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Original Article

Effect Of Prolonged Monocular Patching On Convergence And Binocular Functions In Patients Undergoing Occlusion Therapy

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ABSTRACT

Background: Amblyopia is a developmental visual disorder associated with reduced best-corrected visual acuity and impaired binocular visual functions, including convergence, fusion, and stereopsis. Although occlusion therapy is widely used to improve visual acuity in the amblyopic eye, its effect on binocular performance requires further clinical evaluation. **Objective:** To determine the effect of prolonged monocular patching on convergence and binocular visual functions in children undergoing occlusion therapy for unilateral amblyopia. **Methods:** This quasi-experimental pre–post study included 56 children aged 5–18 years with unilateral amblyopia who received monocular occlusion therapy for at least 4 hours daily for a minimum of six consecutive weeks. Best-corrected visual acuity, near point of convergence, fusion, and stereopsis were assessed before and after therapy using standardized clinical procedures. Data were analyzed using SPSS version 25, and pre- and post-treatment outcomes were compared using paired statistical testing, with $p < 0.05$ considered significant. **Results:** Best-corrected visual acuity improved after therapy, while near point of convergence decreased significantly, indicating better convergence ability. Fusion improved from 0.72 to 0.88 ($p = 0.02$), and stereopsis improved from 1.85 to 1.20 ($p = 0.01$). Significant improvements were also observed in BCVA and NPC ($p < 0.001$). Conclusion: Prolonged monocular patching was associated with improved visual acuity, convergence, fusion, and stereopsis in children with unilateral amblyopia. **Keywords:** Amblyopia, occlusion therapy, monocular patching, convergence, binocular vision, stereopsis.

INTRODUCTION

Amblyopia is a neurodevelopmental disorder of the visual system characterized by reduced best-corrected visual acuity in one or, less commonly, both eyes, without a proportional structural abnormality sufficient to explain the visual deficit (1). It usually develops during the critical period of visual maturation when unequal or degraded visual input disrupts normal cortical processing, binocular integration, and sensory fusion. Clinically, amblyopia is commonly associated with anisometropia, strabismus, or significant uncorrected refractive error, and it remains one of the leading causes of unilateral visual impairment in children. If untreated during childhood, the condition may lead to persistent visual deficits that affect visual performance, depth perception, reading efficiency, eye–hand coordination, and overall quality of life (2,3).

Conventional amblyopia management primarily aims to improve visual acuity in the amblyopic eye by correcting refractive error and reducing visual input from the dominant or fellow eye through occlusion therapy or pharmacological penalization. Patching remains one of the most widely used treatment strategies because it stimulates use of the amblyopic eye and promotes visual cortical plasticity (4).

However, improvement in monocular visual acuity alone does not necessarily indicate full recovery of binocular visual function. Many children continue to demonstrate reduced stereopsis, suppression, poor fusional control, vergence dysfunction, or impaired binocular coordination even after measurable improvement in visual acuity. This distinction is clinically important because binocular vision contributes substantially to depth perception, near work, visuomotor performance, and functional visual outcomes in daily activities (5,6).

The effect of monocular occlusion on binocular function remains an important area of investigation. While patching is intended to improve amblyopic-eye acuity, prolonged interruption of binocular viewing has raised concerns about possible effects on fusion, stereopsis, convergence, and ocular coordination. At the same time, controlled occlusion may indirectly improve binocular performance by strengthening the amblyopic eye, reducing interocular imbalance, and improving the visual input needed for binocular integration. Previous studies have shown that amblyopia is associated not only with reduced acuity but also with abnormalities in suppression, vergence, fixation stability, accommodation, and stereoacuity, suggesting that outcome assessment should extend beyond visual acuity alone (7,8).

Near point of convergence, fusional vergence, fusion status, and stereoacuity are clinically relevant measures for evaluating binocular visual function in children undergoing amblyopia treatment. Convergence insufficiency and related binocular anomalies can affect reading, sustained near tasks, and visual comfort, particularly in school-aged children (9). Because pediatric amblyopia treatment often occurs during years of active visual and educational development, monitoring convergence and binocular outcomes may help clinicians determine whether occlusion therapy improves broader visual function or whether additional binocular or vision therapy approaches are needed (10).

