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Case Reports

Case Report: Novel Use of a Variable Neutral-Density Filter in Vision Therapy for Exotropia with Deep Suppression

Chak Yin, Charles Li, MClinOptom, FAAO[1][a]

[1] PolyVision Eyecare Center

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Introduction

Suppression is a common sensory adaptation in exotropia and may limit the recovery of fusion during vision therapy. However, simple clinical methods for grading suppression continuously and modifying interocular suppression during office-based vision therapy are limited. This case report describes the novel use of a variable neutral-density filter as both a diagnostic and therapeutic adjunct in the management of exotropia.

Case Report

An 8-year-old girl presented with worsening left exotropia. Examination showed 20/20 visual acuity in each eye, constant left exotropia measuring 50Δ at distance and 55Δ at near, and left eye suppression on Worth 4-dot testing across all distances and lighting conditions. A variable neutral-density filter was placed in front of the dominant right eye to reduce luminance in a graded manner. At an optical density of 0.6 log units, pathological diplopia was elicited at near with Worth 4-dot testing, and the patient achieved a near point of convergence of 20 cm. The filter was then incorporated into office-based vision therapy to facilitate sensory rebalancing, reduce suppression, and make earlier convergence training possible. Over 12 sessions, binocular stability was achieved without luminance attenuation. The final findings show well-controlled exodeviation, elimination of suppression on Worth 4-dot testing, recovery of global and local stereopsis, and improved fusional vergence reserves.

Conclusion

A variable neutral-density filter may be a practical, low-cost adjunct for treating deep suppression in exotropia. It allows continuous suppression grading, reduces reliance on multiple therapy tools, and enables earlier convergence training in patients with significant suppression.

INTRODUCTION

When 2 dissimilar visual stimuli are presented to each eye, the visual system may adapt by suppressing input from one eye to avoid perceptual conflict. In children with poorly controlled intermittent exotropia, this sensory adaptation often occurs, preventing diplopia.[1,2] Current nonsurgical therapies, including patching[3] and binocular vision training,[4,5] have demonstrated success in improving control of exodeviation. One of the therapeutic goals in these approaches is to remediate suppression, as persistent suppression may hinder the recovery of fusion and binocular stability.

Despite the importance of managing suppression in exotropia patients, there remains a lack of simple clinical tools that allow clinicians to modulate suppression in a graded manner during office-based therapy. Standard tests, such as the Worth 4-dot test, red lens test, and Bagolini test, are well-established clinically for detecting suppression, yet they offer limited insight into its depth. When encountering deep suppression, clinicians often toggle room illumination to break suppression. However, these methods only yield a binary suppression status (present/absent) under either bright or dim lighting conditions.[6] Moreover, the abrupt luminance shift may unintentionally reduce latency and lead to an inaccurate overestimation of binocular sta-

a Corresponding Author: Chak Yin, Charles Li, lichakyin0526@gmail.com

bility.[7] To better estimate the suppression severity, specialized filters, such as 10-step neutral-density filters[8] and Sbisa bars,[9] are reportedly utilized in discrete steps rather than along a continuous scale.

When managing patients with manifest exotropia, pathological diplopia awareness training is important. In practice, however, this often requires simultaneous adjustments to several parameters, including room illumination, the use of filters, and changes in target size or contrast. A simple clinical tool that could both alter interocular luminance in a wide continuous range and directly regulate its level during therapy would be very desirable. Such an approach could streamline therapeutic management and potentially make vision training more efficient for patients with deep suppression.

This case report describes the novel use of a variable neutral-density filter as both a diagnostic and therapeutic tool for vision training in a child with intermittent exotropia and deep suppression. By progressively reducing the luminance reaching the dominant eye, the filter can lessen interocular imbalance and enhance binocular participation during both assessment and training. This approach facilitated the vision training process, with clinically and subjectively satisfactory ocular alignment for both the patient and the parents, achieved after 12 sessions—fewer than the more typical 20–25 sessions reported in office-based vision therapy.[10]

CASE REPORT

INITIAL VISIT

An 8-year-old girl presented to the binocular vision clinic with a history of worsening left eye exotropia over the past 6 months. According to her parents, they had first noticed an outward deviation of the left eye at approximately 3–4 years of age, during which time the eye was reportedly deviated for 70%–80% of waking hours. She had previously been evaluated by both ophthalmologists and optometrists; however, no treatment was initiated because they reported that amblyopia was not present.

