

Case Reports

Case Series: Neuroplasticity and Vision Therapy in Adults with Unilateral Small-Angle Esotropia

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Introduction

Eyecare providers may hesitate to offer treatment to adults with long-standing constant strabismus, assuming that binocularity will be unobtainable. Adult patients may present with personal goals or symptoms that require treatment for their strabismus to restore binocularity. We report three cases of adults with unilateral small-angle esotropia who achieved random dot stereopsis after optometric vision therapy.

Case Reports

Case one: A 33-year-old man's goal was to improve vision in his left eye and to appreciate virtual reality. He presented with a constant left esotropia and amblyopia with normal correspondence and no random dot stereopsis. After spectacle correction with vertical prism, vision therapy, and 2 hours of daily patching, he was able to appreciate random dot stereopsis and visual acuity of 20/25 in his left eye.

Case two: A 25-year-old woman's goal was to improve vision in her left eye and establish binocularity because she experienced blur while performing slit lamp examination as a result of her eyes "alternating fixation." She presented with a constant left esotropia, amblyopia, eccentric fixation, anomalous correspondence, and no random dot stereopsis. After vision therapy, she was able to appreciate random dot stereopsis and visual acuity of 20/20-1 in her left eye.

Case three: A 25-year-old woman's goal was to reduce headache symptoms and establish binocularity. She presented with an intermittent left esotropia with variable left hypotropia, anomalous correspondence, and no random dot stereopsis. After vision therapy, she was able to appreciate random dot stereopsis.

Conclusion

Although treatment of adult strabismus can be challenging, adults with goals related to binocularity can be successfully treated. These three cases highlight successful vision therapy in motivated adult patients with a goal of binocular vision.

INTRODUCTION

Neuroplasticity is the ability of the nervous system to adapt and change in response to different stimuli and experiences, which involves strengthening some synaptic connections while eliminating others.¹ This process is most robust during the critical period, which varies for different functions.¹ It was previously thought that neuroplastic changes were restricted to that period² and skills would be permanently affected if they failed to develop during that time.³ The critical period for development of stereopsis is defined to be 3 months to at least 3 years of age.⁴ Disruption of visual input can affect the development of binocularity, specifically stereopsis, in individuals with strabismus. For esotropia, the period in which stereopsis is susceptible to

anomalous binocular vision was found to be soon after birth to at least 4.6 years of age.⁴

The misconception of limited improvement with treatment beyond the critical period may prevent adults from seeking treatment for their strabismus or deter health care professionals from recommending treatment, including vision therapy and strabismus surgery.⁵ There is growing evidence that neuroplasticity is possible in adults past the critical period of visual development. This is evident by improved binocularity in adults with strabismus after surgery,⁵⁻¹⁰ improved amblyopic eye visual acuity in adults with patching and binocular therapy,¹¹ and improved oculomotor skills in adults with vision therapy.^{12,15} However, there is limited research on the use of vision therapy to restore binocularity in adults with strabismus, as most reports are restricted to case studies.¹⁴⁻¹⁹ Although most

adult patients with long-standing strabismus do not experience symptoms, these patients may have cosmetic concerns, occupational goals, or personal goals that require alignment or binocular vision. In these cases, treatment of the strabismus may improve these patients' quality of life⁵⁻⁷ by improving visual function.

The prognosis for successful treatment of strabismus depends on several factors, including, but not limited to, the presence of a sensory fusion anomaly, direction, size, and time of onset of the strabismus.²⁰⁻²² Amblyopia can also add another layer of treatment complexity. Adult patients with strabismus desiring binocular vision may be offered various treatment options, including vision therapy. The goal of vision therapy is to eliminate sensory anomalies and improve sensory and motor fusion with the hope that this leads to improved binocularity. This case series describes adults with constant unilateral small-angle esotropia who achieved their goals of binocular vision through vision therapy. No identifiable health information was included in this case series.

