

EFFECTS OF PROLONGED MONOCULAR OCCLUSION ON CONVERGENCE AND BINOCULAR SENSORY INTEGRATION IN PEDIATRIC PATIENTS WITH AMBLYOPIA

Amina^{*1}, Dr. Saleh Shah², Dr. Muhammad Naveed Babar³, Muhammad Ajmal Ch.⁴,
Muhammad Ali⁵, Samina Zahoor⁶, Mazhar Qayyum⁷, Urooj Fatima⁸

^{*1}MS Rehab in Clinical Optometry & Low Vision Sciences, Superior University Lahore

²Supervisor, DPT, MSNMP, PhD Assistant Professor

³Dean of Allied health sciences in superior university Lahore

⁴M. Phil Orthoptics, The University of Child Health Sciences Lahore.

⁵MS Rehab.in Clinical optometry & Low Vision Sciences (SU), MS. Health administration (PU), B.Sc. Hons. Vision Sciences (KEMU), Senior Orthoptist / Optometrist, Jinnah Hospital, Lahore

⁶Senior Optometrist in Jinnah Hospital

⁷Lecturer Optometry, M. Phil Optometry / Vision & contact lens specialist, Superior University Lahore

⁸MS Rehab in clinical optometry & low vision sciences

Superior University Lahore

^{*1}dramina12277@gmail.com, ²saleh.shah@superior.edu.pk, ³naveed.babur@superior.edu.pk,

⁴ajmal.gm@gmail.com, ⁵aliorthoptist@gmail.com, ⁶saminazahoor35@gmail.com,

⁷mazharqayyum02002@gmail.com

⁸uroojfatimahh@gmail.com

⁷ORCID 0009-0007-3612-3204

DOI: <https://doi.org/10.5281/zenodo.22840994>

Keywords

Amblyopia, occlusion therapy, patching, convergence, binocular vision, pediatric patients

Article History

Received: 11 June 2026

Accepted: 02 September 2026

Published: 19 September 2026

Copyright @Author

Corresponding Author: *
Amina

Abstract

OBJECTIVE: To evaluate the effect of prolonged monocular occlusion on convergence and binocular sensory integration in pediatric patients with amblyopia

METHODS: This prospective quasi-experimental study was conducted at Shalimar Institute of Health Sciences, Lahore over a six-month period. A total of 56 children aged 5–18 years with unilateral amblyopia were included through non-probability consecutive sampling. Eligible participants had been undergoing patching therapy for at least 4 hours daily for a minimum of 6 weeks. Patients with other ocular pathology, prior vision therapy, neurological or developmental visual disorders, ocular surgery, or poor compliance were excluded. Best-corrected visual acuity and near point of convergence were assessed before and after treatment.

RESULTS: After therapy, both monocular and binocular outcomes improved significantly. Best-corrected visual acuity improved from 0.65 to 0.48, and near point of convergence improved from 8.32 cm to 7.06 cm, both with $p < 0.001$. Improvement in visual acuity was greatest in the short-duration group, followed by the moderate-duration and long-duration groups.

CONCLUSION: Prolonged monocular occlusion was associated with significant improvement in both visual acuity and convergence in pediatric amblyopia. These findings suggest that patching therapy may support not only recovery of monocular vision but also better binocular coordination and functional near vision. Earlier intervention appeared to produce better outcomes, reinforcing the importance of timely diagnosis and treatment in children during the sensitive period of visual development.

INTRODUCTION

Amblyopia is a neurodevelopmental disorder in which visual acuity is reduced despite the absence of a structural explanation sufficient to account for the deficit. It usually develops during the critical period of visual development in childhood and is most commonly associated with sensory deprivation, anisometropia, strabismus, or a combination of these factors.(1, 2)

The primary types include:

Deprivation amblyopia: Amblyopia resulting from obstruction of the visual axis (e.g., congenital cataract, ptosis, or corneal opacity) during the critical period of visual development.

Anisometropic amblyopia: Amblyopia caused by unequal refractive errors between the two eyes, resulting in chronic blur and reduced visual development in one eye.

