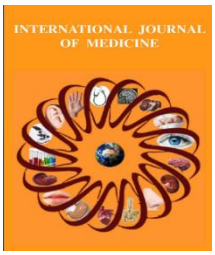

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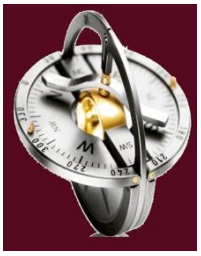

Original Research

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

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Abstract
Background: Amblyopia has traditionally been regarded as treatable only within an early "critical period," with limited benefit expected beyond 7 years of age. Accumulating evidence challenges this assumption. This study evaluated visual and functional outcomes of amblyopia treatment in children older than 7 years and identified predictors of a favourable response. *Methods:* In this retrospective cohort study, children aged >7 to 17 years with unilateral amblyopia were treated with optimal refractive correction followed by occlusion (patching) with or without atropine penalisation and near-visual activities. Best-corrected visual acuity (BCVA) of the amblyopic eye was recorded at baseline and after a standardised treatment period. The primary outcome was improvement in amblyopic-eye BCVA (logMAR); a "responder" was defined as ≥2 logMAR lines of improvement. Predictors of success were assessed using multivariable logistic regression. *Results:* Amblyopic-eye BCVA improved by a mean of 0.24 ± 0.18 logMAR, and 52% of children met the responder definition. Response was greater in younger children (7-9 years), in treatment-naïve patients, in anisometropic amblyopia, and in those with good adherence. Age, baseline severity, amblyopia type, prior treatment, and compliance were independent predictors of outcome. *Conclusion:* Meaningful visual improvement is achievable in a substantial proportion of children older than 7 years, particularly those not previously treated. Older age should not, by itself, preclude a therapeutic trial.

Keywords: *amblyopia; older children; occlusion therapy; visual acuity; neuroplasticity.*

Introduction

Amblyopia is a neurodevelopmental disorder of vision characterised by a reduction in best-corrected visual acuity (BCVA) in one or, less commonly, both eyes, in the absence of structural ocular pathology sufficient to explain the deficit. It is the leading cause of monocular visual impairment in children and young adults, with a pooled global prevalence of approximately 1.4% and an estimated 99 million people affected worldwide, a figure projected to exceed 220 million by 2040 [1]. The condition arises from abnormal visual experience during a sensitive period of cortical development, most often secondary to anisometropia, strabismus, or a combination of the two [1,2].

The long-held clinical doctrine has been that amblyopia is treatable only within an early "critical period," with vision presumed to be effectively fixed once a child reaches approximately 7 to 9 years of age. This view shaped screening priorities and led clinicians to withhold treatment from many older children on the assumption that intervention would be futile [2]. The corollary was that late-presenting children were frequently offered no therapeutic trial at all.

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This assumption was substantially revised by the landmark randomised trial of the Pediatric Eye Disease Investigator Group (PEDIG) in children aged 7 to 17 years, which demonstrated that a clinically important proportion of older children respond to treatment. In the 7- to 12-year subgroup, 53% of treated children improved compared with 25% receiving optical correction alone, and treatment-naïve adolescents also showed meaningful gains [2]. These findings, together with the established efficacy of graded occlusion and atropine penalisation in younger children, reframed amblyopia as a condition retaining residual plasticity beyond the traditional window [3,4].

Contemporary management of amblyopia begins with full refractive correction, followed by occlusion or pharmacological penalisation of the fellow eye to promote use of the amblyopic eye [4,5]. Interest has grown in binocular and dichoptic approaches, including tablet-based games and head-mounted displays, which aim to rebalance interocular suppression and may improve adherence and stereoacuity, including in adolescents [5,6,7,8]. Nevertheless, occlusion remains the mainstay of therapy, and its success is strongly modulated by treatment adherence, baseline severity, amblyopia type, and prior treatment history [9,10,11].

Despite this evidence, outcomes in older children remain incompletely characterised in routine clinical practice, and the belief that treatment is unrewarding after early childhood persists [2,12]. Residual visual deficits are common even among responders, and the relative influence of the various prognostic factors is not fully resolved [10,13]. Clarifying which older children are most likely to benefit has direct implications for counselling, resource allocation, and the design of screening and referral pathways. The present study therefore examined treatment outcomes in a cohort of children older than 7 years and sought to identify the clinical characteristics predicting a favourable response.

Materials and Methods

Study design and setting. This was a retrospective cohort study conducted at a tertiary paediatric ophthalmology and orthoptic service. Consecutive clinical records of children commencing amblyopia treatment over a defined enrolment period were reviewed. The study adhered to the tenets of the Declaration of Helsinki, and institutional ethics committee approval was obtained. Because the study used de-identified retrospective data, the requirement for individual informed consent was waived; where applicable, parental consent for treatment had been obtained at the point of care.