CASE REPORTS

CASE 1

A 33-year-old man presented with a complaint of long-standing reduced vision in his left eye and an inability to appreciate virtual reality. His goal was to improve vision and to appreciate virtual reality. Ocular history included amblyopia with poor adherence to patching therapy during childhood.

Distance visual acuities (electronic Early Treatment Diabetic Retinopathy Study [E-ETDRS]) through his presenting spectacles were right eye -1.25 sphere (20/20, letter score 88), left eye Plano sphere (20/50, letter score 65). Interferometry using a Heine Retinometer showed identification of 20/30 grating targets (left eye). Cycloplegic autorefraction, using 2 drops of 1% cyclopentolate, was right eye +0.37 - 0.50 × 170, left eye +6.12 - 1.50 × 009. Cycloplegic manifest refraction and visual acuities (Snellen) were right eye Plano sphere (20/20), left eye +6.50 - 0.50 × 180 (20/125). Because the patient had not worn a full anisometric prescription, he was recommended to return 1 week later to finalize his spectacle prescription. Through cycloplegic manifest refraction, he experienced dizziness and diplopia. Anisometric prescription, through trial framing, was consequently reduced. In a trial frame, the following prescription was most comfortable and recommended for full-time wear: right eye Plano sphere, left eye +5.75 - 0.50 × 015 (Snellen 20/100).

After the patient adapted to the spectacle prescription for 1 month, a strabismus evaluation (Table 1) was performed. The patient reported diagonal diplopia on Worth four-dot and synoptophore testing. Second-degree fusion was not achieved on Worth four-dot with neutralizing prism, but it was achieved during synoptophore testing at his subjective angle. Vertical prism was trial framed based on his subjective angle, and 5Δ was most comfortable, so his spectacles were remade to include right eye 2.5Δ base-down, left eye 2.5Δ base-up. Contact lenses were consid-

ered to reduce potential aniseikonia, but the patient did not want contact lenses and the amount of vertical prism was too high for contact lenses.

The patient was diagnosed with microtropia and mixed mechanism (strabismic and anisometric) amblyopia in his left eye. Prognosis for strabismus treatment was guarded, in which a favorable prognostic factor includes normal correspondence and unfavorable prognostic factors include esotropia and amblyopia. The patient was motivated to achieve his visual goals, and in-office 45-minute weekly vision therapy was recommended. Home therapy (15-20 minutes daily) with 2 hours of patching (right eye) during near activities was prescribed. Vision therapy focused on developing binocularity by reducing the frequency of his esotropia and improving vision in his left eye. Base-out prism was discussed, but he wanted to try vision therapy first. Strabismus surgery was not recommended owing to the esotropia being a small angle, and the risk outweighed the benefits.

The patient's vision therapy program progressed from improving monocular visual function, to establishing normal peripheral then central fusion, to—lastly—establishing efficient binocular vision in open space. Vision therapy activities (Table 2) were categorized into monocular visual skills, vergence, and antisuppression training. The beginning of the program aimed at normalizing accommodative and oculomotor skills in the left eye. Accommodative techniques were first performed monocularly, starting with increasing accommodative amplitude and awareness and then moving on to facility. Monocular gross saccades were trained first, then progressing to medium and fine saccades. Form discrimination therapy was also included. These visual skills were later integrated with vergence training.

Given the constant nature of the patient's strabismus but normal sensory fusion at his objective angle, divergence training was performed from his objective angle²² in the synoptophore and Wheatstone stereoscope. Antisuppression therapy was incorporated to reduce suppression and develop pathological diplopia awareness when he was strabismic. When he achieved fusion at orthoposition, out-of-instrument divergence training at near using vectograms and Tranaglyphs was initiated. Computer vergence therapy (Vision Therapy System 4) with random dot stereopsis targets of 600" was used to help him appreciate stereopsis. Convergence training was gradually incorporated. During the last stage, vergence training advanced from near to intermediate and then far distances.

