Article • Effectiveness of Vision Therapy for Divergence Insufficiency: A Case Series

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ABSTRACT

Background: When base-out prism glasses are not successful in maintaining binocularity and eliminating symptoms in divergence insufficiency, vision therapy serves as a viable non-surgical treatment option. We report three cases of patients with divergence insufficiency who improved negative fusional vergence, eliminated symptoms, maintained binocularity, and achieved stereopsis through vision therapy.

Case one: An 18-year-old female student presented with complaints of an occipital headache and occasional double vision, which was more pronounced at a distance and in the evening for the past four years. Orthoptic evaluation led to a diagnosis of divergence insufficiency. She was treated with base-out prism glasses and vision therapy. Over five months, the prism glasses were gradually weaned off, and the patient became asymptomatic with well-controlled deviation.

Case two: A 35-year-old male driver had to leave his job due to double vision. He had been using prism glasses for the past ten years. However, his negative fusional vergence and prism glasses were insufficient to control the deviation. After several sessions of vision therapy, his double vision was eliminated, and he was able to resume driving.

Case 3: A 12-year-old female student had headaches, usually while focusing on the board at school. She was diagnosed with left eye suppression and divergence insufficiency. After several sessions of office and home-based vision therapy, she experienced relief from symptoms and achieved binocularity and stereopsis.

Conclusion: Vision therapy is a non-surgical treatment approach for divergence insufficiency and offers an effective and promising alternative to surgical intervention. These three cases highlight successful and positive outcomes in patients with divergence insufficiency.

Keywords: divergence insufficiency, divergence therapy, prism glasses, vision therapy

Introduction

Divergence insufficiency (DI) is an uncommon condition that is characterized by a concomitant esodeviation that is greater at a distance than near.[1] DI in adults accounts for 10.6% of adult strabismus cases in population-based studies[2] and 0.1% to 7.0% in subjects without strabismus.[3-5] The etiology of DI remains unclear. There are different hypotheses, including age-related degeneration of the orbital connective tissues[6] and the shortening or increased tone of the medial rectus muscles.[7,8] Studies suggest that DI, divergence paresis, and divergence paralysis are part of a continuum of the same condition, differing only in their clinical and neurological findings.[9]

Various treatments are used to manage DI, such as refractive correction,[10] base-out prism correction,[11] divergence exercises or vision therapy,[10,12] and strabismus surgery.[8,13,14] Prism correction or surgery is usually the first line of treatment.[15] There is limited literature available on the effectiveness of vision therapy for DI.[16] This case series describes patients with DI who were managed with prism correction

and vision therapy, demonstrating improvements in binocularity and visual symptoms.

Case Reports

Case 1

An 18-year-old female student presented with complaints of an occipital-area headache and occasional double vision. The complaint of double vision was less pronounced during near activities and gradually increased at the end of the day. Her father remembers that the first time she complained of similar symptoms was at the age of 12 years. At that time, an eye examination was conducted elsewhere, but no documentation was available. Over time, her condition gradually worsened. Her father also mentioned that her symptoms significantly improved after she had rested or gotten some sleep, and she denied any history of head trauma, physical or psychological illness, or medication use. She was in good health, and her sleep pattern was normal.

Upon examination, her unaided visual acuity was 6/6 (N6 at 40 cm) in each eye. Dry refraction revealed +0.50-0.50x090 OD and +0.50-0.50x085 OS. With this correction, visual acuity was recorded as 6/6, N6 at 40 cm OD/OS. Cycloplegic refraction, using two drops of 1% cyclopentolate and one drop of 0.5% tropicamide, was +1.00-0.50x090 OD and +0.75-0.50x085 OS. Glasses +0.50-0.50x090 OD and +0.50-0.50x085 OS were prescribed, and she was advised to follow up after one month for an orthoptic evaluation.