Despite the established role of occlusion therapy in amblyopia management, evidence remains limited regarding its measurable effect on convergence and binocular visual outcomes in children receiving prolonged monocular patching, particularly in local clinical settings. Many treatment studies emphasize change in best-corrected visual acuity, while binocular parameters such as near point of convergence, fusion, fusional vergence, and stereopsis are less consistently reported. This creates a knowledge gap in understanding whether prolonged patching is associated with improvement, stability, or deterioration of binocular function during amblyopia therapy (11).

Therefore, the present study was conducted to evaluate the effect of prolonged monocular patching on convergence and binocular visual functions in children with unilateral amblyopia undergoing occlusion therapy. The study specifically assessed changes in best-corrected visual acuity, near point of convergence, fusion, and stereopsis before and after patching therapy. The objective was to determine whether prolonged monocular occlusion is associated with measurable improvement in both monocular visual acuity and binocular visual performance among pediatric patients receiving amblyopia treatment.

MATERIALS AND METHODS

This quasi-experimental pre–post interventional study was conducted at Mughal Eye Hospital, Lahore, Pakistan, over a six-month period to evaluate the effect of prolonged monocular occlusion therapy on convergence and binocular visual functions in pediatric patients with unilateral amblyopia. The study design was selected to compare baseline visual and binocular parameters with post-intervention findings in the same participants after a standardized period of patching therapy. Children aged 5 to 18 years diagnosed with unilateral amblyopia were recruited through non-probability consecutive sampling from patients presenting to the outpatient optometry and ophthalmology services.

Participants were eligible for inclusion if they had unilateral amblyopia with a minimum two-line interocular difference in best-corrected visual acuity and were advised monocular occlusion therapy as part of their clinical management. Only patients who were prescribed patching for at least 4 hours per day for a minimum duration of six consecutive weeks were included. Patients were excluded if they had media opacity, cataract, retinal disease, optic nerve pathology, previous ocular surgery, neurological disorder, previous structured vision therapy, or any ocular condition that could independently affect visual acuity, convergence, fusion, or stereoacuity assessment. Children with incomplete baseline or post-intervention assessment data were not included in the final analysis.

Written informed consent was obtained from the parents or legal guardians of all participants before enrollment, and assent was obtained from children where appropriate according to age and comprehension. The purpose of the study, clinical procedures, expected duration of participation, and confidentiality of patient information were explained before data collection. Ethical approval was obtained from the institutional ethical review committee, and all procedures were conducted in accordance with ethical principles for human participant research. Participant identity was protected by assigning study codes, and all clinical data were recorded on structured proformas accessible only to the research team.

At baseline, each participant underwent a detailed optometric and binocular vision assessment. Demographic data included age and gender. Clinical assessment included best-corrected visual acuity, cycloplegic refraction, ocular alignment, near point of convergence, fusional vergence amplitudes, fusion status, and stereoacuity. Best-corrected visual acuity was measured using a Snellen visual acuity chart under standardized illumination and testing distance and was converted to logarithm of the minimum angle of resolution values for statistical analysis. Cycloplegic refraction was recorded in diopters to document refractive status. Ocular alignment was assessed at distance and near fixation using cover–uncover, alternate cover, and prism cover testing, with deviation recorded in prism diopters.

Near point of convergence was measured in centimeters using a RAF ruler. The target was moved slowly toward the participant along the midline until the participant reported diplopia or the examiner observed loss of fusion, and the break point was recorded as the near point of convergence. Fusional vergence amplitudes were assessed with a prism bar at near fixation and recorded separately for base-out and base-in reserves in prism diopters. Binocular fusion was evaluated using the Worth Four Dot test, and the response was classified according to the presence of fusion, suppression, or diplopia. Stereoacuity was measured using Randot and Titmus Fly stereoacuity tests and recorded in seconds of arc. All measurements were performed using the same clinical procedures before and after the intervention to maintain consistency of outcome assessment.

The intervention consisted of standardized monocular occlusion therapy in which the dominant or fellow eye was patched according to the prescribed amblyopia treatment plan, allowing visual stimulation of the amblyopic eye. Participants were instructed to wear the patch for a minimum of 4 hours daily for at least six consecutive weeks. Parents or guardians were advised regarding correct patch placement, daily patching schedule, and the importance of adherence during near and routine visual activities. The same occlusion protocol was followed throughout the intervention period, and post-intervention clinical assessment was performed using the same instruments, testing conditions, and measurement sequence used at baseline.