Her parents reported that she was born full-term via cesarean delivery, with unremarkable systemic and developmental histories. There was no history of long-term medication use or prior ocular surgery. However, regarding the recent increase in the magnitude of the exodeviation, particularly over the preceding months, her parents were concerned about cosmetic appearance and sought consultation regarding the potential role of vision therapy.

The unaided entrance visual acuity was 20/20 in each eye. Worth 4-dot testing demonstrated suppression in the left eye across all distances and lighting conditions. Pupils were equal, round, reactive, and had no relative afferent pupillary defect. Extraocular motilities and confrontation fields were full in both eyes and no A/V pattern was found. Retinoscopy and subjective refraction revealed right eye +0.25 and left eye plano. The binocular vision evaluation revealed constant left exotropia at both distance and near, graded by the Intermittent Exotropia Control Score (level 5).[11] An alternating cover test, neutralized by the Fresnel prism over the subjective refraction, showed 50Δ exotropia at distance and 55Δ exotropia at near. The synoptophore (first-degree targets Ex and square were used) confirmed equality of the subjective and objective angles at 50Δ Base-in, indicating normal retinal correspondence.

The monocular accommodation amplitudes of the right and left eyes were 20 D. Accommodation facility with ±2.00 D was 18 cycles per minute in the right eye and 16 cycles per minute in the left eye. No binocular accommodative facility was attempted due to manifest exotropia. The calculated accommodation-convergence/accommodation ratio was 3.75/1.

Even with an additional −3.00 D lens at near, she was unable to achieve gross convergence at near. Stereopsis was further evaluated using the Random Dot 2-S Stereo Acuity Test (Vision Assessment Corporation, United States) in conjunction with the −3.00 D lens. However, no local and global stereopsis could be elicited. In addition to conventional binocular vision testing, a variable neutral-density filter (Shenzhen Shixin Trading Company, China) was used to assess the depth of suppression (Figure 1).

Variable neutral-density filters used by professional photographers consist of 2 stacked linear polarizers. The reduction in luminance when one polarizer rotates relative to the other is governed by Malus' Law:

$$I = I_0 \cos 2(\theta)$$

Where:

- I = The resultant intensity of light passing through the polarizers.
- I_0= The initial intensity of light passing through the first polarizer.
- θ = The angle between the transmission axes of the 2 polarizers.

In optometry, filter strength is often expressed as optical density, the negative logarithm of transmittance. Transmittance is defined as $T = \frac{I}{I_0}$.

By substituting Malus' Law into the density formula, the following table provides a conversion from the angle of rotation in the trial frame to the equivalent optical density used in a clinical setting (Table 1). The values reported in Table 1 are at discrete 10-degree increments to demonstrate the progression of transmittance or optical density. However, the filter can be adjusted to present any degree between 0 and 90.

Given that the patient exhibited constant suppression on previous Worth 4-dot testing, a variable neutral-density filter was placed in front of the fixating right eye, and the test was re-performed. In the presence of manifest exotropia, she was asked to report the number of dots perceived at 40 cm with the light off. The optical density of the filter was then gradually increased. At 60° of rotation (approximately 0.6 log unit of attenuation), she reported pathological diplopia (perception of crossed 5 dots).

To further evaluate if stereopsis could be elicited under altered interocular luminance conditions, a −3.00 D lens was placed in front of both eyes, and the filter was rotated to 60° in front of the right eye. Under these conditions, the

