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The Role of Gait Analysis, Egocenter and Yoked Prism in Parkinson's Disease

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ABSTRACT

Background: Parkinson's patients commonly experience a visual midline shift that causes postural and gait changes, increasing the risk of falls. If the optometrist can improve the visual midline shift with the use of yoked prism prescriptions, the risk of falls will decline and ultimately decrease the overall potential healthcare cost.

Case Report: A 77-year-old white male diagnosed with Parkinson's presented for an evaluation. The patient complained of double vision and difficulty judging space perception that was affecting his balance when walking. He was treated with a lens prescription that included a combination of yoked and base-in prisms.

Conclusion: After 1 month of wearing the new prism prescription, he no longer experienced double vision and showed improved balance when walking. This case emphasizes the importance of evaluating visual midline shifts and prescribing yoked prisms in this patient population to improve overall balance and to lower the risk of falls.

Keywords: balance, Parkinson's disease, visual midline shift, yoked prisms

Introduction

Parkinson's disease (PD) is the second most common neurodegenerative disorder, following Alzheimer's disease. It is a disorder affecting basal ganglia function, leading to the cardinal signs of tremor, rigidity, akinesia (bradykinesia), and postural instability. Parkinson's disease is caused by a loss of nigrostriatal dopaminergic neurons, which in turn causes the loss of motor function.[1] The classic pill-rolling resting tremor (a tremor that occurs at rest wherein the fingers/wrist move in a repetitive motion similar to a rhythmic voluntary manipulation of small objects or pills in the hand) is one of the best indicators for Parkinson's, although some other neurological disorders can also present with the same finding.[2]

Many professionals will use the general term Parkinsonism when a patient is found to have stiffness, slowness of movement, and tremors before a definitive diagnosis for Parkinson's is made.[3] Other types of disorders that fall under Parkinsonism include: progressive supranuclear palsy, multiple system atrophy, vascular Parkinson's, and drug-induced Parkinsonism.[4]

A Parkinson's patient will seek neuro-optometric eye care due to poor visual spatial orientation that affects balance and posture, thus increasing the patient's risk of falls.[5]

This article presents:

1) A review of Parkinson's characteristics, including diagnosis, testing, prevalence, visual consequences, and postural changes
2) A review of visual midline and posture/gait analysis
3) A systematic method to help determine a yoked prism prescription to decrease risk of falls
4) A case review

PD Characteristics

Diagnosis

Diagnosing Parkinson's is not easy and can take considerable time. There is not one specific test available that confirms the diagnosis. When a patient consults with a Parkinson's examiner (a neurologist who is trained specifically to treat movement disorders), one critical component of the work-up is the detailed neurological history. The examiner will ask about common early symptoms, including decreased sense of smell, anxiety, depression, disturbed sleep, tiredness, constipation, and loss of memory.[4] The examiner will also want to know if the patient has common motor symptoms, including slowness of movement (bradykinesia), small handwriting tendencies, and a resting tremor (Parkinson's tremors are less noticeable with movement).[3] These symptoms will often worsen with illness or stress.[6]

During the evaluation, the patient will be asked to draw/write, walk, and speak.[4] A Parkinson's patient will print very small and show a gradual fade.[7] When asked to walk, the PD patient will exhibit a reduced arm swing, stride length, and speed. Speech will be soft and lack volume.[3]

A brain scan may be suggested to help rule out other types of Parkinsonism, but there is no scan available at this time that can confirm a definitive diagnosis of Parkinson's.[3] The brain scans of Parkinson's patients usually show no abnormalities. A newer type of brain imaging scan, known as a dopamine transporter scan or DAT-SPECT, can help specialists determine whether there is a loss of dopamine-containing brain cells. Unfortunately, an abnormal DAT-SPECT can also be found with other rarer neurological disease processes[3] and so is not a definitive test for diagnosing Parkinson's.

Prevalence of Parkinson's Disease

Currently, the exact prevalence of Parkinson's in the United States is uncertain. Many estimates are based upon rates extrapolated from older studies conducted in smaller regions of the United States and are taken to represent the entire United States population.