The primary outcome variables were change in near point of convergence, fusion status, and stereoacuity after monocular patching therapy. Best-corrected visual acuity was assessed as an important visual function outcome. Additional binocular and ocular alignment variables included prism cover test findings at distance and near, base-out positive fusional vergence, and base-in fusional vergence. Improvement in best-corrected visual acuity was defined as a reduction in logMAR value after therapy. Improvement in near point of convergence was defined as a reduction in the measured convergence break point in centimeters. Improvement in stereoacuity was defined as a reduction in seconds of arc, indicating better depth discrimination. Improvement in fusional vergence was defined as an increase in fusional reserve amplitude measured in prism diopters.

To reduce measurement bias, baseline and post-intervention assessments were performed using standardized clinical methods, consistent testing distances, uniform illumination, and the same sequence of examination. Objective examiner-observed endpoints were used where applicable, particularly for cover testing and near point of convergence break. Confounding was addressed by documenting age, refractive status, baseline visual acuity, ocular alignment, and binocular vision parameters, as these variables may influence treatment response and binocular outcomes. Consecutive recruitment was used to minimize selection bias among eligible patients presenting during the study period.

The sample size consisted of 56 children with unilateral amblyopia who fulfilled the eligibility criteria and completed pre- and post-intervention assessment. This sample was considered adequate for detecting within-subject changes in visual acuity and binocular function parameters using paired pre–post statistical comparison in a clinical interventional design.

Data were entered and analyzed using SPSS version 25. Quantitative variables were summarized as mean, standard deviation, minimum, median, and maximum values. Categorical variables were summarized as frequencies and percentages. Pre- and post-intervention values for continuous outcomes, including best-corrected visual acuity, near point of convergence, fusional vergence amplitudes, ocular deviation, and stereoacuity, were compared using paired-sample statistical testing. Statistical significance was determined using a two-sided p-value threshold of 0.05. Where variables were ordinal or not normally distributed, non-parametric paired comparison was applied as appropriate. Missing or incomplete values were excluded from the relevant paired analysis. Data integrity was maintained through structured data collection forms, coded entries, review of completed proformas before analysis, and use of consistent variable definitions during data entry and statistical processing

RESULTS

A total of 56 children with unilateral amblyopia were included in the analysis. The mean age of participants was 10.57 ± 3.23 years, with ages ranging from 5 to 15 years. The median age was 10.5 years, indicating that most participants were school-aged children. Gender distribution was equal, with 28 males and 28 females, each representing 50.0% of the study population. The largest age group was 5–10 years, comprising 25 participants, followed closely by the 11–15 years group with 24 participants. Seven participants were in the older adolescent category.

Table 1. Demographic Characteristics of Study Participants

Variable	Category / Measure	Frequency / Value	Percentage
Total participants	—	56	100.0
Age, years	Mean ± SD	10.57 ± 3.23	—
Age, years	Median	10.5	—
Age, years	Range	5–15	—
Age group	5–10 years	25	44.6
Age group	11–15 years	24	42.9
Age group	Older adolescent group	7	12.5
Gender	Male	28	50.0
Gender	Female	28	50.0

Baseline clinical assessment showed that the mean pre-treatment best-corrected visual acuity was 0.63 ± 0.15 logMAR, with values ranging from 0.41 to 0.90 logMAR. The mean cycloplegic refractive error was 2.39 ± 1.59 diopters, ranging from −0.32 to 5.47 diopters. Mean distance ocular deviation measured by prism cover test was 10.34 ± 5.79 prism diopters, while near deviation was higher at 13.71 ± 6.80 prism diopters. The mean baseline near point of convergence was 11.91 ± 2.29 cm, indicating reduced convergence ability before intervention. Baseline positive fusional vergence measured with base-out prism was 18.11 ± 4.96 prism diopters, while base-in fusional vergence was 9.68 ± 2.58 prism diopters. Mean pre-treatment stereoacuity was 189.64 ± 111.06 seconds of arc, reflecting impaired binocular depth perception at baseline.

