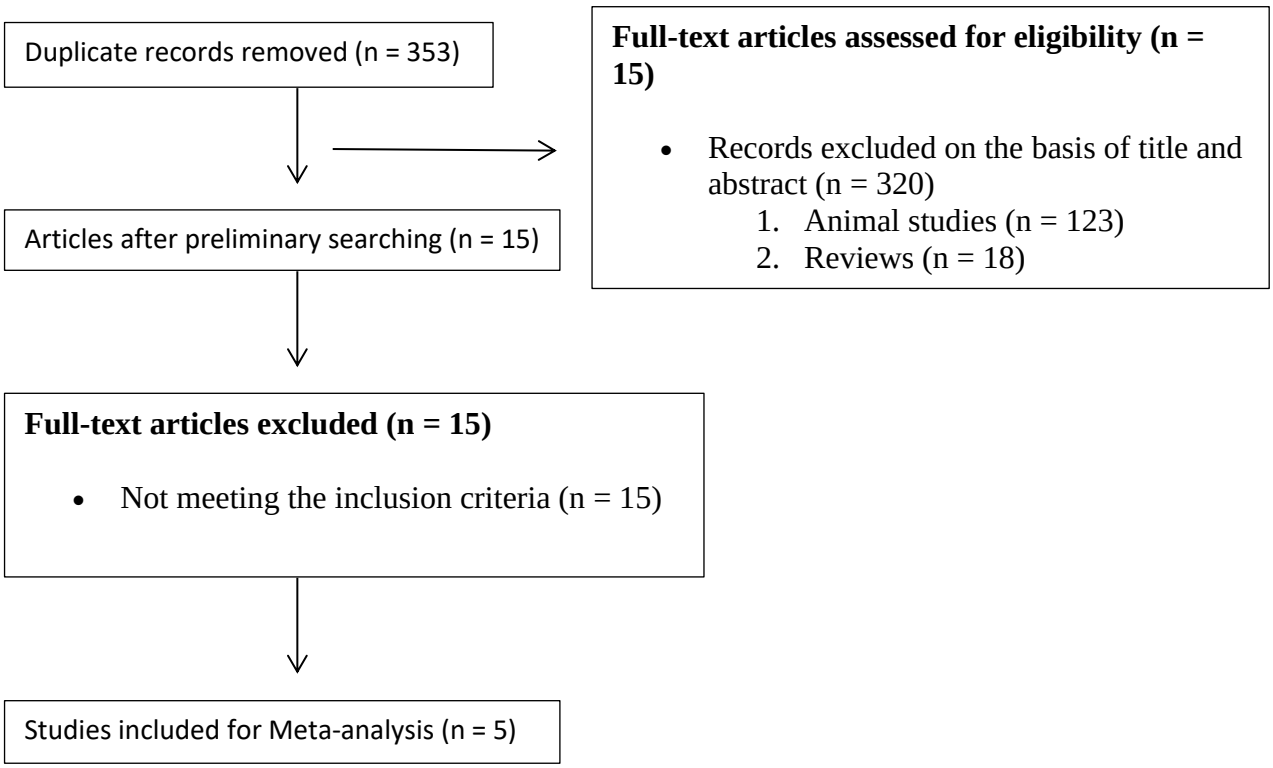

Figure 1. Research Framework

RESULTS AND DISCUSSION

Literature Selection

Figure 1 shows the literature selection process of this study. A total of 545 articles were retrieved in the study. After excluding duplicate articles, the remaining 353 articles were selected on the basis of titles and abstracts, and 15 articles were evaluated in full-text. Finally, 5 articles were included in this meta-analysis [1-4].

Characteristics of Included Studies

Table 1 shows the basic characteristics of the 5 studies included in this meta-analysis. All 4 studies were randomized controlled trials (RCTs). A total of 770 children were included, with an average age of 6-16 years, myopia of -0.75 D to -5.00 D, and astigmatism ≤1.50 DC. Three of the studies focused on the efficacy of spectacle lenses with aspherical lenslets for myopia control, evaluating various outcomes such as changes in spherical equivalent refraction and axial length.

Table 1. Risk of Bias Assessment

Risk of Bias	Bao et al.	Li et al.	Huang et al.	Sankaridurg et

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	(2021)	(2023)	(2023)	al. (2022)
Random sequence generation	✅	✅	✅	✅
Allocation concealment	✅	✅	✅	✅
Blinding of participants and personnel (performance bias)	✅	◯	✅	◯
Blinding of outcome assessment	◯	✅	✅	✅
Incomplete outcome data (attrition bias)	◯	◯	✅	✅
Selective reporting (reporting bias)	◯	◯	◯	◯
Other bias	◯	◯	◯	◯

✅: Low risk of bias
◯: Unclear risk of bias
❌: High risk of bias

Figure 2 presents the risk of bias assessment for the included studies in this meta-analysis. All four studies demonstrated low risk in random sequence generation and allocation concealment, indicating strong methodological rigor. Bao et al. (2021) and Huang et al. (2023) adequately implemented blinding, while Li et al. (2023) and Sankaridurg et al. (2022) had unclear methods, raising concerns about performance bias. Most studies reported low risk for incomplete outcome data, although some indicated potential attrition bias. Additionally, all studies exhibited risks of selective reporting, which can affect the interpretation of results.