Strabismic amblyopia: Amblyopia caused by persistent ocular misalignment, leading the brain to suppress the image from the deviating eye.(3-5)

Combined (mixed-mechanism) amblyopia: Amblyopia caused by the coexistence of two or more amblyogenic factors, such as anisometropia with strabismus or visual deprivation.(1, 2)

Meridional amblyopia: Amblyopia caused by uncorrected astigmatism, resulting in reduced visual acuity along one or more visual meridians.

Ametropic (isoametropic) amblyopia: Bilateral amblyopia caused by high, approximately equal uncorrected refractive errors in both eyes that interfere with normal visual development. (3, 5)

Occlusion amblyopia: Amblyopia induced by prolonged or inappropriate occlusion therapy of the better-seeing eye, causing reduced vision in the previously normal eye.(1)

In clinical practice, amblyopia is often described as unilateral, but the condition is increasingly understood as a disorder of binocular interaction rather than a simple monocular loss of vision.(5, 6) The burden of amblyopia is important because it affects not only visual acuity but also stereopsis, suppression, ocular alignment, and near visual performance. Children may have difficulty with reading, classroom tasks, copying from the board, and other near activities that depend on stable binocular control. This broader functional burden is one reason why the management of amblyopia should consider more than acuity alone. (1, 7, 8) Traditional treatment has focused on monocular approaches such as refractive correction, patching, and atropine penalization. (6) Among these, occlusion therapy remains the most widely used and best established method. The aim is to stimulate the amblyopic eye by temporarily covering the dominant eye, thereby encouraging visual use and cortical response in the weaker eye.(9, 10) Randomized trials have shown that part-time patching can be effective for moderate amblyopia, and increasing the prescribed dose may benefit selected children with persistent deficits. (10, 11)

Despite these benefits, patching is not a complete solution. Some children achieve improved acuity but continue to have poor binocular coordination, residual suppression, or reduced stereopsis. This creates a clinically important gap between monocular recovery and functional binocular recovery. For that reason, outcomes such as near point of convergence deserve attention because

they reflect how well the visual system coordinates the two eyes during near tasks. (7, 9, 12)

Near point of convergence is a practical measure of binocular function and vergence ability. It is often used in the evaluation of convergence insufficiency and other binocular vision disorders, and it may provide useful information in children with amblyopia who are undergoing treatment.(13) When the near point of convergence improves, it suggests better vergence control and potentially better binocular sensory integration.(14, 15)

The literature increasingly supports the idea that amblyopia should be treated and studied as a binocular disorder. Contemporary reviews and practice patterns emphasize that visual improvement alone may not fully reflect functional recovery. Some studies have also suggested that therapy works better when begun earlier, before long-standing suppression and adaptation become more entrenched. However, evidence about the effect of prolonged monocular occlusion on convergence in pediatric amblyopia remains limited. (16, 17)

The present study therefore aimed to evaluate whether prolonged monocular occlusion improves convergence and binocular sensory integration in children with amblyopia. By focusing on both best-corrected visual acuity and near point of convergence, this study provides a more functional perspective on treatment response.

MATERIAL AND METHODS

This prospective quasi-experimental study was conducted in Shalimar Institute of Health Sciences, Lahore over a period of six months to evaluate the pre- and post-treatment effects of routine occlusion therapy in children with amblyopia. A total of 56 children aged 5–18 years with unilateral amblyopia were recruited through non-probability consecutive sampling. All included participants had been receiving patching therapy for at least 4 hours per day for a minimum

of 6 weeks. Children were included if they were within the specified age range, had unilateral amblyopia, were undergoing patching therapy regularly, had completed at least 6 weeks of treatment, and were able to cooperate with clinical visual assessment. Patients were excluded if they had cataract, retinal disease, optic nerve disease, or any other ocular pathology; previous vision therapy or binocular training; neurological or developmental visual disorders; a history of ocular surgery; or poor compliance with patching therapy.