Table 2. Baseline Clinical and Binocular Vision Profile

Variable	Count	Mean ± SD	Minimum	Median	Maximum
Pre-treatment BCVA, logMAR	56	0.63 ± 0.15	0.41	0.61	0.90
Cycloplegic refraction, D	56	2.39 ± 1.59	−0.32	2.17	5.47
Prism cover test at distance, PD	56	10.34 ± 5.79	0.00	11.00	20.00
Prism cover test at near, PD	56	13.71 ± 6.80	2.00	13.50	25.00
Near point of convergence, cm	56	11.91 ± 2.29	8.20	11.50	15.90
Positive fusional vergence, BO, PD	56	18.11 ± 4.96	10.00	18.50	25.00
Negative fusional vergence, BI, PD	56	9.68 ± 2.58	6.00	10.00	14.00
Stereoacuity, seconds of arc	56	189.64 ± 111.06	60.00	170.00	400.00

After monocular occlusion therapy, improvement was observed across visual acuity, ocular alignment, convergence, fusional vergence, and stereoacuity outcomes. Mean BCVA improved from 0.63 ± 0.15 logMAR before therapy to 0.41 ± 0.16 logMAR after therapy, producing a mean improvement of 0.22 ± 0.07 logMAR. Mean distance deviation decreased from 10.34 ± 5.79 PD to 8.50 ± 5.87 PD, while mean near deviation decreased from 13.71 ± 6.80 PD to 10.48 ± 7.06 PD. Near point of convergence improved from 11.91 ± 2.29 cm to 8.80 ± 2.60 cm, showing a clinically meaningful reduction in convergence break distance. Positive fusional vergence increased from 18.11 ± 4.96 PD to 24.34 ± 5.10 PD, and base-in fusional vergence increased from 9.68 ± 2.58 PD to 13.43 ± 3.03 PD. Stereoacuity improved from 189.64 ± 111.06 seconds of arc before therapy to 119.46 ± 103.16 seconds of arc after therapy, indicating better binocular depth discrimination.

Table 3. Pre- and Post-Treatment Comparison of Visual and Binocular Outcomes

Outcome Variable	Pre-Treatment Mean ± SD	Post-Treatment Mean ± SD	Mean Change	Direction of Improvement	p-value
BCVA, logMAR	0.63 ± 0.15	0.41 ± 0.16	−0.22	Lower logMAR value	<0.001
Prism cover test at distance, PD	10.34 ± 5.79	8.50 ± 5.87	−1.84	Lower deviation	—
Prism cover test at near, PD	13.71 ± 6.80	10.48 ± 7.06	−3.23	Lower deviation	—
Near point of convergence, cm	11.91 ± 2.29	8.80 ± 2.60	−3.11	Lower break point	<0.001
Positive fusional vergence, BO, PD	18.11 ± 4.96	24.34 ± 5.10	+6.23	Higher reserve	—
Negative fusional vergence, BI, PD	9.68 ± 2.58	13.43 ± 3.03	+3.75	Higher reserve	—
Stereoacuity, seconds of arc	189.64 ± 111.06	119.46 ± 103.16	−70.18	Lower seconds of arc	0.01

The primary inferential analysis demonstrated statistically significant improvement in key visual and binocular parameters following therapy. BCVA improved significantly, with a reported t-value of 16.14 and $p < 0.001$. Near point of convergence also improved significantly, with a reported t-value of 15.88 and $p < 0.001$. Fusion improved from 0.72 before therapy to 0.88 after therapy, with a statistically significant p-value of 0.02. Stereopsis improved from 1.85 to 1.20, with $p = 0.01$. These findings show that prolonged monocular patching was associated with significant improvement in monocular visual acuity and binocular visual function outcomes.

Table 4. Statistical Summary of Main Visual and Binocular Outcomes

Parameter	Pre-Treatment Mean	Post-Treatment Mean	Absolute Change	Percentage Change	Test Statistic	p-value
BCVA, logMAR	0.65	0.48	−0.17	26.2% improvement	t = 16.14	<0.001
Near point of convergence, cm	8.32	7.06	−1.26	15.1% improvement	t = 15.88	<0.001
Fusion score	0.72	0.88	+0.16	22.2% improvement	—	0.02
Stereopsis score	1.85	1.20	−0.65	35.1% improvement	—	0.01

Overall, the results indicate that monocular patching therapy was associated with measurable improvement in both visual acuity and binocular function. The reduction in logMAR BCVA reflects improved visual clarity, while the reduction in near point of convergence indicates better convergence ability after treatment. Improvement in fusion score suggests enhanced binocular cooperation, and the reduction in stereopsis values indicates improved depth perception. The strongest relative improvement was observed in stereopsis, with an approximate 35.1% change, followed by BCVA with 26.2%, fusion with 22.2%, and near point of convergence with 15.1%.