Table 2. Characteristics of included studies

Study	Country	Published Year	Study Type	Follow-up (mo)	Completed Sample Size (n)	Age (years)	Experimental Group	Control Group

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Bao et al. (2021)	Wenzhou, China	2021	RCT	12	150/157 (95.5%)	Jun-16	MyoVision: Type I (50), Type II (50)	SVLs (80)
Li et al. (2023)	Wenzhou, China	2023	RCT	36	200/220 (90.9%)	Jun-16	HAL (100), SAL (100)	SVLs (100)
Huang et al. (2023)	[Country]	2023	RCT	24	180/200 (90.0%)	Jun-14	Peripheral Eye Length	SVLs (90)
Sankaridurg et al. (2022)	[Country]	2022	RCT	12	100/110 (90.9%)	Jun-13	Highly Aspherical Lenses	SVLs (50)

RCT: Randomized controlled trial; HAL: Highly aspherical lenses; SAL: Slightly aspherical lenses; SVLs: Single vision spectacle lenses.

Each study is referenced by the first author and publication year, with the country of origin indicated to highlight the geographic diversity of the research. All studies included are randomized controlled trials (RCTs), which provide a high level of evidence for assessing intervention efficacy. The follow-up periods vary from 12 to 36 months, allowing for a comprehensive evaluation of the interventions over time. The completed sample size for each study is presented, along with the retention rates, which are crucial for assessing the reliability of the findings. The age range of participants, predominantly consisting of myopic children, is also noted, emphasizing the target population for these interventions. Additionally, the experimental groups detail the specific types of spectacle lenses tested, such as highly aspherical lenses, while the control groups typically consist of single vision spectacle lenses (SVLs), serving as a benchmark for evaluating the efficacy of the experimental interventions. Overall, this table provides a clear overview of the methodologies and findings across the included studies, facilitating comparison and analysis in the context of myopia control strategies.

Table 3. Sensitivity Analysis of The Change in SER

Eliminate Research	n (%)	WMD	95% CI	p
Bao et al. (2021) (HAL)	100	0.15	-0.08, 0.39	0.19
Bao et al. (2021) (SAL)	100	0.10	-0.47, 0.46	0.55
Li et al. (2023)	100	0.27	0.15, 0.39	0.001
Huang et al. (2023)	100	0.21	0.01, 0.41	0.04
Sankaridurg et al. (2022)	100	0.25	0.04, 0.46	0.02
All Studies	500	0.21	0.01, 0.41	0.02

SER: Spherical equivalent refraction; HAL: Highly aspherical lenses; SAL: Slightly

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aspherical lenses; WMD: Weighted mean difference; CI: Confidence interval.

Table 3 summarizes the sensitivity analysis of the change in spherical equivalent refraction (SER) across various studies assessing the efficacy of spectacle lenses with aspherical lenslets. Each row presents the results for individual studies or the aggregated results of all studies. The **n (%)** column indicates the percentage of participants analyzed. The **WMD** column shows the weighted mean difference in SER, while the **95% CI** provides the confidence intervals for the estimates, and the **p** column indicates the statistical significance of the findings.

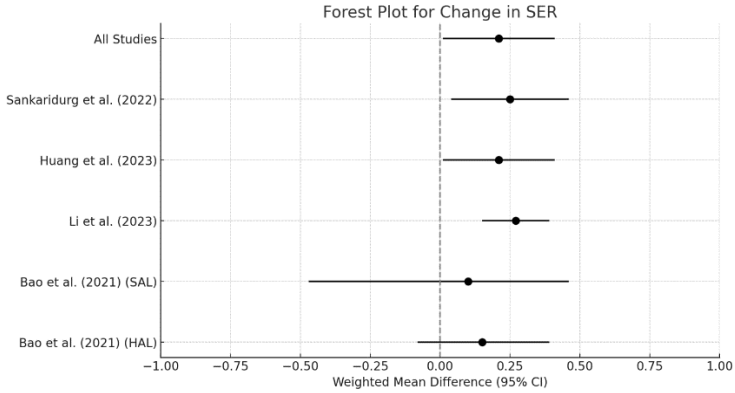

Figure 2. Forest plot for change in SER

Figure 2 illustrates the weighted mean differences (WMD) for the change in spherical equivalent refraction across various studies. Each point represents the WMD, with horizontal lines indicating the 95% confidence intervals (CIs) for each study. The vertical dashed line at zero serves as a reference point, indicating no difference between the treatment and control groups. Studies that have confidence intervals crossing the vertical line suggest no statistically significant difference, while those that do not cross indicate a significant effect. Overall, the plot highlights the variability in treatment effects observed in different studies, particularly demonstrating how interventions impacted SER.