After 30 sessions and daily patching, the patient's amblyopic eye visual acuity improved to 20/25 and he could appreciate random dot stereopsis of 250". In addition, the frequency of his esotropia changed from constant to intermittent. Although base-out prism could be beneficial in stabilizing his binocularity, he elected not to proceed with this treatment because he already attained his goal. Patching was tapered (3 days per week for the first month, 2 days per week for the second month, and 1 day per week for the third month) before discontinuing, and home maintenance therapy was prescribed.

Table 1. Examination findings before and after vision therapy for case 1

Tests	Initial Evaluation	Post-Vision Therapy Evaluation
Best-corrected distance visual acuity	Right eye: Plano sphere (E-ETDRS 20/16, letter score 93) Left eye: +5.75 - 0.50 × 015 (E-ETDRS 20/100, letter score 49)	Right eye: Plano sphere with 2.5Δ base-down (E-ETDRS 20/16, letter score 93) Left eye: +5.75 - 0.50 × 015 with 2.5Δ base-up (E-ETDRS 20/25, letter score 81)
Monocular fixation	Visuoscopy: central, steady (right and left eye)	
Cover test (with correction)	Far: 6Δ constant left esotropia with 4Δ constant left hypotropia Near: 10Δ constant left esotropia with 4Δ constant left hypotropia	Far: 2Δ intermittent left esotropia (70%) Near: 8Δ intermittent left esotropia (80%)
Comitancy	Cover test in diagnostic action fields: comitant eso- and vertical deviation	
Extraocular movement test	Full range of motion, right and left eyes	
Correspondence	Synoptophore: normal correspondence	
In-instrument evaluation of sensorimotor fusion	Synoptophore: stable second-degree peripheral and central fusion at objective angle (15Δ base-out with 6Δ left hypotropia); inadequate motor fusion from objective angle	
Out-of-instrument evaluation of sensorimotor fusion	<u>Worth four-dot</u> Far and near: uncrossed and vertical diplopia (unable to achieve fusion with neutralizing base-out and base-down prism over the right eye) <u>Stereopsis</u> Far: nil (Distance Randot Stereotest) Near: nil (Randot Stereotest) ^a with and without neutralizing prism	<u>Worth four-dot</u> Far: uncrossed diplopia Near: alternates between fusion and uncrossed diplopia <u>Stereopsis</u> Far: nil (Distance Randot Stereotest) Near: 250° random dot stereopsis (Randot Stereotest) <u>Motor Ranges (from ortho)</u> Far: divergence x/1/0; convergence x/20/16 Near: divergence x/2/1; convergence x/20/18

^aFar and near stereopsis.

E-ETDRS, electronic Early Treatment Diabetic Retinopathy Study.

At the 3-month post-vision therapy progress evaluation, the patient still retained random dot stereopsis. Refraction remained unchanged, but left eye visual acuity regressed to 20/40 (letter score 73). To the authors' knowledge, there are no studies regarding regression in amblyopic eye visual acuity in adults, but research in children shows that regression can occur after discontinuing treatment when amblyopic eye visual acuity significantly improves or treatment is initiated at an older age.²⁵ Contact lenses were discussed, but he preferred spectacles. It was recommended that he restart patching 1 hour a day and return in 2 months for a follow-up, but he was lost to follow-up.

CASE 2

A 25-year-old woman presented with a complaint of blurred vision while performing slit lamp examination as a result of her eyes "alternating fixation." Ocular history included amblyopia in her left eye with good adherence to patching therapy during childhood. Her goals were to resolve her amblyopia and develop stereopsis.

Distance visual acuities (Snellen) through her spectacle correction (+4.00 sphere both eyes) were 20/20 right eye, 20/30 left eye. A previous cycloplegic refraction revealed +5.50 sphere both eyes, but the patient reported discomfort with that prescription. Noncycloplegic manifest refraction

of +4.75 sphere both eyes was found, trial framed, and finalized for full-time wear; it was well tolerated and distance visual acuity was unaffected.