In 2010, one official estimate determined an extrapolated prevalence rate of 430,000[10] for the ≥40 y.o. population using the results from a study conducted in a sparsely populated rural county of Mississippi in 1978.[8] Another official estimate found an extrapolated prevalence rate of nearly 920,000[9] for the ≥40 y.o. population based on findings from a more recent study conducted in Nebraska in 2000.[10]

Because we still do not know how many people have Parkinson's, the Parkinson's Disease Foundation has formed the Parkinson's Prevalence Project to conduct a review of numerous current databases to address this problem. This knowledge will be significant in order to help the medical community determine how to distribute funds for diagnostic testing, pharmaceutical treatment, and rehabilitation strategies wisely in order to serve these patients.

Visual Consequences of Parkinson's Disease

Parkinson's disease causes many visual problems, most likely secondary to deficits in the magno-, parvo-, and koniocellular pathways, as reported by Startucci.[11] Armstrong[12] published a review of commonly found visual problems in Parkinson's patients that included poor low-contrast visual acuity, poor color discrimination, abnormal blink reflex, abnormal pupil reactivity with anisocoria, hypometric saccades, smooth pursuit abnormalities (movement interrupted by small saccades), and increased latencies of the visual evoked potential p100.

In addition, Parkinson's patients commonly exhibit problems with visuo-spatial working memory, leading to a shift of egocenter.[13-15] This shift of one's egocenter will directly affect posture, spatial orientation, and balance. This impairment is most likely secondary to the degenerative process that takes place in the basal ganglia, the dorsal visual stream, and the frontal-prefrontal cortex.[16] If the egocentric shift is severe, risk of fall increases, and subsequent injury becomes more likely.

Postural Changes in Parkinson's Disease

It is common to see postural changes at some stage with the Parkinson's patient. The different types of deformities include antecollis (dropped head), lateral flexion (known as Pisa syndrome), and camptocormia (stooped or bent posture due to marked bending of the thoraco-lumbar spine). Muscular rigidity, generalized weakness secondary to myopathy, dystonia affecting the midline (also known as axial dystonia), body perception defects (due to impaired proprioception), and structural changes in the spine are some suggested multifactorial pathophysiological changes that lead to the postural shifts.[17] Yoshi[18] showed that postural changes in Parkinson's patients are also influenced by inter-related

Figure 1. *Spatial Location Board*

factors, including age, gender, disease progression, and anti-Parkinson drugs. Doherty[19] conducted a study that looked at fixed posture problems versus reversible postural problems in Parkinson's patients. She found that many Parkinson's patients had severe postural changes on standing radiograph scans but had completely normal scans when supine. Her study confirmed that many Parkinson's patients will have abnormal tone of posture secondary to muscle changes that occur only when standing/walking, thus indicating a lack of a bony structural change. These studies suggest that early diagnosis and treatment, e.g., utilizing yoked prisms to help center the Parkinson's patient's visual midline, could potentially eliminate or at least delay the progression of postural deformity.

Visual Midline and Posture/Gait Analysis

In order to walk with good balance, constant feedback from our visual, proprioceptive, kinesthetic, and vestibular sensory systems is needed. Parkinson's patients who lack this proprioceptive feedback will exhibit difficulty walking even though their joints move freely. Padula has shown that a visual midline shift will occur when there is a mismatch between spatial information and the proprioceptive base of support (the area of the body in contact with the support surface[20]). This midline shift, also known as Visual Midline Shift Syndrome, will cause changes with posture and balance, thus affecting gait. Yoked prisms have been shown to help remediate these shifts, improving balance and thereby reducing the risk of fall.[21]

When the eye care provider evaluates a Parkinson's patient with gait abnormalities, there needs to be a systematic approach used for the evaluation of a visual midline shift. This evaluation needs to provide clinical measures that can help to determine whether a yoked prism correction is warranted, and if so, what strength/orientation is needed for the patient.

Visual Midline Analysis

There are numerous methods used to evaluate a patient's visual midline. Many practitioners use the Wolf Wand technique, where the patient follows a moving target from the periphery toward the midline and is asked to let the tester know when the target is centered in front of the nose. The

Figure 2. *Photos of static posture*

tester then determines whether the target is "off-center" and notes the direction/amount of the displacement.[22] A technique that provides written documentation is the Spatial Location Board, available from Bernell[a] (Figure 1). This device consists of a grid pattern on both sides of a 3' x 2' board. The board can be easily pivoted to either a vertical or horizontal plane. Three magnetic "peg" targets are arranged on one side of the board in a semi-linear fashion set 50cm from one end of the board. The patient stands at the end of the board, with his/her nose directly placed against the handle. Initially, the board is oriented vertically so that the magnetic targets are positioned on the side of the patient's non-dominant hand. The patient is asked to take a dry-erase marker with the dominant hand and mark the opposite side of the board, mirroring the position of each target. An average of the amount of deviation from each target's center on the vertical y-axis is calculated. The same steps are repeated with the board positioned horizontally, with the magnetic targets now located on the top of the board. The patient is given a different colored marker and again stands with his/her nose against the board. The patient is asked to mark from below where each target's position is perceived. The amount of deviation on the horizontal x-axis is then averaged. The two values are used to estimate the amount of lateral-anteroposterior midline shift.