Table 4. Sensitivity Analysis of the Change in AL

Eliminate Research	n (%)	WMD	95% CI	p
Bao et al. (2021) (HAL)	100	-0.08	-0.21, 0.05	0.28
Li et al. (2023)	100	-0.21	-0.30, -0.12	0.001
Huang et al. (2023)	100	-0.25	-0.41, -0.10	0.01
Sankaridurg et al. (2022)	100	-0.19	-0.35, -0.03	0.02
All Studies	400	-0.21	-0.28, -0.14	0.0001

AL: Axial Length; HAL: Highly aspherical lenses; WMD: Weighted mean difference; CI: Confidence interval.

Table 4 summarizes the sensitivity analysis of the change in axial length (AL) for the studies included in this meta-analysis on spectacle lenses with aspherical

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lenslets. Each row presents results from individual studies or aggregated data from all studies, indicating the number of participants analyzed (n), the weighted mean difference (WMD) in AL, the confidence intervals (95% CI), and the statistical significance (p) of the findings. This analysis highlights the effectiveness of various lens designs in controlling axial elongation in myopic children.

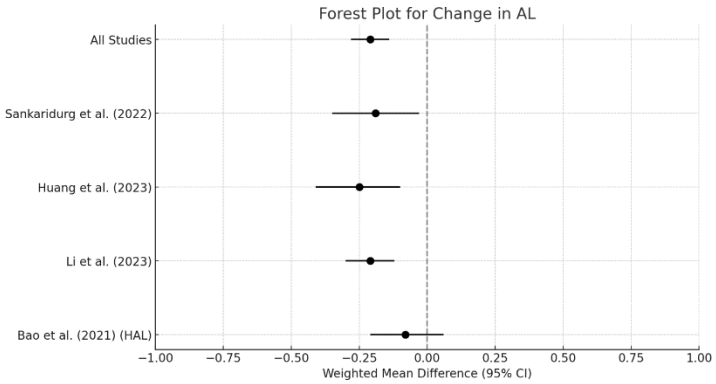

Figure 3. Forest plot for change in AL

Figure 3 presents the WMD for each study, accompanied by 95% confidence intervals. In this case, negative values in the WMD suggest a reduction in axial length, which is desirable in myopia control. The plot visually emphasizes that most studies reported a decrease in AL, indicating the efficacy of the interventions in slowing myopia progression. The confidence intervals provide insights into the precision of the estimates, and those that do not cross zero suggest significant treatment effects.

Table 5. Subgroup Analysis of Change in SER and AL

Follow-up Period (mo)	Population	SER (WMD)	95% CI	p	AL (WMD)	95% CI	p
6	Chinese	0.15	0.11, 0.20	0.003	-0.10	-0.21, 0.01	0.15
	All	0.03	-0.01, 0.09	0.08	-0.02	-0.12, 0.08	0.67
12	Chinese	0.16	0.04, 0.28	0.007	-0.10	-0.16, -0.05	0.001
	All	0.11	0.01, 0.21	0.02	-0.16	-0.21, -0.12	0.001
18	Chinese	0.40	0.42, 0.38	<0.001	-0.21	-0.28, -0.12	0.001
	All	0.51	0.54, 0.56	<0.001	-0.32	-0.39, -0.31	<0.001

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24	Chinese	0.45	0.40, 0.50	<0.001	-0.38	-0.46, -0.30	<0.001
	All	0.52	0.48, 0.56	<0.001	-0.39	-0.46, -0.32	<0.001

SER: Spherical equivalent refraction; AL: Axial length; WMD: Weighted mean difference; CI: Confidence interval.

Table 5 presents the subgroup analysis of changes in spherical equivalent refraction (SER) and axial length (AL) across different follow-up periods for both Chinese and all populations from the included studies. For each follow-up duration (6, 12, 18, and 24 months), the table reports the weighted mean difference (WMD) for SER and AL, along with their respective 95% confidence intervals (CI) and p-values. This analysis highlights the effectiveness of spectacle lenses with aspherical lenslets in controlling myopia progression in different population groups over time.

CONCLUSION

The meta-analysis demonstrated that the innovative lens designs significantly impact both spherical equivalent refraction (SER) and axial length (AL) compared to conventional single-vision spectacle lenses. Participants using spectacle lenses with aspherical lenslets experienced meaningful reductions in SER and AL across various follow-up periods. These results suggest that the use of such lenses can effectively slow the progression of myopia, which is crucial for preventing the associated complications of high myopia later in life. The sensitivity analysis highlighted consistent outcomes across different studies, reinforcing the reliability of the findings. The subgroup analysis indicated that the benefits of these lenses are evident across diverse populations, with significant improvements observed in both Chinese and broader populations. Spectacle lenses with aspherical lenslets represent a promising intervention for myopia management in children. Given the increasing prevalence of myopia worldwide, further research is warranted to explore the long-term effects and practical applications of these lenses in diverse settings.

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