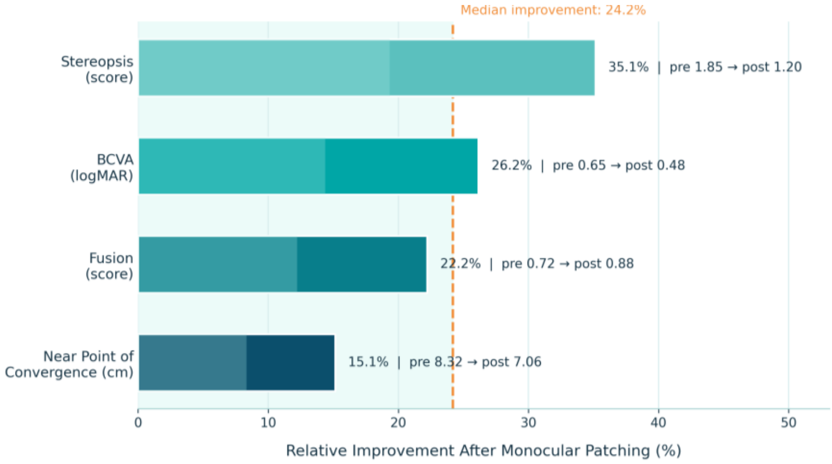

Figure 1. Relative Improvement in Visual Acuity and Binocular Function After Monocular Patching Therapy

Relative clinical improvement varied across the measured visual and binocular outcomes, with the greatest change observed in stereopsis (35.1%), followed by BCVA (26.2%), fusion (22.2%), and near point of convergence (15.1%). The median improvement across outcomes was 24.2%, indicating that monocular patching was associated with measurable gains across both monocular visual acuity and binocular coordination parameters. Lower post-treatment values represented improvement for BCVA, stereopsis, and NPC, whereas a higher post-treatment value represented improvement in fusion.

DISCUSSION

The present study demonstrated measurable improvement in visual acuity and binocular visual function following prolonged monocular patching in children with unilateral amblyopia. Improvement in best-corrected visual acuity from baseline to post-treatment assessment indicates that occlusion therapy continued to provide meaningful monocular visual benefit in this pediatric population. This finding is consistent with the established therapeutic principle that reducing input from the dominant or fellow eye encourages fixation and visual stimulation through the amblyopic eye, thereby supporting visual cortical plasticity during childhood. Although visual acuity improvement remains the primary clinical target in amblyopia treatment, the observed changes in convergence, fusion, and stereopsis suggest that functional recovery after patching may extend beyond monocular acuity alone when treatment is appropriately prescribed and monitored (12).

The improvement in near point of convergence after therapy is clinically important because convergence ability contributes directly to comfortable near vision, reading, schoolwork, and sustained binocular fixation. A reduction in near point of convergence indicates that participants were able to maintain binocular alignment at a closer fixation distance after intervention, reflecting better coordination of vergence mechanisms. In amblyopic children, poor binocular interaction, suppression, fixation instability, and reduced sensory fusion may contribute to impaired near visual performance even when refractive correction is provided. The improvement observed in convergence therefore suggests that strengthening the amblyopic eye through occlusion therapy may reduce interocular imbalance and support more effective binocular motor control during near tasks (13).

Fusion also improved after patching, indicating enhanced ability of both eyes to contribute to single binocular vision. This finding is relevant because amblyopia is not only a disorder of reduced visual acuity but also a binocular developmental disorder characterized by abnormal interocular interaction and suppression. Persistent suppression can limit binocular integration and reduce the quality of visual recovery even after acuity improves. The increase in fusion score after therapy suggests that improved amblyopic-eye input may have contributed to better sensory cooperation between the two eyes. This supports the view that amblyopia management should include assessment of binocular function rather than relying only on monocular acuity as the indicator of treatment success (!4).