Static Posture Analysis

In order to understand postural control, it is best first to define posture. Posture is the ability to align the body biomechanically and to orient it to the environment.[23] In order to achieve postural stability or balance, one must be able to control the center of mass in relationship to the base of support. The nervous system produces force to ensure that the center of mass stays within the boundaries of the base of support. The center of the distribution of the total force applied to the supporting surface is known as the center of pressure.[24] It is this interaction between center of mass and center of pressure that determines one's postural control. It is the responsibility of the optometrist to determine how vision influences this postural control.

The most convenient and least expensive method for documenting one's posture in static stance is with photos and scales. A photograph is taken from 4 different viewpoints (front, back, left, and right lateral). The patient is asked to stand with equal weight on both feet. It helps to have a grid-type background behind the patient (door-size grids are available from www.posturezone.com) to aid with the visualization of weight shift in the anteroposterior and mediolateral directions (Figure 2).

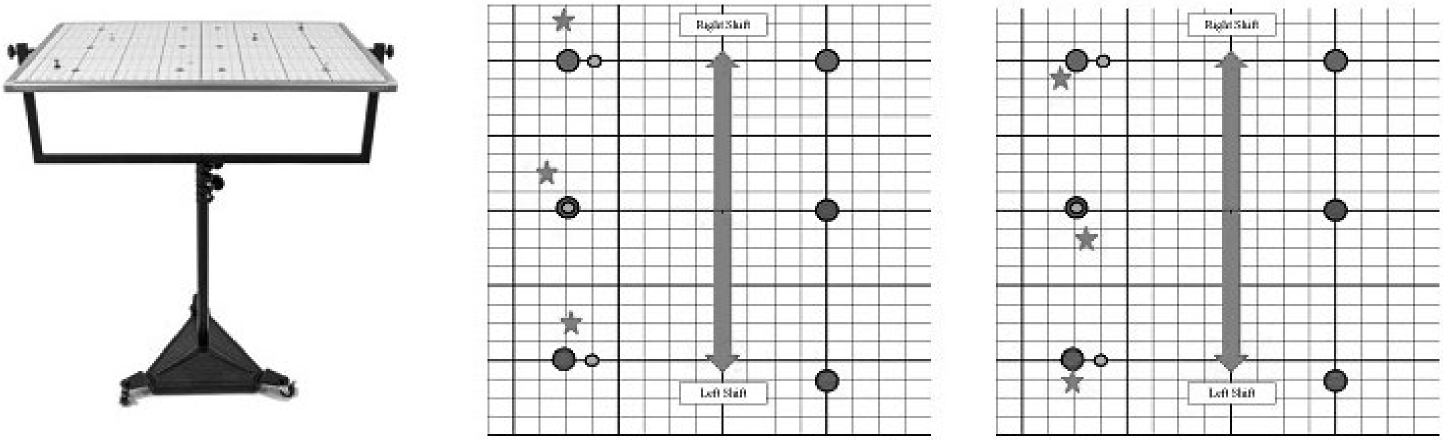
With smart phone technology and apps, one can easily organize the photographs on one sheet of paper and print for easier review/chart documentation. Clinically useful information can be obtained by systematic observational analysis, noting variation of weight displacement laterally or anteroposteriorly, which may be suggestive of a visual midline shift. The amount of postural shift is compared to the visual midline shift to determine whether both analyses suggest the same perceptual shift.