Table 1. Orthoptic Findings Before and After VT: Case 1

Test	Before Therapy	Final Visit (after 5 months)
BCVA	RE: 6/6 (N6 @ 40cm) with +0.50-0.50x090 LE: 6/6 (N6 @ 40cm) with +0.50-0.50x085	RE: 6/6 (N6 @ 40cm) with +0.50-0.50x090 LE: 6/6 (N6 @ 40cm) with +0.50-0.50x085
Cover test (with correction)	Near: 4$^{\Delta}$ esophoria Distance: 15$^{\Delta}$ intermittent right esotropia with poor control	Near: 2$^{\Delta}$ exophoria Distance: 8$^{\Delta}$ esophoria
Gradient AC/A	2:1	2.5:1
NFV (break/recovery)	Near: 4/2 Distance: 2/x	Near: 18/14 Distance: 14/10
Worth four-dot test	Near: uncrossed diplopia Distance: uncrossed diplopia	Near: binocular single vision Distance: binocular single vision
Stereopsis (Titmus fly)	400 sec of arc	60 sec of arc
Correspondence (with synoptophore)	Normal	Normal

The binocular vision evaluation was performed (Table 1) after one month of adaptation with the glasses. The cover test revealed a comitant esophoria at near and intermittent right esotropia with poor control at distance. Extraocular movements were full and painless. The ocular deviation was measured as 4$^{\Delta}$ at near (1/3 meter) using an accommodative target of 6/12 optotype and 15$^{\Delta}$ at distance. When viewing a small, circular, illuminated target through red/green glasses over the spectacles, the patient reported uncrossed diplopia at both distance and near. Fusion was achieved at both distance and near with 10$^{\Delta}$ base out (BO).

The patient was diagnosed with DI. All treatment options, including both surgical and non-surgical, were reviewed in depth with the patient and her father. Her father wanted to try non-surgical treatment first, so she was recommended prism glasses of 10$^{\Delta}$ BO (split evenly) along with vision therapy. The minimum amount of prism required to eliminate the diplopia was prescribed for full time. The positive fusional vergence for near was also assessed and found to be adequate, allowing the patient to tolerate the prism for near work. After wearing prism glasses, a cover test revealed a small exophoria at near and an intermittent esotropia with moderate control at distance. Negative fusional vergence (break/recovery) was measured as 8/6 at near and 2/x at distance with the prism glasses on. Vision therapy focused on enhancing binocularity by improving negative fusional vergence and reducing the frequency of esodeviation. Office-based therapy (45 minutes) five days a week and home therapy (15 to 20 minutes daily) were prescribed.

After four weeks of various vision therapy activities (Table 2), the frequency of her esodeviation changed from intermittent esotropia with moderate control to esophoria at distance. Therapy was initially started at near, where the patient was comfortable, and the distance was then gradually increased. Peripheral fusional targets were used first, followed by central fusional targets. The strength of the prism glasses was gradually decreased by 3$^{\Delta}$ each month, and vision therapy, as outlined in Table 2, continued from the first session. After five months from the initiation of therapy, the prism glasses were discontinued, and the patient was asymptomatic. An evaluation (Table 1), showed a cover test of 2$^{\Delta}$ exophoria at near and 8$^{\Delta}$ esophoria at distance. The negative fusional vergence was sufficient to control the deviation, so we recommended continuing only home therapy