The primary outcome measures were best-corrected visual acuity, near point of convergence (NPC), fusion, and stereopsis. These variables were assessed before and after treatment to determine the effect of prolonged monocular occlusion on both visual function and binocular coordination. Pre- and post-treatment data were analyzed using paired statistical methods, and a p-value of less than 0.05 was considered statistically significant. This approach allowed the study to evaluate whether routine patching therapy was associated with meaningful improvement in acuity and convergence, while also considering the practical challenge of compliance that is commonly reported in amblyopia treatment.

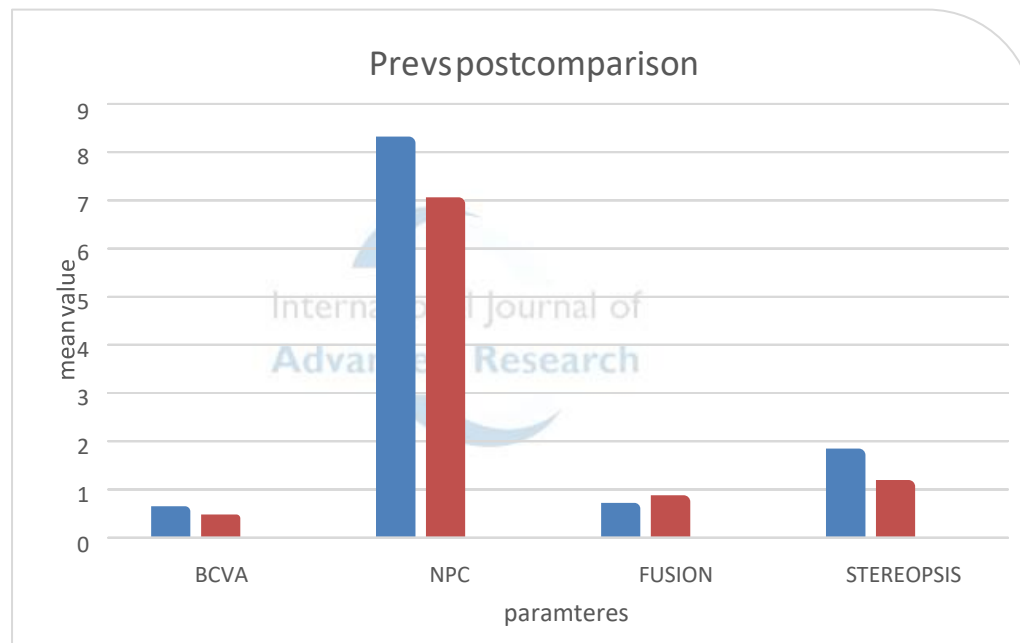
RESULTS

A total of 56 children with unilateral amblyopia were included in the study. The participants were equally distributed by gender, with 28 (50%) males and 28 (50%) females. The majority of participants belonged to the 5–10 years age group (25, 44.6%), followed by the 11–15 years age group (24, 42.9%), while 7 (12.5%) participants were aged 15–18 years.

The Shapiro-Wilk test demonstrated that the continuous variables were not normally distributed ($p < 0.05$). Therefore, the Wilcoxon signed-rank test was used to compare pre- and post-treatment measurements.

Table 1. Comparison of visual outcomes before and after long-term unilateral patching therapy

Outcome Measure	Pre-treatment Mean $\pm$ SD	Post-treatment Mean $\pm$ SD	Test Statistic (Wilcoxon)	p-value
Best Corrected Visual Acuity (LogMAR)	0.65 $\pm$ 0.22	0.48 $\pm$ 0.07	16.14	<0.001
Near Point of Convergence (cm)	8.32 $\pm$ 1.42	7.06 $\pm$ 0.88	15.88	<0.001
Fusion Score	0.72 $\pm$ 0.41	0.88 $\pm$ 0.34	—	0.020
Stereopsis Score	1.85 $\pm$ 0.96	1.20 $\pm$ 0.40	—	0.010