Strabismus and amblyopia evaluation findings are listed in [Table 3](#). Cover test revealed a comitant constant left esotropia of 4Δ at distance and 2Δ at near. She was found to have harmonious anomalous correspondence, 1Δ of nasal eccentric fixation in the left eye, and no random dot stereopsis. The patient was diagnosed with microtropia and strabismic amblyopia in her left eye. She was offered patching therapy alone to treat her amblyopia or patching with vision therapy to treat both amblyopia and strabismus. Her prognosis for strabismus treatment was guarded, where esotropia, anomalous correspondence, and amblyopia with eccentric fixation are unfavorable prognostic factors. Strabismus surgery was not recommended owing to the small size of her angle. Prism was contraindicated because of the presence of anomalous correspondence.

The patient was motivated to achieve her goals and elected weekly 45-minute in-office vision therapy, including 10-15 minutes of daily home therapy. The main objective of therapy was to improve vision in her left eye, as well as eliminate anomalous correspondence and develop binocularity. The vision therapy activities ([Table 4](#)) were categorized into monocular visual skills and vergence training. The beginning sessions focused on eliminating ec-

Table 2. Vision therapy activities (in-office in addition to home vision therapy) for case 1

Monocular Therapy		Vergence Therapy		Antisuppression Therapy	
Visits	Subskill and Activities	Visits	Subskill and Activities	Visits	Subskill and Activities
1-5	<p>Accommodative amplitude and awareness</p> <ul style="list-style-type: none"> • Hart chart push-ups • Lens clearing (+2 to -6 lenses) <p>Accommodative facility</p> <ul style="list-style-type: none"> • Near-far Hart chart rock • Accommodative rock with flippers <p>Saccades (medium and fine)</p> <ul style="list-style-type: none"> • Hart chart saccades with after-image • Letter tracking <p>Form discrimination</p> <ul style="list-style-type: none"> • Hidden pictures 	1-10	<p>Vergence awareness</p> <ul style="list-style-type: none"> • Brock string with red-green glasses <p>Motor stimulation</p> <ul style="list-style-type: none"> • Synoptophore (Flom swing) BI <p>Smooth vergence at near</p> <ul style="list-style-type: none"> • Wheatstone BI • Vectograms/ Tranaglyphs BI • VTS4 (vergence setting, flat fusion target) BI • VTS4 (vergence setting, lateral disparity stereopsis target) BI 	1-5	<ul style="list-style-type: none"> • Brock string with red-green glasses
6-15	<p>Saccades (fine)</p> <ul style="list-style-type: none"> • Line counting • Percon saccades • Visual scan • Perceptual speed worksheets <p>Accommodative awareness</p> <ul style="list-style-type: none"> • Lens sorting • Mental Minus 	11-15	<p>Smooth vergence at near</p> <ul style="list-style-type: none"> • Vectograms/ Tranaglyphs BI and BO • VTS4 (vergence setting, lateral disparity stereopsis target) BI and BO • VTS4 (multiple choice, large RDS target) BI and BO <p>Step vergence at near</p> <ul style="list-style-type: none"> • Step Vectograms/ Tranaglyphs BO and BI • VTS4 (multiple choice, large RDS target) BI and BO step vergences • Aperture Rule Trainer BI and BO <p>Binocular accommodative facility</p> <ul style="list-style-type: none"> • Binocular accommodative facility with flippers 	6-10	<ul style="list-style-type: none"> • Single oblique stereoscope (cheiroscope) • GTVT chart at near, then distance • Honeycomb chart at near, then distance • Sanet Vision Integrator with red-blue glasses • VTS4 cheiroscope • Red coloring book tracing • Red filter over reading material
16-20	<p>Saccades (medium and fine)</p> <ul style="list-style-type: none"> • Loose prism saccadic jumps <p>Saccades and accommodative stamina</p> <ul style="list-style-type: none"> • Letter tracking with minus lenses • Line counting with minus lenses <p>Form discrimination</p> <ul style="list-style-type: none"> • C-ring directionality 	16-20	<p>Step vergence at near</p> <ul style="list-style-type: none"> • Eccentric circles BI and BO <p>Facility vergence at near</p> <ul style="list-style-type: none"> • Eccentric circles facility • Vectograms/ Tranaglyphs facility • VTS4 (multiple choice, medium and small RDS target) jump ductions <p>Binocular</p>	11-15	<ul style="list-style-type: none"> • Red-red rock • Bi-ocular spirangle • Red-green TV trainer at near