Gait Analysis

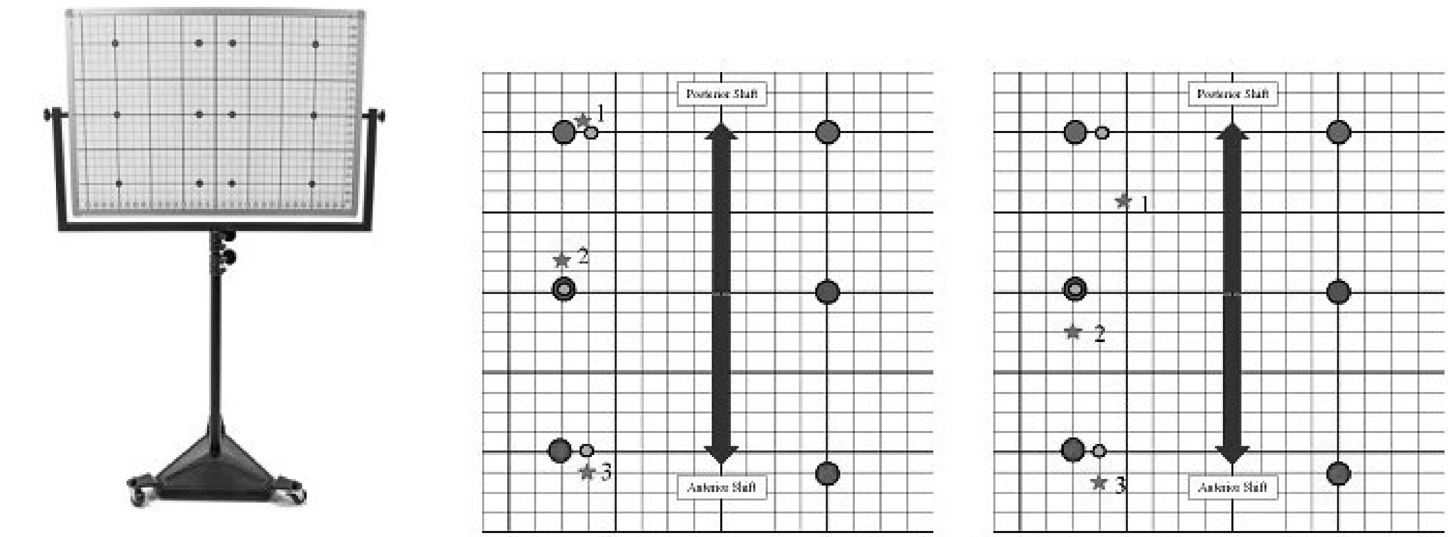
When the static posture and visual midline assessments suggest a shift, the eye care provider next needs to consider whether the midline shift is present during walking. In order to look at one's gait, familiarity with the mechanics and the terminology used for observations of pathological gait is needed to understand the functional implications. A well-accepted gait model is the Perry Model.[25] Dr. Jacquelyn Perry and colleagues from Ranch Alas Amigos, California videotaped hundreds of patients' gait patterns from 1980 to 2000. They used the video tapes to analyze and to collate data in order to create common definitions/defined methods for observational gait analysis. They defined 8 phases of the gait cycle using a systematic approach that compares one limb to the other. When there is disease or trauma, a disruption will occur to the timing, coordination, speed, and versatility of the gait. Differences are seen in the way each foot strikes the ground and the length of the stride; the positioning of the knees will improve if the visual midline is centered. In addition to the observational gait analysis method, there are also many different devices/instruments used to gather information about gait mechanics.

Observational gait analysis is not typically done in an optometry office, and many private practices do not have the necessary space or the funds to invest in complex, comprehensive equipment.[26] However, there are some screening techniques that can be used to help guide our assessment of the Parkinson's patient's gait.

One easy and inexpensive stride analysis technique is the timed up and go test (TUG). All that is needed is a standard stopwatch. The TUG method evaluates gait speed and is a relatively objective test used to guide decision making regarding the patient's risk of fall.[27] The patient wears his regular footwear and can use a walking aid if needed. For the testing area, an identifiable line is marked on the floor 10 feet away. This can easily be done in the exam lane by placing a piece of colored electrical tape 10 feet from the exam chair. The patient begins by sitting back in the exam chair, and he is asked to identify the



Figures 3a,b,c. *a) Spatial Location Board presented along x-axis. b) and c) represent examples of positions marked by patient (green stars) assessing perception of spatial localization. In Figure 3b, the average amount of displacement from the positioned pegs (4R+4R+4R/3) is 4pd of perceptual shift to the right side. In Figure 3c, the average amount of perceptual shift (2L+3L+2L/3) is 2.25pd to the left side.*



Figures 4a,b,c. *a) Spatial Location Board presented along y-axis. b) and c) represent examples of positions marked by patient (purple stars) assessing perception of spatial localization. In Figure 4b, the average amount of displacement from the positioned peg (1pd P+3pd P+2pd A/3) is approximately 0.50pd of perceptual shift posteriorly. In Figure 4c, the amount of perceptual shift (7pd A+4pd A+3pd A/3) is approximately 4.50pd of perceptual shift anteriorly.*

line 10 feet away on the floor. The instructions to the patient are as follows:

"When I say 'Go,' I want you to stand up from the chair, walk to the line on the floor at your normal pace, turn, walk back to the chair at your normal pace, and then sit down again."

