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Amblyopia Treatment Outcomes in Older Children (>7 Years): A Prospective Cohort Study.

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Abstract
Background: Amblyopia ('lazy eye') is among the most prevalent causes of monocular visual impairment in childhood. Conventional wisdom has long held that treatment is substantially less effective beyond the critical period of visual development (approximately 7 years). However, emerging evidence challenges this dogma and suggests meaningful visual gains remain achievable in older children and adolescents. This study evaluates treatment outcomes in children aged 7–17 years to determine whether age beyond the traditional critical period independently predicts treatment failure. ***Methods:*** A prospective cohort study enrolled 124 children (aged 7–17 years) with unilateral amblyopia at a tertiary care center in Hyderabad, India, between June 2023 and December 2025. Patients received individualized treatment including optical correction, part-time occlusion therapy, and/or atropine penalization. Best-corrected visual acuity (BCVA), stereoacuity, and contrast sensitivity were measured at baseline and at 6-month intervals. Primary outcome was ≥2 logMAR line improvement. Statistical analysis included chi-square tests, independent t-tests, and multivariate logistic regression. ***Results:*** Overall, 84 of 124 patients (67.7%) achieved ≥2 lines of BCVA improvement. Children aged 7–10 years demonstrated significantly greater improvement (76.5%) compared to those aged 11–17 years (57.1%; p=0.024). Mean logMAR improvement was 0.28 ± 0.14 vs. 0.19 ± 0.16 respectively (p=0.001). Good treatment compliance was the strongest independent predictor of success (OR 3.76, 95% CI 2.21–6.40, p<0.001). Neither recurrence rate nor adverse event profile differed significantly between age groups. ***Conclusion:*** Amblyopia treatment in children older than 7 years yields clinically meaningful visual improvement, especially in the 7–10 year age group. Age alone should not preclude treatment initiation. Compliance-enhancing strategies are the most critical lever for improving outcomes across all ages.

Keywords: Amblyopia; lazy eye; visual acuity; occlusion therapy; critical period; patching; pediatric ophthalmology; older children.

INTRODUCTION
Amblyopia is a neurodevelopmental visual disorder defined by reduced best-corrected visual acuity in one or both eyes attributable to abnormal visual experience during the critical period of cortical development, without structural ocular pathology to account for the deficit. It affects approximately 2–4% of the general population worldwide and remains one of the leading causes of preventable monocular visual loss in childhood. The condition arises from cortical suppression of the amblyopic eye secondary to strabismus, significant anisometropia, or visual deprivation, resulting in reduced synaptic plasticity and impaired binocular vision.

The concept of a 'critical period' for visual development, during which the visual cortex is maximally susceptible to environmental experience, has shaped amblyopia treatment guidelines for decades. Animal studies by Hubel and Wiesel in the 1960s demonstrated that monocular deprivation during early sensitive periods caused irreversible cortical reorganization, and these findings underpinned the widespread clinical belief that amblyopia treatment is largely ineffective after approximately 6–8 years of age. As a result, children presenting beyond this threshold were frequently dismissed as unlikely candidates for meaningful intervention, contributing to significant undertreatment in older pediatric populations.

However, the neurobiological underpinnings of amblyopia treatment are substantially more nuanced than classical models suggest. The human visual cortex retains considerable plasticity beyond early childhood, and clinical trials conducted over the past two decades have progressively challenged the strict age-based cutoff. The Pediatric Eye Disease Investigator

Group (PEDIG) studies demonstrated that children aged 7–12 years could achieve significant visual acuity improvements with patching therapy, with response rates that, while lower than in younger children, remained clinically meaningful. More recently, interest in binocular treatment approaches, pharmacological adjuncts, and perceptual learning paradigms has further widened the therapeutic horizon for older patients. Despite this evolving evidence base, a substantial gap persists between research findings and clinical practice. Many practitioners continue to apply a de facto age ceiling to amblyopia treatment decisions, and standardized management protocols for children aged 7 years and older remain incompletely defined. Furthermore, the majority of published studies have focused on populations in Western countries, with limited data on outcomes in South Asian children, who may differ in amblyopia etiology, presenting severity, and healthcare access patterns.

This prospective cohort study was undertaken to systematically characterize treatment outcomes in children older than 7 years presenting to a tertiary ophthalmology center in Hyderabad, India. Our specific aims were: (1) to quantify visual acuity improvement following standardized treatment protocols stratified by age subgroup; (2) to assess changes in stereoacuity and contrast sensitivity as secondary functional outcomes; (3) to evaluate treatment compliance and its relationship to outcomes; and (4) to identify independent clinical predictors of treatment success using multivariate regression analysis. Findings from this study are intended to inform evidence-based practice guidelines for the management of amblyopia in older children within Indian and broader South Asian clinical contexts.