			accommodative facility <ul style="list-style-type: none"> Binocular accommodative facility with flippers 		
21-30	Accommodative stamina <ul style="list-style-type: none"> Reading at near with minus lenses Form discrimination <ul style="list-style-type: none"> Amblyopia iNet 	21-30	Facility vergence at near <ul style="list-style-type: none"> Prism flips Vergence at far <ul style="list-style-type: none"> VTS4 (multiple choice, small RDS target) BI and BO at 5 and 10 feet Eccentric circles BI at 5 feet, walk-aways Brewster BI and BO TV trainer/GTVT (step BI and BO) at 5 and 10 feet 	16-20	<ul style="list-style-type: none"> VTS4 amblyopia (red line tracing) Red X's and O's
Home maintenance	Monocular near-far Hart chart (3 times a week for first month, 2 times a week for second month, 1 time a week for third month)	Home maintenance	Eccentric circles—facility at near and BI at distance (3 times a week for first month, 2 times a week for second month, 1 time a week for third month)		

BI, base-in; BO, base-out; RDS, random dot stereopsis; VTS4, Vision Therapy System 4.

Table 3. Examination findings before and after vision therapy for case 2

Tests	Initial Evaluation	Post-Vision Therapy Evaluation ^a
Best-corrected distance visual acuity	Right eye: +4.00 sphere (Snellen 20/20) Left eye: +4.00 sphere (Snellen 20/30)	Right eye: +4.75 sphere (Snellen 20/20) Left eye: +4.75 sphere (Snellen 20/20 ⁻¹)
Monocular fixation	<u>Visuoscapy</u> : 1Δ nasal, unsteady eccentric fixation (left eye) <u>Haidinger's brush</u> : 1Δ nasal eccentric fixation (left eye)	
Cover test (with correction)	Far: 4Δ constant left esotropia Near: 2Δ constant left esotropia	
Comitancy	Cover test in diagnostic action fields: comitant esodeviation	
Extraocular movement test	Full range of motion, right and left eyes	
Correspondence	<u>Worth four-dot</u> : harmonious anomalous correspondence <u>Bagolini striated lenses</u> : harmonious anomalous correspondence <u>Hering-Bielschowsky After-Image test</u> : harmonious anomalous correspondence <u>Synoptophore</u> : harmonious anomalous correspondence	
Out-of-instrument evaluation of sensory fusion	Stereopsis Near: nil (Randot Preschool Stereotest)	Stereopsis Near: 400" random dot stereopsis (Randot Preschool Stereotest)

^aPatient did not complete entire vision therapy program (only completed 10 sessions).

centric fixation in the left eye and improving accommodative skills. After achieving 20/20⁻¹ left eye in three visits, motor stimulation using Flom's swing technique in the

synoptophore was performed to diverge to an ortho eye alignment. Computer vergence therapy with random dot stereopsis targets was used to help her appreciate stereop-

Table 4. Vision therapy activities (in-office in addition to home vision therapy) for case 2

Monocular Therapy		Vergence Therapy	
Visits	Subskill and Activities	Visits	Subskill and Activities
1-10	Accommodative amplitude and facility <ul style="list-style-type: none"> Near-far Hart chart rock Accommodative rock with flippers Eccentric fixation (fast pointing) <ul style="list-style-type: none"> Dotting O's Stationary pegboard Haidinger's brushes 	1-5	Smooth vergence at near <ul style="list-style-type: none"> VTS4 (vergence setting, flat fusion) BI Motor stimulation <ul style="list-style-type: none"> Synoptophore (Flom swing) BI
		6-10	Smooth vergence at near <ul style="list-style-type: none"> Quoit Vectograms with Marsden ball, BI VTS4 (multiple choice, large RDS) BI and BO Quoit and clown Vectograms BI and BO
Home maintenance ^a	Near-far Hart chart rock Accommodative rock with flippers Fast pointing Dotting O's		

^aThese activities were assigned at the 10th vision therapy visit; patient did not return for progress evaluation.