On the word "Go," the timer is started. The timer is stopped after the patient sits back down. The time to complete the task is recorded. Also, differences are recorded as to the way each foot strikes the ground, how the weight is shifted to each side, the length of the stride, and the positioning of the knees. A patient who takes ≥12 seconds to complete the TUG is considered to be at high risk for falling.[28] If the risk of fall is determined to be significant and the patient has an observable visual midline shift, it is our responsibility to prescribe the best prism prescription that will improve spatial perception. The patient will then have a better visual system to support the motor system. A referral for treatment is then made to a physical therapist trained in gait assessment.

Determining Yoked Prism Correction

Research has shown the effectiveness of yoked prisms on improving spatial orientation.[29] Padula et al. have shown that center of mass can be altered when yoked prisms improve visual midline centration.[20] If yoked prisms can center the visual midline, we can ultimately center and stabilize the center of mass for Parkinson's patients, which will lead to improved weight distribution when walking and decreased risk of fall.

Padula uses a graph analysis technique, where the weight shift is assigned a value between 1 and 12, with 12 being the greatest amount of weight shift in any one direction (the center of gravity limit within or beyond the base of support). I have found that one square on both the Spatial Location Board and Postural Zone door grid correlates to a 2pd visual midline shift. The values obtained from the Spatial Location Board and static postural photos are averaged to determine the starting strength and direction of the prism correction. Figures 3a-c and 4a-c represent examples of visual midline shifts along the x

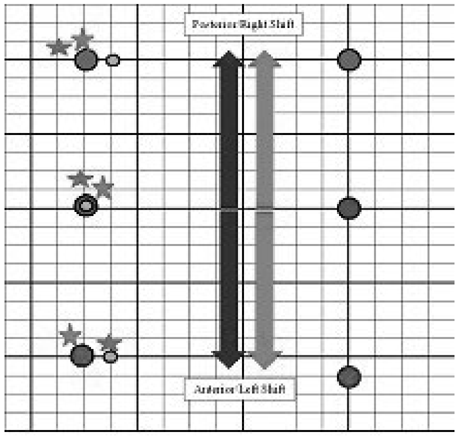


Figure 5. *Spatial Location Board representation of 2pd right (green stars) and 1.5pd (purple stars) posterior visual midline shift*

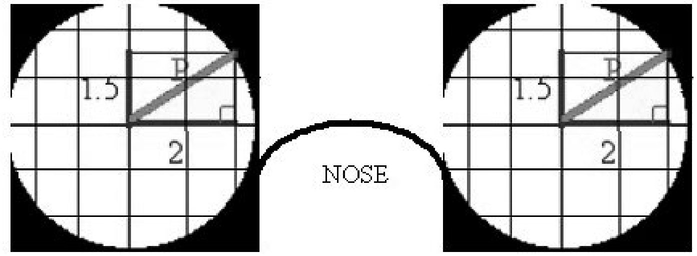


Figure 6. *Graphical representation of 2pd base left/1.5pd base up*

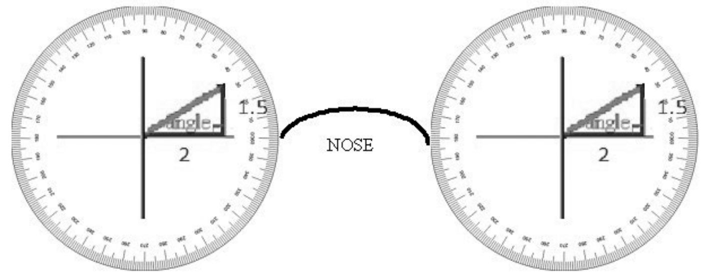


Figure 7. *Graphical representation of angle created by 2pd base left/1.5pd base up*

and y axes that can be seen during the Spatial Location Board analysis.