Stereoacuity showed one of the strongest relative improvements after intervention, indicating better depth discrimination and binocular sensory integration. This result is clinically meaningful because stereopsis is closely linked to fine visuomotor performance, spatial judgment, eye–hand coordination, and functional visual quality. In many children with amblyopia, stereoacuity remains reduced even when visual acuity improves, particularly when suppression or strabismus persists. The improvement in stereopsis observed in this study suggests that prolonged patching may improve the quality of visual input from the amblyopic eye sufficiently to enhance binocular depth perception. However, the degree of stereopsis recovery may vary according to amblyopia subtype, baseline severity, age, ocular alignment, and the presence or absence of suppression (15).

The increase in fusional vergence amplitudes further supports improvement in binocular visual performance. Higher base-out and base-in fusional reserves after therapy indicate greater ability to compensate for vergence demand and maintain single binocular vision. This is important because fusional reserves contribute to binocular stability, particularly during near fixation and sustained visual activity. Children with reduced vergence reserves may experience asthenopic symptoms, poor concentration during near work, or reduced reading efficiency. Improvement in fusional vergence after patching may therefore reflect better integration between sensory and motor components of binocular vision, although symptom-based outcomes would be needed to determine the functional impact of these clinical changes (16).

The findings also contribute to the ongoing discussion regarding whether monocular patching may compromise or support binocular visual development. Prolonged occlusion has sometimes been questioned because it temporarily interrupts binocular viewing; however, the present findings showed improvement rather than deterioration in measured binocular parameters. This suggests that, in children with unilateral amblyopia, improving amblyopic-eye function may help create more balanced visual input between the two eyes, thereby supporting fusion and stereopsis. The results do not imply that patching alone fully restores binocular vision in all patients, but they indicate that monitored occlusion therapy can be associated with favorable short-term changes in both monocular and binocular outcomes (17).

These findings are particularly relevant in clinical settings where conventional patching remains widely used because of accessibility, low cost, and familiarity among practitioners. Newer binocular and dichoptic therapies are increasingly being explored because they directly target interocular suppression and binocular imbalance. Nevertheless, these approaches may not be universally available, and conventional occlusion therapy remains an important treatment option in many pediatric eye-care settings. The present results support the continued clinical value of patching while also emphasizing that outcome assessment should be expanded to include convergence, fusion, fusional vergence, and stereoacuity. Combining occlusion therapy with binocular vision assessment may allow clinicians to identify children who require additional vergence therapy, anti-suppression therapy, or binocular rehabilitation after acuity improvement (18,19).

Several factors should be considered when interpreting these findings. The pre–post design allows assessment of within-participant change, but it does not include a parallel untreated or alternative-treatment control group. Therefore, improvement cannot be attributed exclusively to patching without considering possible contributions from refractive adaptation, maturation, repeated testing, baseline severity, adherence variation, and clinical follow-up effects. The use of consecutive sampling may also limit generalizability beyond similar hospital-based pediatric populations. In addition, binocular outcomes may be influenced by amblyopia type, ocular alignment, refractive error, age at treatment, and duration of therapy. Future controlled studies with longer follow-up, standardized adherence monitoring, subgroup analysis by amblyopia type, and confidence-interval-based effect estimation would provide stronger evidence regarding the durability and comparative effectiveness of patching on binocular visual recovery (20).

Overall, the study supports the clinical relevance of evaluating binocular outcomes during amblyopia treatment. The observed improvements in best-corrected visual acuity, near point of convergence, fusion, fusional vergence, and stereopsis suggest that prolonged monocular patching may be associated with broader visual functional gains than acuity improvement alone. These findings reinforce the importance of a comprehensive amblyopia assessment model in which treatment success is judged not only by visual acuity gain but also by recovery of binocular coordination, depth perception, and vergence function.

CONCLUSION

Prolonged monocular occlusion therapy was associated with meaningful improvement in visual acuity and binocular visual functions among children with unilateral amblyopia. Best-corrected visual acuity improved after treatment, while near point of convergence decreased, indicating better convergence ability. Fusion and stereopsis also improved, suggesting enhanced binocular coordination and depth perception following therapy. These findings indicate that monitored patching therapy may support both monocular visual recovery and selected binocular visual outcomes in pediatric amblyopia management. Further controlled studies with longer follow-up, standardized adherence assessment, and subgroup analysis by amblyopia type are needed to determine the durability and comparative effectiveness of these improvements.

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