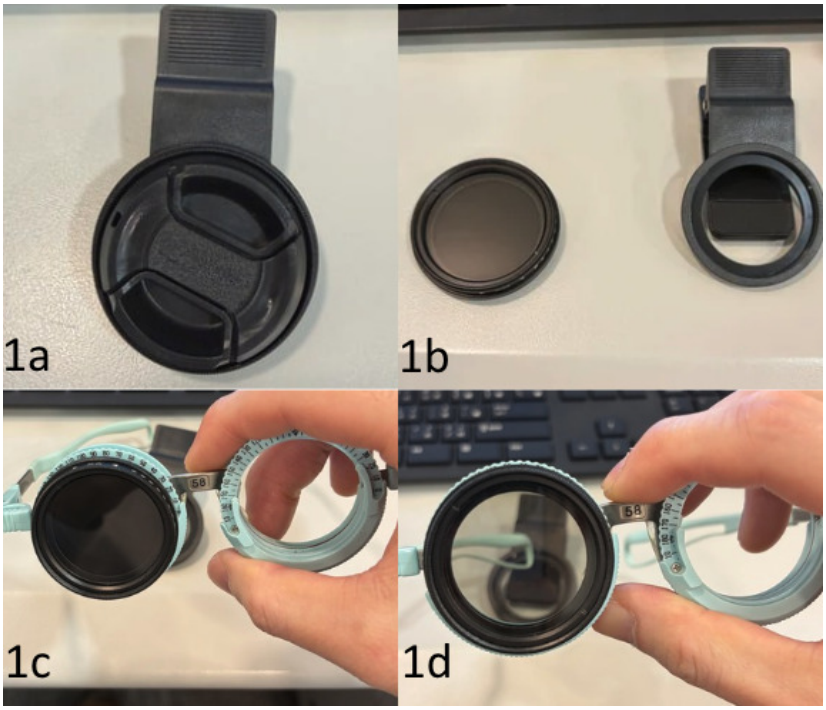


Figure 1. Demonstration of using a variable neutral-density filter for suppression testing and vision therapy. 1A and 1B show the original 37 mm smartphone neutral-density filter and the separated filter respectively. The filter can be readily isolated by detaching the mounting clip and inserted directly into a trial frame. 1C and 1D show the filter at rotation angles of 90° and 0°, respectively.

Table 1. Optical Densities Relative to the Angle of Rotation in the Trial Frame

Rotation angle (θ) (degree)	Transmittance (**T**)	Optical Density (Log Units)
0	1.00	0.00
10	0.97	0.01
20	0.88	0.05
30	0.75	0.12
40	0.59	0.23
50	0.41	0.38
60	0.25	0.60
70	0.12	0.93
80	0.03	1.52
90	0	Complete darkness

near point of convergence improved to 20 cm. The patient was able to perceive the random-dot stereoscopic target, with a base-out fusional reserve of 8Δ and a base-in reserve of 1.5Δ in the computerized dichoptic training program at 40 cm, indicating a favorable prognosis for vision therapy.

The incorporation of the variable filter demonstrated that the suppression in this case was not absolute. Under specifically modified visual conditions, the deviation exhibited intermittent features, and the patient was able to re-establish fusion. After discussion, she was diagnosed to have basic type, large, constant left exotropia (Intermittent Exotropia Control Score: Level 5 at both distance and near). In view of the substantial magnitude and deep suppression, both strabismic surgery and vision training were discussed. However, parents preferred a nonsurgical approach. Vision therapy was then discussed, and a 3-month training program was recommended to evaluate whether training alone could produce meaningful improvements in ocular alignment and cosmetic appearance. The patient was asked to schedule sessions every 1–2 weeks. Daily 15–30 minutes of home vision therapy was recommended. Parents and the patient were informed that approximately 20–25 lessons might be required.

VISION THERAPY SESSIONS

A total of 12 vision therapy sessions were completed, which was significantly fewer than planned. The 12-session vision therapy protocol (Table 2) targeted monocular skills (accommodation, pursuits, and saccades), anti-suppression, and vergence. Treatment began by normalizing accommodation facility, awareness, and saccadic eye movement, progressing from gross to fine saccades. To eliminate deep suppression, the variable neutral-density filter was first placed over the dominant eye during binocular training, including the Brock String, cheiroscope, aperture rule, anti-suppression Hart Chart reading, eccentric circles, and free-space fusion with random-dot stereograms. The density of the neutral-density filter was gradually increased until suppression was eliminated. As the interocular sensory balance improved throughout the training, the filter was subsequently removed and then applied to the nondominant eye.

This intentional sensory stress introduced an additional binocular challenge in maintaining alignment. Training advanced from near to distance, from smooth to step vergence. Ultimately, all visual skills were integrated. Both the patient and parents reported excellent adherence to the home reinforcement regimen. The patient was motivated by her own observation of improved ocular alignment, which encouraged consistent engagement in the prescribed 30-minute daily training sessions throughout the treatment course.