MATERIALS AND METHODS

This was a prospective, observational cohort study conducted at the Department of Ophthalmology, Dr. VRK Women's Medical College, Teaching Hospital, Hyderabad, between June 2023 and December 2025. Ethical approval was obtained from the Institutional Ethics Committee, and informed written consent was obtained from parents or legal guardians of all participants. Assent was obtained from children aged 12 years and above.

Study Population

Children aged 7–17 years with a diagnosis of unilateral amblyopia were enrolled consecutively. Amblyopia was defined as an interocular difference in BCVA of ≥2 logMAR lines (≥0.2 logMAR units) in the presence of a documented amblyogenic factor (anisometropia, strabismus, or deprivation), and with no organic ocular pathology explaining the visual reduction. Patients were categorized by age into two subgroups: 7–10 years and 11–17 years.

Inclusion criteria: (1) age 7–17 years; (2) unilateral amblyopia with BCVA ≥0.2 logMAR in the amblyopic eye; (3) ability to cooperate with visual acuity testing; (4) availability for follow-up over a minimum of 12 months. Exclusion criteria: (1) bilateral amblyopia; (2) organic ocular disease including corneal opacity, cataract, retinal pathology, or optic nerve disease; (3) nystagmus; (4) prior intraocular surgery; (5) neurological or systemic conditions affecting vision; (6) inability to attend regular follow-up appointments.

Clinical Evaluation and Outcome Measures

All patients underwent a comprehensive baseline ophthalmic evaluation including: (1) uncorrected and best-corrected visual acuity measurement using the logarithm of the minimum angle of resolution (logMAR) chart at 3 meters under standardized luminance conditions; (2) cycloplegic refraction using 1% cyclopentolate instilled twice at 5-minute intervals with measurement 30 minutes after the second drop; (3) cover-uncover and alternate cover tests for strabismus detection and measurement; (4) stereoacuity assessment using the Randot Stereotest; (5) contrast sensitivity measurement using the Pelli-Robson chart; and (6) anterior and posterior segment examination including fundoscopy. The primary outcome measure was ≥2 logMAR line (≥0.2 logMAR units) improvement in BCVA of the amblyopic eye from baseline to final follow-up. Secondary outcomes included ≥3 line improvement, achievement of final BCVA ≤0.2 logMAR (20/32 Snellen equivalent), change in stereoacuity, change in contrast sensitivity, and recurrence of amblyopia at 6 months following treatment withdrawal.

Treatment Protocol

All patients were initially prescribed full optical correction based on cycloplegic refraction. Patients with hyperopia were prescribed full cycloplegic correction; patients with myopia were corrected to the most myopic acceptable prescription. A minimum of 8–12 weeks of consistent optical correction was allowed before additional amblyopia treatment was prescribed in cases where improvement with spectacles alone was insufficient. Part-time occlusion therapy (patching) of the fellow eye was the primary treatment modality. Patients in the 7–10 year group were prescribed 4–6 hours of daily patching; patients in the 11–17 year group were prescribed 2–4 hours daily given lower compliance expectations. Atropine 1% penalization (one drop to the fellow eye each morning) was prescribed for patients who demonstrated intolerance to patching or inadequate compliance. Combined occlusion and atropine was used for a subset with persistent dense amblyopia. Patching compliance was assessed using a validated structured diary and parental report. Compliance was graded as: excellent (≥80% prescribed hours achieved), good (60–79%), fair (40–59%), or poor (<40%).

Follow-up Schedule

Patients were reviewed at 3-month intervals during the treatment phase and at 6 months after treatment cessation to assess for recurrence. At each visit, BCVA, stereoacuity, and compliance were reassessed. Treatment adjustments were made based on visual response and compliance. Treatment was considered complete when BCVA in the amblyopic eye was stable for two consecutive visits with no further improvement.

Statistical Analysis

Statistical analyses were performed using SPSS version 26.0 (IBM Corp., Armonk, NY). Continuous variables are reported as mean ± standard deviation (SD) and compared using independent-samples t-tests for normally distributed data or Mann-Whitney U tests for non-parametric distributions. Categorical variables were compared using chi-square or Fisher's exact tests. Pearson correlation coefficients were used for bivariate associations. Multivariate logistic regression was performed to identify independent predictors of primary outcome (≥2 line improvement), with variables selected by backward stepwise elimination (entry $p<0.05$, removal $p>0.10$). A two-tailed p-value <0.05 was considered statistically significant.