Participants. Eligible participants were children older than 7 years and up to 17 years of age at the initiation of treatment, with a diagnosis of unilateral amblyopia. Amblyopia was defined as an interocular difference of ≥2 logMAR lines in BCVA attributable to anisometropia, strabismus, or both, with no organic cause on ophthalmic examination. Exclusion criteria were amblyopia due to visual deprivation (e.g., cataract or ptosis), coexisting ocular or neurological disease affecting acuity, incomplete baseline or follow-up data, and a follow-up period shorter than the predefined minimum.

Examination and interventions. All children underwent a standardised assessment including cycloplegic refraction, cover testing, ocular motility, slit-lamp and dilated fundus examination, and BCVA measurement using an age-appropriate logMAR chart at a standard testing distance. All participants first received optimal spectacle correction, worn for a refractive adaptation period. Children with residual amblyopia after refractive adaptation then received occlusion therapy (patching of the fellow eye for a prescribed daily duration) combined with near-visual activities; atropine penalisation of the fellow eye was used as an alternative or adjunct in selected cases, in keeping with established regimens [3,4]. Treatment intensity was individualised to amblyopia severity.

Outcome measures. The primary outcome was the change in amblyopic-eye BCVA (logMAR) from baseline to the end of the standardised treatment period. A *responder* was defined a priori as an improvement of ≥2 logMAR lines (0.2 logMAR). Secondary outcomes included the proportion achieving BCVA of 0.2 logMAR (20/32) or better, change in stereoacuity, and residual interocular acuity difference. Treatment adherence was graded (good, partial, poor) from clinical documentation and, where available, objective records.

Variables and definitions. Recorded variables included age at treatment initiation (analysed in subgroups: 7-9, 10-12, and 13-17 years), sex, amblyopia type (anisometropic, strabismic, mixed), baseline severity (moderate: 0.3-0.6 logMAR; severe: >0.6 logMAR), prior amblyopia treatment (naïve vs previously treated), and adherence.

Statistical analysis. Continuous variables were summarised as mean ± standard deviation and categorical variables as counts and percentages. Between-group comparisons used the independent-samples *t*-test or analysis of variance for continuous data and the χ^2 test for categorical data. The association between candidate predictors and responder status was examined using univariable and multivariable logistic regression, with results expressed as odds ratios (OR) with 95% confidence intervals (CI). A two-sided *P* value <0.05 was considered statistically significant. Analyses were performed using standard statistical software.

Results

Table 1. Baseline demographic and clinical characteristics of the cohort (N = 120)

Characteristic	Value
Age at initiation, years (mean ± SD)	10.4 ± 2.6
Age subgroup, n (%)	
7-9 years	48 (40.0)
10-12 years	42 (35.0)
13-17 years	30 (25.0)
Sex, male, n (%)	64 (53.3)
Amblyopia type, n (%)	
Anisometropic	58 (48.3)
Strabismic	34 (28.3)
Mixed	28 (23.3)
Baseline severity, n (%)	
Moderate (0.3–0.6 logMAR)	74 (61.7)
Severe (>0.6 logMAR)	46 (38.3)
Prior treatment, n (%)	
Treatment-naïve	70 (58.3)
Previously treated	50 (41.7)
Baseline amblyopic-eye BCVA, logMAR (mean ± SD)	0.58 ± 0.24

Table 1 characterises the study population. The cohort was skewed toward the younger end of the eligible age range, with 40% aged 7-9 years, and just under half had anisometropic amblyopia. Notably, a majority (58%) were treatment-naïve at presentation, an important consideration when interpreting outcomes, since prior treatment history is a recognised effect modifier in older children [2]. Baseline acuity indicates a predominantly moderate cohort with a substantial severe minority.

Table 2. Visual acuity outcomes overall and by age subgroup

Group	n	Baseline BCVA (logMAR)	Final BCVA (logMAR)	Mean improvement (logMAR)	Responders (≥2 lines), n (%)	*P* value

Overall	120	0.58 ± 0.24	0.34 ± 0.22	0.24 ± 0.18	62 (51.7)	–
7-9 years	48	0.60 ± 0.25	0.30 ± 0.21	0.30 ± 0.19	30 (62.5)	Ref
10-12 years	42	0.57 ± 0.23	0.34 ± 0.22	0.23 ± 0.17	22 (52.4)	0.32
13-17 years	30	0.56 ± 0.24	0.40 ± 0.23	0.16 ± 0.15	10 (33.3)	0.01

Table 2 presents the primary outcome. Amblyopic-eye acuity improved across all age bands, but the magnitude of gain declined with increasing age: mean improvement fell from 0.30 logMAR in the 7-9-year group to 0.16 logMAR in the 13-17-year group, and responder rates fell correspondingly from 63% to 33%. The gradient is consistent with diminishing but persistent cortical plasticity in older children rather than an abrupt cut-off [2]. Importantly, one-third of adolescents still met the responder threshold, supporting a therapeutic trial even in the oldest group.