OUTCOME

After 12 vision therapy sessions, the patient was exophoric. Both the parents and the patient expressed satisfaction with the cosmetic outcome, noting that her eyes appeared straight most of the time, with manifest exotropia occurring about once per week. On occasions when exotropia decompensated during fatigue, the patient reported that she could voluntarily regain fusion with minimal effort. Her entering distance and near visual acuities were 20/20 in each eye, and subjective refraction was unchanged. Clinical evaluation findings from the initial visit, discharge, and the 4-month follow-up are compared in Table 3. Although residual intermittent exotropia persisted, the patient's office control score improved markedly from level 5 to level 1, a measure recognized in previous literature as a primary indicator of clinical success.[4,5] A reduction in the exodeviation magnitude was also noted (from 50Δ to 30Δ at distance and from 55Δ to 30-35Δ at near), as shown in previous literature.[12] This ⩾10Δ change can be regarded as a significant change rather than a measurement error,[12] and may be attributed to the improved tenacious proximal fusion[13] or slow fusional vergence.[14,15] When integrated with objective improvements in near point of convergence, accommodation facility, sensory-motor fusion, alongside positive subjective reports of ocular alignment from both the patient and parents, this case was considered clinically cured.

At discharge, the patient was prescribed home maintenance therapy, including eccentric circles at far and near, together with lens rock with flippers. She was instructed to perform home therapy twice weekly and to return in 3 months for reassessment. At the 4-month progress evaluation, the patient and parents reported good control of eye alignment. No suppression was found in the Worth 4-dot testing at all distances under standard room illumination. Other clinical findings remained unchanged. After discussion, the patient chose to continue home-based exercises 1–2 times per week, reporting that they were easy to perform and were not burdensome.

DISCUSSION

This case highlights a novel clinical application of a commercially available variable neutral-density filter in the management of poorly controlled exotropia (control score of 5) with deep suppression. Although discrete 10-step neutral-density filters[8] or Sbisa bars[9] can be utilized to attenuate interocular luminance and quantify suppression, their fixed-step nature can limit precise measurement. In contrast, the variable neutral-density filter used in this case report provides a continuous, gradual assessment of suppression depth. By combining the variable filter with the Worth 4-dot test, the patient's scotoma depth can be evaluated, and the precise luminance transmittance required to eliminate suppression can be recorded. This offers a more accurate and objective measure of sensory improvement across visits than conventional suppression testing.

Another notable advantage is that a gradual reduction of luminance to the dominant eye may allow convergence training to begin earlier than would be possible using standard methods alone. In patients with significant exodeviation and suppression, direct binocular training is often delayed because the patient cannot appreciate simultaneous perception or fusion under standard viewing conditions. Although over-minus power or base-in prism may be used to reduce the angle of deviation for training, these methods may not be useful in patients with exodeviation of 40Δ or more.[6] As a result, therapy may need to begin with prolonged monocular or synoptophore activities before meaningful convergence tasks can be introduced. In the present case, reducing the luminance of the dominant eye enabled testing of gross convergence and training at an earlier stage. Earlier access to binocular tasks may, in turn, shorten the overall duration of therapy by accelerating the transition from sensory preparation to active vergence rehabilitation. Furthermore, the variable filter transformed into an active sensory challenge during the final stages of training. By placing the filter over the originally deviated eye rather than the dominant eye (Table 2), this added additional sensory loading and challenged the stability of the patient's binocular system. This dual capability highlights the variable filter's rehabilitative utility in this case.

The gradual luminance modulating feature also has important implications for task simplification in vision therapy. Conventionally, trainings for intermittent exotropia and associated suppression often require clinicians to modify target characteristics—such as size, brightness, contrast, detail, color, or contour similarity—to make binocular integration more achievable. Although this approach is well-established, not all target parameters can be easily manipulated using available office- or home-based therapy tools. In addition, assembling multiple tools with a wide range of visual characteristics may impose a considerable financial burden on both practitioners and patients. This is particularly relevant in settings where access to specialized computerized systems or an extensive range of vision therapy materials is limited. The variable neutral-density filter offers a comparatively low-cost alternative (approximately $5 USD). Instead of manipulating multiple instruments to alter the target content, the therapists can readily modify the luminance reaching the dominant eye while keeping the same training target and task structure. This simplifies the rehabilitation process and allows suppression to be challenged in a graded, reproducible fashion. The level of suppression can be adjusted and recorded systematically, making it possible to monitor sensory improvement objectively across visits.