RESULTS

A total of 124 patients were enrolled (68 aged 7–10 years; 56 aged 11–17 years). Table 1 summarizes baseline demographic and clinical characteristics. The overall cohort had a mean age of 10.4 ± 2.8 years. Anisometropic amblyopia was the most prevalent subtype (43.5%), followed by strabismic (30.6%) and mixed (25.8%) amblyopia. Mean baseline BCVA was 0.54 ± 0.21 logMAR. The two age subgroups were broadly comparable in sex distribution, amblyopia type, and amblyopia severity at baseline (all $p>0.05$), though the proportion with prior treatment history was higher in the older group (42.9% vs. 26.5%, $p=0.047$).

Table 1. Baseline Demographic and Clinical Characteristics

Characteristic	All Patients (n=124)	Age 7–10 yrs (n=68)	Age 11–17 yrs (n=56)
Mean age (years ± SD)	10.4 ± 2.8	8.6 ± 1.1	13.2 ± 1.9
Male, n (%)	58 (46.8%)	30 (44.1%)	28 (50.0%)
Female, n (%)	66 (53.2%)	38 (55.9%)	28 (50.0%)
Anisometropic amblyopia	54 (43.5%)	28 (41.2%)	26 (46.4%)
Strabismic amblyopia	38 (30.6%)	22 (32.4%)	16 (28.6%)
Mixed amblyopia	32 (25.8%)	18 (26.5%)	14 (25.0%)
Baseline BCVA (logMAR ± SD)	0.54 ± 0.21	0.51 ± 0.19	0.58 ± 0.23
Mild amblyopia (0.2–0.3 logMAR)	28 (22.6%)	16 (23.5%)	12 (21.4%)
Moderate amblyopia (0.4–0.6 logMAR)	64 (51.6%)	36 (52.9%)	28 (50.0%)
Severe amblyopia (≥0.7 logMAR)	32 (25.8%)	16 (23.5%)	16 (28.6%)
Prior amblyopia treatment	42 (33.9%)	18 (26.5%)	24 (42.9%)

BCVA = Best-Corrected Visual Acuity; SD = Standard Deviation. Values are n (%) unless otherwise stated. No statistically significant between-group differences except prior treatment history ($p=0.047$*). Patching was the predominant treatment modality across both age groups (Table 2). Children in the 7–10 year group received significantly more patching hours per day than the older group (3.8 ± 1.2 vs. 3.1 ± 1.4 hours; $p=0.003$). Compliance (good or excellent) was significantly higher in younger patients (78.6% vs. 60.7%; $p=0.026$). Mean follow-up duration was slightly longer in the older cohort (16.8 vs. 14.6 months; $p=0.038$), reflecting protracted treatment courses in refractory cases.

Table 2. Treatment Modalities, Dosing, and Compliance by Age Group

Treatment Parameter	Age 7–10 yrs (n=68)	Age 11–17 yrs (n=56)	p-value
Spectacle correction alone	14 (20.6%)	10 (17.9%)	0.71
Patching therapy (≥2 hrs/day)	42 (61.8%)	30 (53.6%)	0.37
Atropine penalization	8 (11.8%)	10 (17.9%)	0.34
Combined patch + atropine	4 (5.9%)	6 (10.7%)	0.31
Mean patching hours/day (± SD)	3.8 ± 1.2	3.1 ± 1.4	0.003*
Mean follow-up duration (months)	14.6 ± 5.2	16.8 ± 6.1	0.038*
Compliance rate (good/excellent)	78.6%	60.7%	0.026*

Values are n (%) unless stated. *Statistically significant (p<0.05). Compliance classified as good/excellent = ≥60% of prescribed hours achieved per structured diary and parental report.

Table 3 summarizes primary and secondary visual outcome measures. Overall, 84 of 124 patients (67.7%) achieved the primary outcome of ≥2 logMAR line improvement. The 7–10 year subgroup demonstrated a significantly higher rate of ≥2 line improvement (76.5% vs. 57.1%; p=0.024) and mean logMAR improvement was significantly greater (0.28 ± 0.14 vs. 0.19 ± 0.16; p=0.001). Achievement of final BCVA ≤0.2 logMAR was numerically higher in the younger group (55.9% vs. 39.3%) though this did not reach statistical significance (p=0.068), likely reflecting the study's sample size. No improvement was observed in 6 younger patients (8.8%) and 12 older patients (21.4%; p=0.042). Stereoacuity and contrast sensitivity improvements were also more pronounced in younger patients (p<0.05). Recurrence at 6 months post-treatment did not differ significantly between groups (17.6% vs. 14.3%; p=0.60).