Table 2. Various Vision Therapy Activities (Office-Based and Home-Based): Case 1

Sessions	Tools and activities (office-based)	Tools and activities (home-based)
1-5 (first week)	1. Brock string (10 min) -Red bead at 0.3 meters, yellow bead at 0.6 meters, and green bead at 0.9 meters 2. Prism bar: base in (10 min) -Near (1/3 meter) only 3. Random Dot near base-in therapy on the VisuoPrime Professional Edition software (10 min) 4. Variable tranaglyphs: base-in (10 min) -Use peripheral target	1. Brock string (10 min) -Red bead at 0.3 meters, yellow bead at 0.6 meters, and green bead at 0.9 meters 2. Transparent eccentric card (5 min) -Hold the card at a close distance (0.5 meters)
6-10 (second week)	1. Brock string (10 min) -Red bead at 0.5 meters, yellow bead at 1 meter, and green bead at 1.5 meters 2. Prism bar: base in (10 min) -Near (1/3 meter) and 2 meters 3. Random Dot near base-in therapy on the VisuoPrime Professional Edition software (10 min) 4. Variable tranaglyphs: base-in (10 min) -Begin with peripheral target and move to central target	1. Brock string (10 min) -Red bead at 0.5 meters, yellow bead at 1 meter, and green bead at 1.5 meters 2. Transparent eccentric card (5 min) -Slowly move the card away (0.5 to 1 meter)
11-15 (Third week)	1. Brock string (10 min) -Red bead at 0.5 meters, yellow bead at 1.5 meters, and green bead at 3 meters 2. Prism bar: base in (10 min) -Near (1/3 meter) and 3 meters 3. Random Dot near and distance base-in therapy on the VisuoPrime Professional Edition software (15 min) 4. Variable tranaglyphs: base-in (10 min) -Use central targets	1. Brock string (10 min) -Red bead at 0.5 meters, yellow bead at 1.5 meters, and green bead at 3 meters 2. Transparent eccentric card (5 min) -Hold the card at 1 meter
16-20 (fourth week)	1. Brock string (10 min) -Red bead at 0.5 meters, yellow bead at 1.5 meters, and green bead at 3 meters 2. Prism bar: base in (10 min) -Near (1/3 meter) and 3 meters 3. Random Dot near and distance base-in therapy on the VisuoPrime Professional Edition software (15 min) 4. Variable tranaglyphs: base-in (10 min) Use central targets with more central demand	1. Brock string (10 min) -Red bead at 0.5 meters, yellow bead at 1.5 meters, and green bead at 3 meters 2. Transparent eccentric card (5 min) -Hold the card at 1 meter

with the Brock string and eccentric card for three days per week (15-20 minutes each session) and advised a six-month follow-up.

Case 2

A 35-year-old male driver presented with complaints of eyestrain and intermittent double vision at both distance and near, which usually occurred at the end of the day. He was forced to leave his job two years prior due to persistent double vision. He had been using prism glasses since the age of 25. Initially, the prism glasses resolved the double vision, but over time, the symptoms gradually reoccurred. He had no documentation of prior consultations and denied any history of trauma or psychological illness. His medical history was negative, and he was not taking any medication.

Visual acuity was 6/6 (N6 at 40 cm) in each eye through his presenting glasses (Plano with 3^{Δ} BO OD, OS). The dry refraction revealed no changes. Cycloplegic refraction was +0.25 OD, OS. The final subjective acceptance was plano in each eye. After one week, a binocular vision evaluation was conducted (Table 3). Without his prism glasses, the cover test revealed a comitant, high-frequency left intermittent esotropia of 10^{Δ} at near and a constant left esotropia of 20^{Δ} at distance. With the prism glasses on, he showed intermittent left esotropia with moderate control of 4^{Δ} at near and intermittent left esotropia with poor control of 15^{Δ} at distance.

He was diagnosed with DI with normal correspondence. Since the patient did not want strabismus surgery and was already using glasses with prism that did not eliminate diplopia, vison therapy to enhance negative fusional vergence was the selected treatment option. With prism glasses (Plano with 3^{Δ} BO OD, OS), office-based therapy was conducted six sessions per week (45 minutes per session), and home-based therapy for 15 minutes daily was prescribed (Table 4). The initial sessions of vision therapy were aimed at increasing the amplitude of negative fusional vergence at near. Once he was comfortable at near, the distance was gradually increased. We started with peripheral fusional targets, and as the amplitude increased, we progressed to macular and foveal fusional targets in the synoptophore to increase the difficulty of the task.

After one month of vision therapy, he had no visual complaints. The cover test revealed orthophoria at near and intermittent left esotropia with good control at a distance while wearing prism glasses. Without the glasses, the frequency of intermittent esodeviation increased. He had to discontinue office-based vision therapy because he needed to return to his hometown, so we advised him to continue home-based therapy with his prism glasses using the Brock string, prism bar, and eccentric card, and to follow up after three months.