Table 2. Overview of the Vision Therapy for the 12 Sessions

Monocular Therapy		Vergence Therapy	Anti-suppression Therapy
Subskill and Activities		Subskill and Activities	Subskill and Activities
Visit 1–3		Visit 1–5	Visit 1–3
1. Accommodative facility and awareness - Lens clearing (+2.50 to −6.00D) - Lens sorting -Accommodative rock with flippers - Near-far Hart Chart rock 2. Saccades and pursuits (medium) - Letter Tracking - Percon Saccades		1. Vergence awareness - Modified Brock String push-up with the variable ND filter in RE To build upon the 20 cm NPC via -3.00D lenses and a 60° ND filter in front of RE, Brock String exercise was implemented (Figures 2 and 3). Filter density was titrated upward to eliminate suppression and maintain physiological diplopia. 2. Smooth near convergence training - Computerized dichoptic random-dot stereoscopic program - Tranaglyph smooth BO reserve training (BC 500 series)	1. Near anti-suppression - R/G glasses and penlight Leveraging assessment findings where a 60° of ND filter rotation over RE successfully elicited pathological diplopia, training started using anaglyphic filters and a penlight at 40 cm. The filter's optical density was gradually tapered as the patient achieved and maintained stable simultaneous perception. - Cheiroscopic drawing with single oblique mirror stereoscope at the objective angle of deviation 2. Synoptophore anti-suppression training
Visit 4–5		Visit 6–7	Visit 4–8
1. Monocular Accommodative awareness - Mental minus 2. Monocular saccades and pursuits (fine) - Letter Tracking - Percon Saccades - Visual tracing - Xs and Os		1. Smooth vergence at near - Vectogram (Variable Quoits)/ Tranaglyphs BO and BI training (BC 500 and 600 series) - Computerized smooth vergence training (both BO and BI) 2. Step vergence at near - Aperture rule for BO training - Brock string jump (5 cm/20 cm/40 cm)	1. Near-to-intermediate anti-suppression - Cheiroscopic drawing with single oblique stereoscope at the ortho position - R/G Hart Chart reading (from 40 cm to 1 m)
NA		Visit 8–9	Visit 9–10
NA	NA	1. Eccentric circles at near 2. Free-space fusion with random-dot stereogram in computerized program 3. Brock string rock at 40 cm, 1.5 m and 3 m 4. Computerized dichoptic jump BO and BI training at intermediate-to-far distance	1. Intermediate-to-far anti-suppression - R/G Hart Chart reading (beyond 1 m) - Polaroid Hart Chart reading (beyond 1 m)
NA		Visit 10–12	Visit 11–12
NA	NA	1. Free-space fusion with eccentric circles at intermediate-to-far distances (with lens flippers and loose base-out prism) 2. Free-space fusion with stereogram in computerized program at intermediate-to-far distances (with loose BO prism) 3. Polaroid Hart Chart reading rock at distance and near with loose prism challenge 4. Polaroid visual tracings at distance with loose prism rock 5. Cover and uncover with loose prism	1. Free-space fusion with eccentric circles and stereogram in computerized program at intermediate-to-far distances The ND filter was transitioned to the LE to create intentional fusion challenge.
NA		Home maintenance	
NA	NA	Eccentric circles at far and near, together with 12Δ BO/3Δ BI (twice weekly)	

Abbreviation: D, Dioptre; cpm, Cycles per Minute; ND, Neutral Density; RE, Right Eye; NPC, Near Point of Convergence; R/G, Red/Green; BO, Base-Out; BI, Base-In; LE, Left Eye

Despite these advantages, the use of a variable neutral-density filter should be interpreted as an adjunct rather than a replacement for established binocular vision assessment and therapy techniques. Further studies would be valuable to determine its reproducibility, its reliability compared to other established suppression grading methods, and its effectiveness across different types and severities of strabismus. In addition, its use should only be limited to in-office training, as the filter's luminance reduction depends on the absolute luminance.[16] Given that ambient luminance can vary substantially over the course of a day, in some circumstances by as much as 100000:1,[16] the therapeutic effect may be less predictable unless lighting conditions are carefully controlled (for example, in a clinic



Figure 2. A photo demonstrating the patient's left eye deviating outward, with suppression persisting when filter transmittance was set to 30 degrees.



Figure 3. A photo demonstrating fusion in an open-spaced environment as the transmittance to the dominant eye was progressively reduced, and the angle of rotation was set to 60 degrees.

cubicle). Nonetheless, this case report demonstrated the meaningful clinical utility of the filter. It offers a simple means of continuously grading suppression, reduces dependence on multiple specialized therapy tools, and facilitates the timely initiation of convergence training by progressively reducing luminance to the dominant eye. Together, these features support its potential role as both a diagnostic and therapeutic instrument in the management of exotropia with deep suppression.