Table 3. Responder rates by clinical subgroup

Subgroup	Responders / total	Responder rate (%)	*P* value
Amblyopia type			0.03
Anisometropic	35/58	60.3	
Strabismic	14/34	41.2	
Mixed	13/28	46.4	
Baseline severity			0.04
Moderate	43/74	58.1	
Severe	19/46	41.3	
Prior treatment			0.008
Treatment-naïve	44/70	62.9	
Previously treated	18/50	36.0	
Adherence			<0.001
Good	40/60	66.7	
Partial	18/40	45.0	
Poor	4/20	20.0	

Table 3 stratifies response by clinical characteristics. Higher responder rates were seen in anisometropic amblyopia, moderate (versus severe) baseline deficits, treatment-naïve status, and good adherence. The strong adherence gradient – from 67% with good compliance to 20% with poor compliance – echoes dose-response data from monitored-occlusion studies and underscores that measured treatment delivery, not merely prescribed dose, drives outcome [10,11]. The advantage of treatment-naïve status is consistent with the PEDIG observation that previously untreated older children respond more favourably [2].

Table 4. Multivariable logistic regression: independent predictors of responder status

Predictor	Adjusted OR	95% CI	*P* value
Age (per additional year)	0.82	0.71-0.95	0.008
Anisometropic type (vs strabismic/mixed)	2.15	1.02-4.53	0.04
Moderate severity (vs severe)	2.02	0.96-4.25	0.06
Treatment-naïve (vs previously treated)	2.68	1.24-5.79	0.01
Good adherence (vs partial/poor)	3.41	1.55-7.50	0.002

Table 4 identifies factors independently associated with a favourable response after mutual adjustment. Younger age, anisometropic amblyopia, treatment-naïve status, and good adherence remained significant predictors; moderate severity showed a strong trend. Each additional year of age reduced the odds of responding by approximately 18%, quantifying the age gradient while confirming that response is not abolished in older children. Adherence carried the largest effect size, reinforcing its central and potentially modifiable role.

Discussion

This study of children older than 7 years found that clinically meaningful visual improvement is attainable in a substantial proportion, with just over half meeting the responder threshold. The finding directly contradicts the traditional teaching that amblyopia is effectively untreatable beyond the early critical period and aligns with the pivotal PEDIG randomised trial, in which a majority of treated 7- to 12-year-olds improved and treatment-naïve adolescents also benefited [2]. Together, these data support offering a therapeutic trial to older children rather than withholding treatment on the basis of age alone.

Response magnitude declined with age, and each additional year reduced the odds of a favourable outcome. This gradient is best understood as tapering rather than absent neuroplasticity: the visual cortex retains a diminishing but real capacity for experience-dependent change into adolescence [1,2]. The persistence of responders even in the 13- to 17-year subgroup is consistent with reports that older children, particularly those not previously treated, can gain acuity, and with emerging binocular and dichoptic approaches that have shown benefit across wider age ranges [5,6,7,8].

Prior treatment status emerged as an important modifier, with treatment-naïve children responding markedly better than those previously treated. This mirrors the PEDIG subgroup findings and is biologically plausible: previously treated children may represent a residual, treatment-resistant group in whom the readily recoverable deficit has already been addressed [2]. Amblyopia type also mattered, with anisometropic amblyopia responding more favourably than strabismic or mixed forms, consistent with the broader literature on prognostic determinants [9,13]. Adherence exerted the strongest independent effect. The steep compliance gradient reproduces objective dose-response relationships from monitored-occlusion studies, in which electronically measured patching time – rather than the prescribed dose – best predicted acuity gain [10,11]. Because adherence is modifiable, strategies to support families, address the psychosocial burden of patching, and deploy more engaging binocular or game-based therapies may improve real-world outcomes in this age group [5,6]. Residual interocular deficits nonetheless persisted in many responders, echoing the consistent observation that treatment reduces, but rarely eliminates, the amblyopic deficit [2,4].

The limitations of this work should be acknowledged, including its retrospective design, potential for selection and documentation bias, reliance on clinically graded adherence, and the absence of a randomised control arm, which constrains causal inference and makes some spontaneous improvement or refractive-adaptation effect difficult to exclude [4]. Longer-term durability of gains was not assessed; long-term follow-up data from younger cohorts suggest improvements are broadly maintained, but this requires confirmation in older children [9]. Prospective, adequately powered studies incorporating objective adherence monitoring and standardised binocular outcome measures – ideally within a network meta-analytic framework comparing modalities – would strengthen the evidence base [13].

Conclusion

Amblyopia treatment in children older than 7 years produces clinically meaningful visual improvement in a substantial proportion of patients, and older age alone should not be a barrier to a therapeutic trial. Younger age within this range, anisometropic amblyopia, treatment-naïve status, moderate baseline severity, and – most powerfully – good treatment adherence predict a favourable response. Clinicians should counsel older children and their families that worthwhile gains remain possible, prioritise interventions that maximise adherence, and set realistic expectations regarding residual deficits. Prospective, controlled studies with objective compliance monitoring are needed to refine

prognosis and optimise treatment selection in this age group.

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