Table 1. Orthoptic Findings Before and After VT: Case 2

Test	Before Therapy		After Therapy	
	Without prism glasses	With prism glasses	Without prism glasses	With prism glasses
BCVA	RE: 6/6 (N6 @ 40cm) LE: 6/6 (N6 @ 40cm)	RE: 6/6 (N6 @ 40cm) LE: 6/6 (N6 @ 40cm)	RE: 6/6 (N6 @ 40cm) LE: 6/6 (N6 @ 40cm)	RE: 6/6 (N6 @ 40cm) LE: 6/6 (N6 @ 40cm)
Cover test (with correction)	Near: 10^{Δ} left intermittent esotropia with poor control Distance: 20^{Δ} constant left esotropia	Near: 4^{Δ} left intermittent esotropia with moderate control Distance: 15^{Δ} left intermittent esotropia with poor control	Near: 6^{Δ} esophoria Distance: 16^{Δ} left intermittent esotropia with moderate control	Near: orthophoria Distance: 10^{Δ} left intermittent esotropia with good control
Gradient AC/A	2.5:1		3:1	
NFV (break/recovery)	Near: 2/x Distance: x/x	Near: 4/2 Distance: 2/x	Near: 10/6 Distance: 6/4	Near: 20/16 Distance: 16/10
Worth four-dot test	Near: uncrossed diplopia Distance: uncrossed diplopia	Near: uncrossed diplopia Distance: uncrossed diplopia	Near: binocular single vision Distance: uncrossed diplopia	Near: binocular single vision Distance: binocular single vision
Stereopsis (Titmus fly)	400 sec of arc	200 sec of arc	80 sec of arc	60 sec of arc
Correspondence (with synoptophore)	Normal		Normal	

Table 4. Various Vision Therapy Activities (Office-Based and Home-Based): Case 2

Sessions	Tools and activities (office-based)	Tools and activities (home-based)
1-5 (first week)	1. Brock string (10 min) -Red bead at 0.2 meters, yellow bead at 0.4 meters, and green bead at 0.6 meters 2. Prism bar: base in (10 min) -At near (1/4 meter) 3. Random Dot near base-in therapy on the VisuoPrime Professional Edition software (15 min) 4. Synoptophore: base in (10 min) -Peripheral fusional target	1. Brock string (10 min) -Red bead at 0.3 meters, yellow bead at 0.6 meters, and green bead at 0.9 meters 2. Transparent eccentric card (5 min) -Hold the card at a close distance (0.5 meters)
6-10 (second week)	1. Brock string (10 min) -Red bead at 0.4 meters, yellow bead at 0.8 meters, and green bead at 1.2 meters 2. Prism bar: base in (10 min) -At 1/3 meter and 1 meter 3. Random Dot near base-in therapy on the VisuoPrime Professional Edition software (10 min) 4. Synoptophore: base in (10 min) - Start with peripheral fusional slides and proceed up to macular fusional slides 5.Transparent eccentric card (5 min) -Hold the card at close distance (0.5 meters)	1. Brock string (10 min) -Red bead at 0.5 meters, yellow bead at 1 meters, and green bead at 1.5 meters 2. Transparent eccentric card (5 min) -Slowly move the card away (0.5 to 1 meters)
11-15 (Third week)	1. Brock string (5 min) -Red bead at 0.5 meters, yellow bead at 1.3 meters, and green bead at 2 meters 2. Random Dot near and distance base-in therapy on the VisuoPrime Professional Edition software (15 min) 3. Variable tranaglyphs: base-in (10 min) -Begin with peripheral targets and move to central targets 4. Synoptophore: Base in (10 min) -Start with macular fusional slides and proceed to foveal fusional slides	1. Brock string (10 min) -Red bead at 0.5 meters, yellow bead at 1.5 meters, and green bead at 3 meters. 2. Transparent eccentric card (5 min) -Hold the card at 1 meter
16-20 (fourth week)	1. Brock string (5 min) -Red bead at 0.5 meters, yellow bead at 1.5 meters, and green bead at 3 meters 2. Random Dot near and distance base-in therapy on the VisuoPrime Professional Edition software (15 min) 3. Variable tranaglyphs: base-in (10 min) -Use targets with more central demand 4. Synoptophore: base in (10 min) -Foveal fusional target	1. Brock string (10 min) -Red bead at 0.5 meters, yellow bead at 1.5 meters, and green bead at 3 meters 2. Transparent eccentric card (5 min) -Hold the card at 1meter 3. Prism Bar: base in (10 min) -Near (1/3 meter) and 3 meters.

Case 3

A 12-year-old female student presented with complaints of asthenopia, occasional inward deviation of her left eye, and headache, which had gradually increased over the past four years. Her headache worsened, particularly when she had to take notes from the board at school. Pain relief medication was used, but her symptoms did not improve. She had not undergone an eye examination in the past four years. Her mother denied any history of trauma, systemic illness, or medication use. She had normal sleep patterns as well.