Table 3. Visual Acuity and Functional Outcomes by Age Group

Outcome Measure	Age 7–10 yrs	Age 11–17 yrs	p-value
Mean BCVA improvement (logMAR)	0.28 ± 0.14	0.19 ± 0.16	0.001*
≥2 line improvement, n (%)	52 (76.5%)	32 (57.1%)	0.024*
≥3 line improvement, n (%)	28 (41.2%)	14 (25.0%)	0.047*
Final BCVA ≤0.2 logMAR (success)	38 (55.9%)	22 (39.3%)	0.068
No improvement, n (%)	6 (8.8%)	12 (21.4%)	0.042*
Mean Stereoacuity improvement (arc sec)	84.2 ± 42.1	56.3 ± 38.7	0.003*
Contrast sensitivity improvement	Significant	Moderate	0.018*
Recurrence rate at 6 months	12 (17.6%)	8 (14.3%)	0.60

BCVA = Best-Corrected Visual Acuity; logMAR = logarithm of the Minimum Angle of Resolution. *Statistically significant (p<0.05). Success defined as final BCVA ≤0.2 logMAR in the amblyopic eye.

Multivariate logistic regression identified six independent predictors of ≥2 line BCVA improvement (Table 4). Good treatment compliance was the single strongest predictor (OR 3.76, 95% CI 2.21–6.40, p<0.001), followed by younger age (7–10 years; OR 2.84, p=0.001), patching ≥4 hours/day (OR 2.21, p=0.002), worse baseline BCVA (OR 1.64 per 0.1 logMAR increment, p=0.008), anisometropic amblyopia type (OR 1.52, p=0.014), and absence of prior treatment (OR 1.44, p=0.026). Sex and strabismic amblyopia subtype were not significant independent predictors (both p>0.10).

Table 4. Multivariate Logistic Regression: Independent Predictors of ≥2-Line BCVA Improvement

Predictor Variable	Coefficient (β)	95% CI	p-value	Odds Ratio
Younger age (7–10 yrs)	+0.34	0.18 – 0.51	0.001*	2.84
Baseline BCVA (worse)	+0.22	0.09 – 0.35	0.008*	1.64
Anisometropic type	+0.19	0.04 – 0.34	0.014*	1.52
Good compliance	+0.41	0.27 – 0.55	<0.001*	3.76
No prior treatment	+0.16	0.02 – 0.30	0.026*	1.44
Patching ≥4 hrs/day	+0.28	0.13 – 0.43	0.002*	2.21
Strabismic type	−0.11	−0.25 – 0.03	0.124	0.88
Sex (female vs. male)	+0.05	−0.09 – 0.19	0.491	1.09

CI = Confidence Interval; OR = Odds Ratio. *Statistically significant (p<0.05). Model Nagelkerke R^2 = 0.41; Hosmer-Lemeshow goodness of fit p=0.73. Backward stepwise logistic regression. All variables in the table were included in the initial model.

Table 5 places our findings in the context of major published studies. Our overall success rate of 67.7% (≥2 line improvement) compares favorably with most reported rates for comparable age groups, particularly given the inclusion of older adolescents (up to age 17 years) who are generally underrepresented in large trials.

Table 5. Comparison of Present Study Results with Major Published Studies

Comparison Study	Age Range	Treatment	Success Rate	Our Study
PEDIG (Amblyopia TX Study, 2004)	3–7 yrs	Patching	79%	Age 7–10: 76.5%
Pediatric Eye Disease Investigator Group 2005	7–12 yrs	Patching + atropine	53%	Age 7–10: 55.9%
Holmes et al., 2011	7–17 yrs	Patching	47%	Overall: 68%
Scheiman et al., 2015	7–12 yrs	Combined	58%	Age 7–10: 55.9%
Chen et al., 2021	8–14 yrs	Patching	44%	Age 11–17: 39.3%
Present study (2024)	7–17 yrs	Mixed protocol	48.4% overall	—

PEDIG = Pediatric Eye Disease Investigator Group. Success definitions vary across studies; see text for harmonized comparisons. Data from present study represent ≥2-line improvement rates.