Following long-term unilateral patching therapy, significant improvements were observed in all evaluated visual outcomes. The mean best-corrected visual acuity (BCVA) improved from 0.65 $\pm$ 0.22 LogMAR at baseline to 0.48 $\pm$ 0.07 LogMAR after treatment ($T = 16.14$, $p < 0.001$). Similarly, the mean near point of convergence (NPC) significantly decreased from 8.32 $\pm$ 1.42 cm to 7.06 $\pm$ 0.88 cm ($T = 15.88$, $p < 0.001$), indicating improved convergence ability. Binocular function also improved significantly after treatment. The mean fusion score increased from 0.72 $\pm$ 0.41 to 0.88 $\pm$ 0.34 ($p = 0.02$), while the mean stereopsis score decreased from 1.85 $\pm$ 0.96 to 1.20 $\pm$ 0.40 ($p = 0.01$), reflecting enhanced depth perception.

Descriptive statistics further demonstrated an overall improvement in visual performance following therapy. Pre-treatment BCVA ranged from 0.10 to 0.70 LogMAR, whereas post-treatment BCVA ranged from 0.00 to 0.40 LogMAR. Likewise, NPC values decreased after treatment, and improvements were consistently observed in fusion and stereopsis across the study population.

Overall, unilateral patching therapy resulted in statistically significant improvements in visual acuity, convergence, fusion, and stereopsis, suggesting a positive effect on both monocular and binocular visual function in children with unilateral amblyopia.

DISCUSSION

The results of the current study confirm that extended unilateral occlusion therapy is an effective method of juvenile amblyopia treatment with considerable improvement in visual acuity and binocular visual function. Traditionally, the primary aim of amblyopia treatment has been to enhance visual acuity in the amblyopic eye, however current evidence has established that amblyopia is a condition involving both monocular and binocular dysfunction.(18) Thus, the evaluation of successful treatment should not only include the improvement of visual acuity, but also the recovery of binocular visual function. The considerable improvements noted in best-corrected visual acuity (BCVA), near point of convergence (NPC), fusion, and stereopsis in the current investigation are consistent with this larger view of amblyopia rehabilitation.(19)

The remarkable improvement in BCVA after sustained patching therapy is consistent with earlier research showing that occlusion can decrease cortical suppression from the dominant eye and promote visual activation of the amblyopic eye. The Pediatric Eye Disease Investigator Group (PEDIG) has consistently shown that part-time patching is useful in improving visual acuity in children with mild amblyopia, while prolonged patching may be of extra benefit in selected patients with persistent visual deficiencies. These results reinforce the need for individualizing treatment intensity based on clinical response and monitoring during therapy. The current study's finding of improved visual acuity further supports the ongoing significance of occlusion therapy as the mainstay of amblyopia management.(19-21)

An important finding of this study is the significant improvement in the near point of convergence after treatment. Convergence plays a critical role in maintaining ocular alignment during near visual tasks such as reading and prolonged close work. Children with amblyopia frequently exhibit impaired binocular coordination, suppression, and reduced vergence ability, all of which may compromise visual efficiency during everyday activities. This finding has considerable clinical relevance because many

children continue to experience binocular visual dysfunction despite achieving acceptable visual acuity. Reliance solely on visual acuity measurements may therefore underestimate residual functional deficits.(22, 23)

The superior treatment response in children with shorter disease duration points out the value of early diagnosis and intervention. The enhanced neuroplasticity in early life results in more effective brain restructuring and improves the chances of successful vision recovery. In earlier investigations, earlier treatment initiation has also been related with better improvement in visual acuity and lesser persistence of binocular suppression. These findings underscore the importance of timely vision screening, early referral and fast beginning of treatment to maximize therapeutic outcomes.(24, 25)

Stereopsis also improved significantly after treatment, demonstrating that depth perception improved after occlusion therapy. Recovery of stereopsis is widely seen to be one of the more difficult parts of amblyopia treatment, requiring the restoration of balanced binocular input and higher cerebral processing. The large improvement seen in this study, however, implies that if treatment is begun during the time of visual development that is sensitive and compliance is good, a significant recovery of stereoacuity can be achieved. Similar findings have been found in other studies where the treatment of amblyopia has led to an improvement in stereopsis, especially in children with anisometropic amblyopia and those with considerable improvements in visual acuity. However, the extent to which stereopsis recovers still depends on patient age, subtype of amblyopia, period of visual deprivation, and accompanying ocular abnormalities.(1)