Unaided visual acuity was 6/6 (N6 at 40 cm) in each eye. Both dry and cycloplegic refractions were performed. Dry refraction revealed plano OD, OS, while cycloplegic refraction showed +0.25 OD, +0.50 OS. She did not require any glasses for refractive error correction. A binocular vision evaluation was conducted (Table 5). The cover test revealed a comitant, high-frequency left intermittent esotropia of 2^{Δ} at near and a constant left esotropia of 12^{Δ} at distance. The Worth four-dot test showed left eye suppression at both distance and near. She had poor negative fusional vergence for both near and distance, measured as 2/x (break/recovery). Fusion was achieved only when using peripheral fusional target slides on the synoptophore. Stereoacuity was absent.

Table 5. Orthoptic Findings Before and After VT: Case 3

Test	Before Therapy	Final Visit (After 5 Months)
BCVA	RE: 6/6 (N6 @ 40cm) with plano LE: 6/6 (N6 @ 40cm) with plano	RE: 6/6 (N6 @ 40cm) with plano LE: 6/6 (N6 @ 40cm) with plano
Cover test (with correction)	Near: 2^{Δ} intermittent left esotropia with poor control Distance: 12^{Δ} intermittent left esotropia with poor control	Near: orthophoria Distance: 8^{Δ} esophoria
Gradient AC/A	3:1	3:1
NFV (break/recovery)	Near: 4/2 Distance: 2/x	Near: 20/16 Distance: 14/10
Worth four-dot test	Near: left suppression Distance: left suppression	Near: binocular single vision Distance: binocular single vision
Stereopsis (Titmus fly)	Absent	50 sec of arc
Correspondence (with synoptophore)	Normal	Normal

She was diagnosed with DI with normal correspondence. The angle of deviation was small, so strabismus surgery was not recommended. The options of vision therapy and prism glasses were discussed with the mother (Table 6). The initial goal was to eliminate suppression, followed by establishing binocularity, maintaining fusion, and strengthening the negative fusional vergence. Once suppression was eliminated, relieving prism glasses (2^{Δ} BO OD, OS) were used to maintain fusion. Prism glasses (Plano with 2^{Δ} BO OD, OS) were worn to maintain fusion. Positive fusional vergence at near was evaluated prior to prescribing prism glasses and was found to be sufficient, allowing the patient to comfortably tolerate the prism during near work. The therapy was continued with the glasses until negative fusional vergence was strong enough to control the deviation. An evaluation was performed after 10 weeks (Table 5). The patient was asymptomatic, and negative fusional vergence was normal. We advised continuing home-based therapy and bi-annual follow-up.

Discussion

This case series highlights that vision therapy, in combination with prism lenses, is an effective treatment option for DI. All three patients showed improvement in visual symptoms, negative fusional vergence, and the frequency of deviation.

The etiology of the DI in these patients was unclear. DI must be differentiated from divergence paralysis and sixth nerve paresis.[16] The comitant nature, occasional double vision (more pronounced at distance) that increased over time and disappeared after rest, and the gradual onset help to differentiate DI from sixth nerve paresis and divergence paralysis.[16]

To determine the best management plan, a thorough evaluation is necessary, which includes a detailed case history, sensorimotor examination, and neurological imaging.[17] An MRI was performed in each case above as a precaution. A sensorimotor exam should include checking the patient's visual acuity, determining the angle of deviation, and evaluating the level of stereopsis and amplitudes of negative fusional vergence. The management of DI lacks a standardized approach. Typically, prism or surgery are the initial treatment strategies.[15] A recent prospective study showed that surgery provides superior outcomes compared to prism glasses.[15] There is limited literature available on the effectiveness of vision therapy for DI,[16] but several studies suggest