If the patient demonstrates a leftward midline shift, base-right prism is used. If the patient demonstrates a rightward midline shift, base-left prism is used. Base-up is used for a posterior midline shift and base-down for an anterior midline shift. Sometimes a patient can have a paradoxical response to the suggested prism, but usually the above applies. When there is a combination of a lateral and either an anterior or posterior shift, the prism amount and base direction/axis can be calculated using basic geometry and trigonometry formulas conceptualizing space along the x and y axes. This is a very basic method to help the optometrist determine a starting point for prism treatment.

Figure 5 illustrates an example of the Spatial Location Board with a 2pd right/1.5pd posterior shift. For the right shift, base-left prism is needed; for the posterior shift, base-up prism is needed. In order to determine the prism amount, an x-y graph (Figure 6) is used to visualize the yoked prism lenses needed for 2pd left and 1.5pd up yoked prisms.

A right triangle is formed by connecting the points for 1.5 up and 2 left. The red line on the diagram ("P") is the value needed. Using the Pythagorean Rule, "P", the longest side of the right triangle, is equal to the square root of the sums of the squares of the two shorter sides. The "P" value for 1.5 up and 2 left is:

- Step 1: P = $\sqrt{}$(2^2 + 1.5^2)
- Step 2: P = $\sqrt{}$(4 + 2.25)
- Step 3: P = $\sqrt{}$(6.25)
- Step 4: P=2.5

2.5pd is the amount of prism that results from 1.5 up and 2 left. The axis is determined by using the rule of trigonometry that the tangent of an angle is the opposite side divided by the adjacent side, or the angle between the horizontal meridian and the line marked P (Figure 7). The opposite side is the vertical portion of the prism, 1.5, and the adjacent side is the horizontal part of the prism, 2.

To calculate the angle for 1.5 up and 2 in, follow these steps:

- Step 1: Angle = tan-1 of opposite/adjacent = 1.5/2 = 0.75
- Step 2: Angle = tan-1 of 0.75 = 37° (corrected to 1 decimal place)

The same amount of prism and angle would be used for the left eye. When the prism direction is other than a base-left/up combination, one will need to add or subtract the angle value from the horizontal or vertical axis to obtain the correct axis value.

Once a numerical value for the yoked prism correction has been estimated, the yoked prisms are trial framed, and the patient is asked to perform the TUG test. Observations are recorded noting stride length, speed, and equality of weight distribution. A sensorimotor evaluation is also done to evaluate binocularity. The Spatial Location Board and static photos are repeated. Adjustments are made to the initial prism amount/base based upon the changes observed.

Case Report

A 77-year-old male with Parkinson's presented to the clinic with problems judging space perception and reduced acuities in both eyes. He reported that he could not read due to constant, horizontal diplopia when viewing print held at near. He was accompanied by his wife and daughter, who both reported that he would frequently veer to the right when walking and bump into people/objects on that side. He used a single-point cane to help maintain his balance. His family was concerned about his risk of falling and requested an evaluation at my clinic. His systemic history included non-insulin type 2 diabetes, hypertension, and Parkinson's disease. Ocular history included dry AMD, pseudophakia OD, and cataract OS. When walking from the waiting room to the exam room, he leaned and veered to the right side of the hall. Static posture photos showed a 4pd left shift (Figure 2); the Spatial Location Board demonstrated a 1pd left shift. The average of these two values approximated a 2.5pd left shift. Entering visual acuities were 20/40-3 OD and 20/30-3 OS wearing the following progressive bifocal correction: +0.75-1.00x085/+2.50 OD, +3.25-1.25x090/+2.50 OS. Pupils, extraocular muscle motility, confrontation fields, and Amsler grid testing results were normal OU. Near point of convergence was receded to 37cm break/1m regain. Sensory fusion with Worth 4 Dot testing showed fusion out to 8 feet then crossed diplopia further out. Unilateral cover testing showed an 8pd intermittent, alternating exotropia at distance and a 14pd intermittent, alternating exotropia at near. Retinoscopy showed no changes with his refractive error OU. Pursuit and saccadic tracking were age appropriate. Anterior segment evaluation showed a centered intraocular implant OD, NS 2+ OS. His dilated fundus exam revealed large macular drusen OU. He was found to show an improved sensory fusion response at distance when 2pd base left OD, 2pd base right OS compensatory prisms were worn. Repeat cover testing showed 4pd exophoria at distance, and he could now hold fusion to read without diplopia.