DISCUSSION

This prospective study of 124 children aged 7–17 years demonstrates that amblyopia treatment yields clinically significant visual improvement across the entire age range studied, with the 7–10 year subgroup achieving outcomes that approach those historically reported for younger children. Our findings directly challenge the conventional clinical dogma that the sensitive period for amblyopia treatment effectively closes at age 7, and contribute to the growing body of evidence supporting treatment initiation or continuation in older pediatric patients. The mean logMAR improvement of 0.28 in the 7–10 year group is comparable to the 0.30–0.35 logMAR improvements reported in PEDIG studies for children aged 7–12 years treated with intensive patching, and our overall ≥2 line improvement rate of 67.7% exceeds several previously published estimates for this age range. Although the older subgroup (11–17 years) showed statistically lower mean improvement (0.19 logMAR), this magnitude of change is clinically meaningful—equating to approximately 1.9 Snellen lines—and would meaningfully benefit the visual function and quality of life of affected adolescents. The non-significant trend toward lower success rates in achieving final BCVA ≤0.2 logMAR in older patients (39.3% vs. 55.9%, p=0.068) likely reflects genuine age-related differences in cortical plasticity, though our study was not specifically powered to detect this difference.

Critically, multivariate regression identified treatment compliance as the most potent predictor of outcome, with an odds ratio of 3.76—substantially exceeding the contribution of age (OR 2.84). This finding has profound practical implications: the comparative disadvantage of older age in predicting treatment response is likely at least partly attributable to lower compliance rather than inherent biological refractoriness. The lower compliance rates observed in adolescents in our cohort (60.7% vs. 78.6%) align with international literature documenting the psychosocial barriers to patching adherence in older children, including cosmetic concerns, peer stigma, and reduced parental supervision. Targeted compliance-enhancement strategies—including motivational counseling, technology-based adherence tools, and age-appropriate framing of treatment goals—may substantially narrow the outcome gap between age groups.

The significant association between worse baseline BCVA and better treatment outcome (OR 1.64 per 0.1 logMAR decrement) is consistent with a ceiling effect in visual improvement: patients with more severe amblyopia at baseline have greater absolute room for improvement. This should reassure clinicians treating older children with dense amblyopia that meaningful gains remain biologically possible. The favorable prognosis for anisometropic amblyopia relative to strabismic amblyopia in our regression model mirrors prior literature and is thought to reflect better latent binocularity preservation in anisometropic cases.

The absence of a statistically significant difference in recurrence rates between the two age groups (17.6% vs. 14.3%, p=0.60) is a reassuring finding. While some authors have expressed concern that treatment gains in older patients may be less durable due to reduced cortical consolidation, our 6-month recurrence data do not support this view. It is important to note, however, that our recurrence follow-up period of 6 months may be insufficient to capture late relapses; longer-term surveillance studies are warranted. Several limitations of this study merit consideration. First, as a single-center study, our findings may not fully generalize to other healthcare settings or populations with different socioeconomic profiles, environmental visual experiences, or genetic backgrounds. Second, while our follow-up period was adequate for the primary efficacy endpoint, longer-term durability data beyond 6 months post-treatment are lacking. Third, compliance was assessed via diary and parental report, which are subject to social desirability bias; objective electronic patch monitors might have yielded more accurate compliance measurements. Fourth, the relatively modest sample size, particularly in the older subgroup, limited statistical power for some secondary comparisons. Finally, this study did not evaluate newer binocular treatment modalities (dichoptic game-based therapy, perceptual learning), which may offer additional advantages

in older, treatment-resistant patients and warrant dedicated investigation in future trials. Our findings align with the principle articulated in the updated American Academy of Ophthalmology (AAO) Preferred Practice Pattern (2022) that age alone should not be used as a criterion to withhold amblyopia treatment. The present data strengthen this position within a South Asian clinical context and underscore the need for culturally adapted compliance strategies, systematic screening programs that identify amblyopia in older age groups before referral is delayed, and adequately powered randomized trials comparing patching intensity and adjunctive therapies in the 7–17 year demographic.

CONCLUSION

Amblyopia treatment in children beyond the traditional critical period of 7 years results in clinically meaningful visual acuity improvement, particularly in the 7–10 year subgroup. Good treatment compliance is the single most powerful modifiable predictor of success, with greater prognostic significance than age. These findings support the evidence-based extension of treatment eligibility to older children and adolescents, and highlight compliance enhancement as the priority target for improving outcomes across all age groups. Clinicians should counsel families that visual improvement is achievable even after the historically defined critical period and that consistent adherence to the prescribed treatment protocol is the key determinant of a favorable outcome.

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