Table 6. Various Vision Therapy Activities (Office-Based and Home-Based): Case 3

Sessions	Tools and activities (office-based)	Tools and activities (home-based)
2 weeks (12 sessions)	1. Cheiroscope (10 min) 2. Red/Green Hart Chart (10 min) -Both near and distance 3. Anti-suppression therapy on the VisuoPrime Professional Edition software (15 min) 4. Synoptophore: base in (10 min) -Start with peripheral fusional slides and later progress to macular slides	1. Red/Green Hart Chart (10 min) 2. Cheiroscope (10 min)
With prism glasses (2^{Δ} BO in each eye)		
4 weeks (24 sessions)	1. Brock string (5 min) -Start with the red bead at 0.4 meters, the yellow bead at 0.8 meters, and the green bead at 1.2 meters. Gradually increase the distance of each bead in subsequent sessions. 2. Random Dot base-in therapy on the VisuoPrime Professional Edition software(10min) -Start at near and gradually increase the distance in subsequent sessions. 3. Synoptophore: base in (10 min) -Start with peripheral fusional slide and later progress to macular and foveal slides. 4. Prism Bar: base in (10 min) -Start at 1/3 meter and gradually increase the distance in subsequent sessions. 5. Variable tranaglyphs: base-in (10 min) -Gradually use the targets with more central demand.	1. Red/Green Hart Chart (5 min) 2. Brock string (10 min) -Gradually increase the distance of the beads. 3. Transparent eccentric card (5min) -Start at 40 cm and gradually increase the distance.
Remove the prism glasses		
4 weeks (24 sessions)	1. Brock string (5 min) -Start with the red bead at 0.4 meters, the yellow bead at 0.8 meters, and the green bead at 1.2 meters, then gradually increase the distance of the beads. 2. Random Dot base-in therapy on the VisuoPrime Professional Edition software (15 min) -Start at near and gradually increase the distance in subsequent sessions. 3. Synoptophore: base in (10 min) -Start with the peripheral slides, then progress to the macular and foveal slides. 4. Prism Bar: base in (10 min) -Start with close distance and increase the distance gradually. 5. Variable tranaglyphs: base-in(10 min) -Gradually use the targets with more central demand.	1. Brock string (10 min) -Gradually increase the distance of the beads. 2. Transparent eccentric card (5 min) -Gradually increase the distance.

that vision therapy can be effective in managing esodeviation.[18]

Vision therapy for DI is quite challenging;[16] this was discussed with of all the patients. Vision therapy for these patients was structured in accordance with the treatment guidelines for DI.[16] In this case series, the objective of vision therapy was to eliminate diplopia if present, enhance sensory and motor fusion, reduce the frequency of deviation, and maintain binocularity. In all three patients, therapy started at near, where the patients were comfortable and successful, and gradually increased to the distance. Additionally, peripheral fusional targets were introduced first, followed by the use of central targets.

Vision therapy may also be necessary with the combination of base-out prism for the management of DI, as in this case series. The amount of prism can be determined using several methods, such as Sheard's criterion, fixation disparity analysis, and Percival's criterion.[16] However, in this case series, we prescribed the minimum amount of prism needed to maintain fusion and eliminate diplopia. Occasionally, this prism successfully relieves the patient's symptoms at distance but may cause discomfort at near when worn full-time. If the patient's positive fusional vergence at near is inadequate, they may not tolerate the prism for near activities.[16]

When all vision therapy objectives have been achieved, therapy can be discontinued.[16] Determining the endpoint of vision therapy in these types of cases is crucial, as there is a risk of rebound. When to discontinue active therapy is primarily determined by the amplitude of negative fusional vergence and the frequency of the deviation. If the patient remains asymptomatic and the fusional vergence reserve is sufficient to control the deviation while meeting Percival's criterion,[16] therapy may be discontinued. Therefore, evaluations should be conducted after each week of therapy sessions and at every follow-up.

While all three cases were successful, there are some limitations. The prism prescriptions were not standardized; we chose the minimum amount of prism needed to eliminate double vision using a trial-based approach. Second, long-term follow-up was not conducted to observe for any rebound effect or regression. Third, distance stereoacuity was not assessed, which could help to evaluate the effectiveness of the treatment and overall binocular visual function.

Conclusion

Vision therapy is a non-surgical treatment approach for DI and offers an effective and promising alternative to surgical intervention. This case series demonstrates that vision therapy is a viable option and can provide positive results. A thorough assessment, including case history, binocular vision parameters, and imaging, is crucial for determining the appropriate treatment. It is necessary to conduct further longitudinal comparative studies on the outcomes of optical correction, vision therapy, prism glasses, and surgery for DI.

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