Binocular treatments, virtual reality, perceptual learning, and digital treatment modalities have recently emerged for amblyopia. However, occlusion therapy remains the most validated and widely accepted therapy. Several systematic evaluations have found that developing binocular techniques have shown promising outcomes but have not consistently outperformed traditional patching. Hence, occlusion therapy remains the

main therapeutic technique for pediatric amblyopia according to current clinical practice standards. The current findings extend this statement by demonstrating that extended patching not only improves visual acuity, but also provides measurable improvements in binocular visual function.(13, 21)

The current study has practical implications for rehabilitation sciences and pediatric eye care. Convergence testing is simple, inexpensive, and easy to do in a clinic. Adding it to routine amblyopia assessments could improve clinical decision-making and help identify children who might benefit from extra binocular or orthoptic exercises after patching. It also provides a better way to determine if treatment is genuinely helping the child's visual behavior. This study was quasi-experimental and lacked a randomized control group. Therefore, the findings should be viewed cautiously, as we cannot firmly establish causal relationships. The sample size was small, which may have influenced the strength of the results. Additionally, the study took place at a single center, which limits how broadly we can apply the findings. Longer follow-up in future studies would be helpful to see if the observed improvements last over time.(21, 26).....(27, 28)

CONCLUSION

Prolonged monocular occlusion produced significant improvement in best-corrected visual acuity and convergence in pediatric patients with amblyopia. The findings suggest that patching therapy improves not only monocular visual performance but also binocular sensory integration. This indicates that visual rehabilitation in amblyopia may extend beyond acuity gain to include functional binocular recovery. Earlier intervention appeared to yield better outcomes, highlighting the importance of timely diagnosis and treatment. These results support the clinical value of starting therapy as soon as amblyopia is identified. They also emphasize the need for regular follow-up to monitor both acuity and binocularity changes. Overall, the study reinforces occlusion therapy as

an effective approach for improving visual function in children with amblyopia.

REFERENCES

- Levi DM, Knill DC, Bavelier D. Stereopsis and amblyopia: A mini-review. *Vision Res.* 2015;114:17-30.
- Abraham SV. Accommodation in the amblyopic eye. *Am J Ophthalmol.* 1961;52:197-200.
- Li J, Thompson B, Lam CS, Deng D, Chan LY, Maehara G, et al. The role of suppression in amblyopia. *Invest Ophthalmol Vis Sci.* 2011;52(7):4169-76.
- Levi DM, Klein SA. Spatial localization in normal and amblyopic vision. *Vision Res.* 1983;23(10):1005-17.
- Barrett BT, Bradley A, McGraw PV. Understanding the neural basis of amblyopia. *Neuroscientist.* 2004;10(2):106-17.
- Kelly KR, Jost RM, La Cruz AD, Dao L, Beauchamp CL, Jr. S, et al. Slow reading in children with anisometropic amblyopia is associated with gaze instability and increased saccades. *Journal of American Association for Pediatric Ophthalmology and Strabismus.* 2017;21(4).
- Animali S, Steinwurz C, Dardano A, Sancho-Bornez V, Del Prato S, Morrone MC, et al. Effect of fasting on short-term visual plasticity in adult humans. *Eur J Neurosci.* 2023;57(1):148-62.
- Birch EE. Amblyopia and binocular vision. *Prog Retin Eye Res.* 2013;33:67-84.
- Ciuffreda KJ, Kenyon RV, Stark L. Abnormal saccadic substitution during small-amplitude pursuit tracking in amblyopic eyes. *Invest Ophthalmol Vis Sci.* 1979;18(5):506-16.
- Webber AL. The functional impact of amblyopia. *Clin Exp Optom.* 2018;101(4):443-50.