CONCLUSION

This case report illustrated the usefulness of a variable neutral-density filter as an inexpensive adjunct in the management of exotropia by permitting continuous grading of suppression and accelerating sensory rebalancing during vision therapy, ultimately contributing to a shorter treatment course. Although further study is obligatory, this low-cost approach has practical diagnostic and therapeutic insights in selected cases of exotropia with significant suppression.

TAKE HOME POINTS

- A variable neutral-density filter can provide a simple and continuous method for grading suppression.
- The filter may function as a therapeutic tool by reducing luminance to the dominant eye, thereby rebalancing interocular sensory input and promoting binocular participation.
- In patients with large-angle exotropia and deep suppression, gradual luminance attenuation may allow earlier initiation of convergence training, potentially shortening the overall duration of therapy.

PATIENT CONSENT

Consent was granted by the patient and parents for the publication of this case report and any accompanying clinical images.

HUMAN RIGHTS

Procedures were followed in accordance with the Helsinki Declaration. A case report of 3 or fewer patients does not require institutional review board approval.

CONFLICTS OF INTEREST

The author declares no conflicts of interest.

FUNDING SOURCES

The author declares no funding sources.

Table 3. Binocular Vision Findings at Baseline, Post-Vision Therapy Discharge, and Four-Month Post-Discharge Follow-up

	Baseline	Post-Vision Therapy (Discharge)	4-month Follow-up
- IXT Control Score[11]	Score 5 (D & N)	Score 1 (D & N)	Score 1 (D & N)
- Magnitude of exotropia (Prism Alternate Cover Test)	D: 50Δ N: 55Δ	D: 30Δ N: 30–35Δ	D: 30Δ N: 35Δ
- Near point of convergence (without added lens or filter)	No gross convergence	To-the-nose with 5 repeated testing	To-the-nose with 5 repeated testing
- Worth 4-dot (without added lens or filter)	LE suppression across all distances and lighting	Fusion across all distances and lighting conditions	Fusion across all distances and lighting conditions
- Stereopsis (Random Dot 2-S Stereo Acuity Test)	No local and global stereopsis	Global stereopsis: 125" Local stereopsis: 25"	Global stereopsis: 125" Local stereopsis: 25"
- Monocular accommodation amplitude, dioptres	RE: 20 LE: 20	RE: 20 LE: 20	RE: 20 LE: 20
- Accommodation facility with ± 2.00 D	RE: 18 cpm LE: 16 cpm No binocular facility could be assessed due to manifest exotropia	RE: 21 cpm LE: 22 cpm BE: 20 cpm	RE: 23 cpm LE: 22 cpm BE: 21 cpm
- Fusional vergences (with no filter or minus lenses)	No fusion	1. Prism bar: • No break at 35Δ BO prism bar testing (D & N), which represented the ceiling of the clinical prism bar used. • BI fusional reserves were X/15/10Δ (D); 15/20/10Δ (N) 2. Synoptophore testing recorded a BO reserve of 40/60/35Δ from ortho position. This demonstrated that the patient's compensating fusional reserve satisfies the Sheard's criteria, thereby supporting the clinical decision of a 'clinical cure'.	1. Prism bar: • No break at 35Δ BO prism bar testing (D & N), which represented the ceiling of the clinical prism bar used. • BI fusional reserves were X/15/10Δ (D); 15/20/8Δ (N) 2. Synoptophore testing recorded a BO reserve of 45/65/40Δ from ortho position. This demonstrated that the patient's compensating fusional reserve satisfies the Sheard's criteria, thereby supporting the clinical decision of a 'clinical cure'.
- Patient and parents' subjective comment	Obvious LE deviation throughout the day	Eyes appear straight most of the time; manifest exotropia occurs about once per week; able to regain fusion easily.	Eyes appeared straight most of the time; manifest exotropia occurs less than once per week; able to regain fusion easily.

Abbreviation: IXT, Intermittent Exotropia; D, Distance; N, Near; Δ, Prism Dioptre; ", Second of ARC; LE, Left Eye; RE, Right Eye; BE, Both Eyes; cpm, Cycles per Minute; BO, Base-Out; BI, Base-In

DATA AVAILABILITY

Data sharing is not applicable to this manuscript.

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ARTIFICIAL INTELLIGENCE (AI) USE

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