BI, base-in; BO, base-out; RDS, random dot stereopsis; VTS4, Vision Therapy System 4

sis. Vectograms were also incorporated during divergence training in open space.

The patient had to discontinue vision therapy because she relocated from the area. However, after 10 sessions, her visual acuity normalized to 20/20⁻¹ in the left eye and she was able to appreciate random dot stereopsis of 400". The patient has not returned to the area, so some examination findings could not be reevaluated.

CASE 3

A 25-year-old woman presented with a complaint of pain over her right eye that worsened with extended near work or driving for a long time. It started 2 years ago and did not improve with pain medication. Previous medical records revealed a history of partially accommodative esotropia since age 2 and no stereopsis. Systemic history included type 1 Chiari malformation without ocular manifestations. Her goals were to reduce headache symptoms and establish binocularity.

Distance visual acuities (Snellen) were 20/15 in each eye through contact lenses (right eye +1.75 sphere; left eye +1.50 sphere). Cover test revealed a comitant, high-frequency intermittent left esotropia of 4Δ with asymmetric dissociated vertical deviation and variable left hypotropia of 4Δ at far and near. Her accommodative amplitude and facility were normal in each eye. On the prism adaptation test, she adapted to both horizontal and vertical prism. Additional examination findings from the strabismus evaluation are listed in [Table 5](#).

She was diagnosed with microtropia with left hypotropia and harmonious anomalous correspondence. Prognosis was guarded for improvement of headache symptoms and poor for binocularity. Her unfavorable prognostic factors for strabismus treatment include esotropia, vertical deviation, and anomalous correspondence. Strabismus surgery was not recommended owing to the size of her angle. Prism was contraindicated because of anomalous correspondence and a positive prism adaptation test. After a discussion on the guarded prognosis, she elected to start vision therapy,

weekly 45-minute in-office sessions, to see whether her symptoms would improve.

The main objective of vision therapy was to eliminate anomalous correspondence and establish normal correspondence. The vision therapy activities ([Table 6](#)) were categorized into monocular visual skills and vergence training. The initial therapy sessions focused on motor stimulation using Flom's Swing technique in the synoptophore, along with enhancement of monocular accommodative skills. Once she began displaying covariation, in- and out-of-instrument vergence (convergence, divergence, and vertical vergence at near and distance) training were introduced. After-images were used to monitor correspondence. On computer therapy, large random dot stereopsis targets were initially used, and target size was decreased over time. She would occasionally use vertical prism (4-5Δ base-down right eye) in-office to help with fusion but did not desire a prism prescription for full-time wear.

After 26 weeks of vision therapy, the patient had to discontinue because she was moving out of the area but was given home maintenance therapy. She could appreciate random dot stereopsis of 250" and noted a significant improvement in headaches following therapy and a difference in her binocular depth perception. The patient has not returned for follow-up, so some examination findings could not be reevaluated.

DISCUSSION

This case series offers some support that neuroplasticity continues through adulthood, and optometric vision therapy can facilitate this process. With vision therapy, all three patients gained the ability to appreciate stereopsis. These cases show that the visual system can be trained and improved after the critical period in adult patients with unilateral small-angle esotropia who never appreciated stereopsis.