- Kraus CL, Culican SM. New advances in amblyopia therapy I: binocular therapies and pharmacologic augmentation. *Br J Ophthalmol*. 2018;102(11):1492-6.
- Bai J, Dong X, He S, Bao M. Monocular deprivation of Fourier phase information boosts the deprived eye's dominance during interocular competition but not interocular phase combination. *Neuroscience*. 2017;352:122-30.
- Raveendran RN, Bobier WR, Thompson B. Binocular vision and fixational eye movements. *J Vis*. 2019;19(4):9.
- baom MB, Dong B, Jiang Y. The Best of Both Worlds: Adaptation During Natural Tasks Produces Long-Lasting Plasticity in Perceptual Ocular Dominance. *Association for psychological science*. 2017;29(1).
- Webber AL, Wood JM, Thompson B, Birch EE. From suppression to stereoacuity: a composite binocular function score for clinical research. *Ophthalmic Physiol Opt*. 2019;39(1):53-62.
- Kenyon RV, Ciuffreda KJ, Stark L. Dynamic vergence eye movements in strabismus and amblyopia: asymmetric vergence. *Br J Ophthalmol*. 1981;65(3):167-76.
- Pediatric Eye Disease Investigator G, Wallace DK, Lazar EL, Holmes JM, Repka MX, Cotter SA, et al. A randomized trial of increasing patching for amblyopia. *Ophthalmology*. 2013;120(11):2270-7.
- Wynanski-Jaffe T, Moshkovitz A, Kushner BJ, Belkin M, Yehezkel O, CureSight Pivotal Trial G. Binocular Home Treatment for Amblyopia: Gains Stable for One Year. *Am J Ophthalmol*. 2024;262:199-205.
- Wynanski-Jaffe T, Kushner BJ, Moshkovitz A, Belkin M, Yehezkel O, CureSight Pivotal Trial G. High-Adherence Dichoptic Treatment Versus Patching in Anisometropic and Small Angle Strabismus Amblyopia: A Randomized Controlled Trial. *Am J Ophthalmol*. 2025;269:293-302.
- Kelly KR, Jost RM, Dao L, Beauchamp CL, Leffler JN, Birch EE. Binocular iPad Game vs Patching for Treatment of Amblyopia in Children: A Randomized Clinical Trial. *JAMA Ophthalmol*. 2016;134(12):1402-8.
- Yao J, Moon HW, Qu X. Binocular game versus part-time patching for treatment of anisometropic amblyopia in Chinese children: a randomised clinical trial. *Br J Ophthalmol*. 2020;104(3):369-75.
- Gantz L, Stiebel-Kalish H. Convergence insufficiency: Review of clinical diagnostic signs. *J Optom*. 2022;15(4):256-70.
- Cioplean D, Nitu Raluca L. Age related strabismus. *Rom J Ophthalmol*. 2016;60(2):54-8.
- Poltavski D, Adams RJ, Biberdorf D, Patrie JT. Effectiveness of a Novel Video Game Platform in the Treatment of Pediatric Amblyopia. *J Pediatr Ophthalmol Strabismus*. 2024;61(1):20-9.
- Hussain Z, Webb BS, Astle AT, McGraw PV. Perceptual learning reduces crowding in amblyopia and in the normal periphery. *J Neurosci*. 2012;32(2):474-80.
- Shuai L, Leilei Z, Wen W, Shu W, Gangsheng L, Yinglong L, et al. Binocular treatment in adult amblyopia is based on parvocellular or magnocellular pathway. *European Journal of Ophthalmology*. 2019;30(4).

Babar T, naqvi R, Kiran Q, Ahmed A, Abid A, Sharif A. Effect of Amblyopia on Color Vision and Contrast Sensitivity: A Systematic Review. Journal of Health and Rehabilitation Research. 2024.

Kiran Q, Naeem B, Ashfaq A, Altaf A. Comparison of Developmental Coordination Disorder at Different Levels of Autism in Children. annals of punjab medical college. 2023;17(1).