The patient performed the TUG test first wearing his habitual correction. The test took 30 seconds to complete, and his steps were small with a shuffling gait. He leaned and veered to his right. The TUG test was repeated wearing 2pd base left OD, 2pd base right OS compensatory prisms over his spectacle correction to determine whether improved binocularity allowed for better visual midline centration, which would improve his gait and speed. His time did improve to 20 seconds, but he still leaned and veered to the right; step size and gait were unchanged. He continued to show a 4pd left shift observationally, and the Spatial Location Board was unchanged (1pd left shift). The next step was to determine whether the use of yoked prisms would improve his visual midline, binocularity, and gait. The amount used was 2.5pd base-right yoked prisms (the average of the midline shift determined from the space posture board and static photos). The space posture board showed centration. Cover testing, however, showed the return of the intermittent, alternating exotropia. During the TUG test, the patient showed less leaning and veering to the right, but his time worsened to 25 seconds (most likely due to the loss of binocularity). In order to improve both his binocularity and visual midline, a combination of the compensatory and yoked prisms was trialed. The initial amount was determined by taking the average of the two types of prism for each eye: [2pd base left + 2.5pd base right]/2 OD; [2pd base right + 2.5pd base right]/2 OS. The prism amount was determined to be 0.25pd base-right prism OD, 2.25pd base-right OS. When this prism combination was trial framed, cover testing continued to show a mild intermittent, alternating exotropia. In order to aid eye teaming, base-left prism was added back in 1-pd increments OD until sensory fusion was achieved (base-right prism was increased OS first, but the patient noticed a decline with his binocular visual acuity that was intolerable). Two prism diopters base-left prism OD was the amount needed. This, however, eliminated the yoked component from the prescription. The base-right prism was increased to 4.75pd OS to restore the yoked property taken away from OD (2.50pd base right). The patient showed good sensory fusion and achieved 20/25 binocular acuity, and his TUG test was completed in 12 secs. He now leaned and veered slightly to the left. Based on this observation, the base-right prism OS was reduced by 1-pd increments until visual midline centration and sensory fusion were achieved. The patient was able to maintain sensory fusion and 20/25 binocular acuity, and he showed centration on the Spatial Location Board with 2pd base-left prism OD, 3pd base-right prism OS. The TUG speed was 11.45 sec. He now walked a straight path. There was also less shuffling noted with a larger stride length.

Based on the findings and observations, a prism correction in a bifocal format of 2pd base left OD and 3pd base right OS was prescribed for full-time wear. He was referred back to his physical therapist to work on improving his dynamic gait with the prism wear.

Discussion

When evaluating a Parkinson's patient, the eye care provider must remember that the visuo-spatial orientation may be compromised, causing a visual midline shift and poor binocularity, making it difficult to judge spatial localization accurately. Many times, the patient, spouse, or caretaker will not mention the spatial awareness problems since they will not equate those difficulties to a visual dysfunction. Unfortunately, these visual midline shifts with Parkinson's patients will go undiagnosed and lead to fall potentials.

In this example, the patient was prescribed a prism correction to aid eye teaming and visual midline. After one month, he no longer experienced double vison and showed improved balance when walking. The initial calculated amount of yoked prism was 2.5pd base right OU. However, this patient had an intermittent exotropia that also needed a compensatory prism correction of 2pd base left OD, 2pd base right OS. Many times, correcting the binocular issue will improve the midline shift, and vice versa. However, in this case, both the binocularity and visual midline did not improve until a combination of compensatory and yoked prism was used. Averaging the two prism values gave a total of 0.25pd base right OD, 2.25pd base right OS. This amount did not work since the patient needed additional base-left prism OD to maintain his binocularity. When additional base-left prism OD was incorporated into the correction, it reduced the yoked component to aid the visual midline. This patient showed best visual midline centration and gait ability when 3pd base-right prism was used OS. Many times, the calculated yoked prism correction will need to be adjusted to take into account binocular dysfunctions. This case study provides a step-by-step process to help the practitioner determine an initial prism correction for a patient with a visual midline shift. An evaluation of the patient's binocularity with the yoked prism correction must be done, and adjustments must be made to improve both eye teaming and visual midline issues. With our PD patients, if we can improve visual midline shifts, we will reduce the risk of potential falls and ultimately decrease the overall healthcare cost.

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