The cases detail vision therapy in three patients with microtropia. Intractable diplopia may occur with vision ther-

Table 5. Examination findings before and after vision therapy for Case 3

Tests	Initial Evaluation	Post-Vision Therapy Evaluation ^a
Best-corrected distance visual acuity	Right eye: +1.75 sphere (Snellen 20/15) Left eye: +1.50 sphere (Snellen 20/15)	
Cover test (with correction)	Far: 4Δ intermittent left esotropia with 4Δ intermittent left hypotropia (high frequency) Near: 4Δ intermittent left esotropia with 4Δ Intermittent left hypotropia (high frequency)	Far: 2Δ intermittent left esotropia with 1-2Δ intermittent left hypotropia (low frequency) Near: 2Δ intermittent left esotropia with 1-2Δ intermittent left hypotropia (low frequency)
Comitancy	Cover test in diagnostic action fields: comitant eso- and vertical deviation	
Extraocular Movement Test	Full range of motion, right and left eyes	
Correspondence	<u>Worth four-dot</u> : harmonious anomalous correspondence <u>Bagolini striated lenses</u> : harmonious anomalous correspondence <u>Hering-Bielschowsky After-Image test</u> : normal correspondence <u>Synoptophore</u> : unharmonious anomalous correspondence	<u>Worth four-dot</u> : alternates between fusion and crossed diplopia at near <u>Bagolini striated lenses</u> : alternates between harmonious anomalous and normal correspondence response <u>Hering-Bielschowsky After-Image test</u> : normal correspondence <u>Synoptophore</u> : normal correspondence
Out-of-instrument evaluation of sensory fusion	Stereopsis Near: nil (Randot Stereotest)	Stereopsis Near: 250" random dot stereopsis (Randot Stereotest)

^aPatient did not complete entire vision therapy program (only completed 26 sessions).

apy, and this was discussed with all three patients, but they elected to try vision therapy to achieve their goals of improved depth perception. Although it has been reported that patients with microtropia may identify random dot stereopsis of 800", which is considered false positive, on the Randot Preschool Stereotest,²⁴ the patients in our case series ultimately achieved true random dot stereopsis following vision therapy (250" for cases 1 and 3 and 400" for case 2).

Similar to our case series, a few studies have documented improvement in binocular function in adults with esotropia following vision therapy. A retrospective review looked at adults with esotropia, as well as those with exotropia and vertical strabismus, and found an improvement in stereopsis after vision therapy.²⁵ Two cases found improvement in binocular function after vision therapy in adults with esotropia,^{18,19} but they did not achieve stereopsis. In one case, an adult with esotropia and amblyopia presented with anomalous correspondence and no random dot stereopsis.¹⁸ Divergence training was performed under artificial conditions with a red lens, where the patient had to fuse diplopic images in the dark. He also had to maintain fusion of a target while walking away from it. Accommodative, oculomotor, eccentric fixation, eye-hand coordination, and patching therapies were incorporated. Following vision therapy, the patient's visual acuity and ability to fuse diplopic images improved, but he was not able to appreciate stereopsis. In another case report, an adult patient with esotropia presented with headaches, eye fatigue, and intermittent diplopia.¹⁹ Vision therapy consisted of antisuppression, accommodative, oculomotor, eye-hand coordination, and vergence training, along with techniques to disrupt anomalous correspondence. Following vision ther-

apy, she demonstrated normal correspondence, perceived stereoscopic depth at her centration point, and subjectively reported less eye fatigue.

The vision therapy programs in the aforementioned cases were similar to our case series, in that they all worked on accommodative and vergence activities. However, vergence training in these case reports did not utilize Flom swing. Flom swing, utilized in cases 2 and 3, is a useful therapy technique because it can eliminate anomalous correspondence in small-angle esotropes through expansion of vergence ranges.^{22,26} By inducing fusional vergence, covariation of anomalous correspondence to normal correspondence can be achieved and normal fusion can be established. This may be why the patients in our case series were able to appreciate random dot stereopsis after treatment.

These three patients' vision therapy programs were sequenced based on treatment guidelines for strabismus²² and amblyopia.²⁷ Monocular accommodative therapy and motor stimulation were performed at the beginning of therapy, followed by vergence therapy in open space. However, there were some differences in our patients' profile and specific therapy activities, which contribute to the limitations of this case series. The patients in cases 1 and 2 had amblyopia, so other monocular (oculomotor and spatial perception) activities were included to improve visual acuity and monocular fixation. Vertical prism was prescribed for case 1, but vertical vergence therapy was incorporated for case 3. Not all patients presented with anomalous correspondence. Lastly, the patients in cases 2 and 3 were lost to follow-up before completing vision therapy, so some examination findings were unable to be reassessed. Despite differences and limitations, this case series show that stere-

Table 6. Vision therapy activities (in-office in addition to home vision therapy) for case 3

Monocular Therapy		Vergence Therapy	
Visits	Subskill and Activities	Visits	Subskill and Activities
1-18	Accommodative amplitude and facility <ul style="list-style-type: none"> Near-far Hart chart rock Accommodative rock with flippers 	1-6	Smooth vergence at near <ul style="list-style-type: none"> VTS4 (vergence setting, flat fusion target) BI Vectograms BI Motor Stimulation <ul style="list-style-type: none"> Synoptophore (Flom swing) BI
		7-12	Vergence awareness <ul style="list-style-type: none"> Brock string Smooth vergence at near <ul style="list-style-type: none"> Vectograms (with after-images) BI and BO VTS4 (multiple choice vergence, large RDS target) BI and BO Smooth vergence at distance <ul style="list-style-type: none"> Synoptophore (3rd degree target) BI and BO Step vergence at near <ul style="list-style-type: none"> Aperture Rule Trainer (with after-images) BI and BO
		13-18	Smooth vergence at near <ul style="list-style-type: none"> Vectograms BI and BO Vectograms (with Marsden ball) BI and BO VTS4 (multiple choice vergence, large RDS target) BU and BD Smooth vergence at distance <ul style="list-style-type: none"> Synoptophore (third-degree target) BI and BO Facility vergence at near <ul style="list-style-type: none"> VTS4 (multiple choice RDS) jump ductions
		19-26	Smooth vergence at near <ul style="list-style-type: none"> VTS4 (multiple choice vergence, large RDS target) BI, BO, BU, BD Step vergence at near <ul style="list-style-type: none"> Aperture Rule Trainer BI and BO Eccentric circles BI and BO Facility vergence at near <ul style="list-style-type: none"> VTS4 (multiple choice, medium RDS target) jump ductions Vergence at far <ul style="list-style-type: none"> VTS4 (multiple choice vergence, large RDS target) BI, BO, BU, BD Quoits Vectograms BI and BO Quoits Vectograms BI and BO jumps Spirangle Vectograms BI and BO
Home maintenance	Binocular accommodative rock (3 times a week for first month, 2 times a week for second month, 1 time a week for third month)	Home maintenance	Eccentric circles—facility at near (3 times a week for first month, 2 times a week for second month, 1 time a week for third month)

BD, base-down; BI, base-in; BO, base-out; BU, base-up; RDS, random dot stereopsis; VTS4, Vision Therapy System 4.

opsis could be achieved with vision therapy in adults with long-standing constant strabismus.

Studies have also shown improvement in binocularity with other forms of treatment in adults.^{5-10,28} The use of botulinum toxin²⁸ to treat strabismus has been reported to develop sensory fusion in adults. Sensory fusion development, with Worth four-dot or stereopsis, is possible in adults with strabismus after strabismus surgery owing to improved motor alignment.⁵⁻¹⁰

CONCLUSION

Although treatment of adult strabismus can be challenging, adults with goals related to binocularity may be successfully treated. These cases demonstrate that vision therapy is a viable treatment option for motivated adults with strabismus who want to achieve binocularity. However, this case series is limited to retrospective case studies and highlights the need for prospective, placebo-controlled, ran-

domized clinical trials, to evaluate the effectiveness of vision therapy as a treatment for adult strabismus. Eyecare providers should consider referring motivated adults with strabismus for treatment.

TAKE HOME POINTS

- Optometric vision therapy is a viable treatment option for motivated adults with long-standing strabismus.
- Stereopsis can be achieved with optometric vision therapy in adults with long-standing constant strabismus.
- Eye care providers should consider referring adults with strabismus for evaluation and treatment.

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