The Spectrum of Prism Optics – Part 2

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Intended Audience - Technical Level II

Welcome back to those of you either brave enough, or disturbed enough, to return for the exciting sequel that promises to be more thrilling and exciting than the next Star Wars movie! Yes, after years in the making, (well, weeks), here is the eagerly awaited *Spectrum of Prism Optics – Part 2*. We'll begin by explaining the concept of prismatic imbalance, with an emphasis on vertical at the near point. I'll continue with a detailed discussion on the options at our disposal to compensate for it, together with examples and calculations.

<u>Part 2 Objectives</u>

1) Discuss Prismatic Imbalance with an emphasis on vertical at the near point
2) Present the options we have at our disposal to compensate for induced vertical imbalance at near
3) Present real-world examples with calculations to help establish a routine for dealing with such scenarios

<u>Prismatic Imbalance</u>

As presented in part 1, prisms form the basis of the ophthalmic lenses we use every day which function as follows:

- Rays of light passing through the lens optical center (OC) pass directly through without deviation
- Rays of light passing through any other point are deviated due to a prismatic effect.
- The amount of deviation is affected by both lens power and the distance of the incident rays from the OC
- The direction of deviation is dependent on whether the lens is "plus" or "minus", and the direction of gaze

The magnitude of the prismatic effect can be calculated using *Prentice's Rule*. Perhaps we should just call it *The Prism Rule!*

<u>Prentice's Rule</u>

Prism, P (Δ) = Lens Power, D (D) x Distance from OC, d (cm)

Knowing this, opticians must do their best to optimize a patient's acuity by minimizing the need to look through a point in the lens away from its optical center. Otherwise, the prismatic effect induced can create visual discomfort for the patient in the form of eyestrain, fatigue, a "pulling" sensation, and distortion of objects. Here's where it's important to discuss the distinction between Prescribed and Induced Prism.

<u>Prescribed Prism:</u> Prism is part of the doctor's written prescription (Beneficial)

<u>Induced Prism:</u> Prismatic effect is induced due to the patient looking through a point in the lens other than the optical center (Detrimental)

As discussed in part 1, when MRPs or OCs are misaligned with the patient's visual axis, for example, if PDs / OCs are measured, ordered, or fabricated incorrectly, such misalignment can occur.

Sometimes, however, unintentionally looking through prism is difficult to avoid. Our extra ocular muscles make it possible to move our eyes up and down, and from side to side. This avoids having to continually move the head to "point your nose where you want to look" – as we so frequently advise our new PAL wearers. With ophthalmic lenses, however, this range of vision comes at a price – induced prism from looking through a point in the lens other than the optical center. Horizontal results in either Base In (BI), or Base Out (BO); vertical results in Base Up (BU), or Base Down (BD).

One major benefit of contact lenses is that the lens moves with the eye, regardless of direction of gaze, so alignment of the visual axis and OC is always maintained, providing the contact lens is fitted correctly and remains centered. This eliminates the prismatic effect that would otherwise be induced by an ophthalmic lens due to a change in direction of gaze. When fitting a patient with a multi-focal lens, the "add" is intentionally positioned in the lower half of the lens forcing the patient to look down, away from the distance OC, resulting in vertical prismatic effects at near.

There are certain refractive errors more prone to this than others . . .

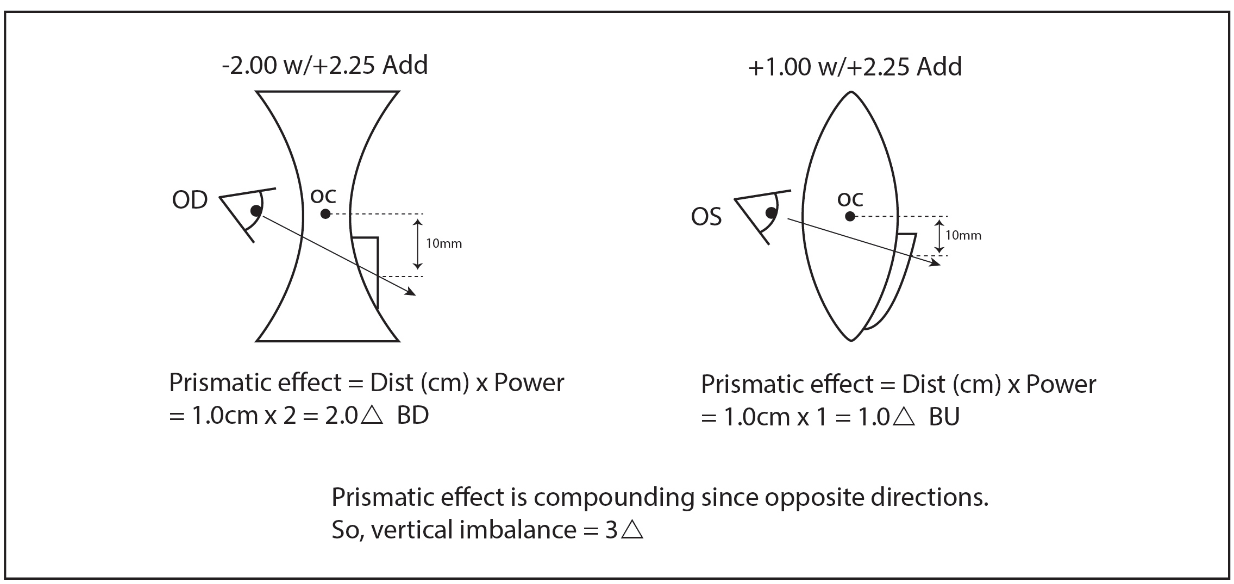
- Patients with Anisometropia: A difference in refractive error of 1D or more and both eyes are either myopic, or hyperopic
- Patients with Antimetropia: A difference in refractive error of 1Do or more and one eye is hyperopic, the other myopic.

Patients with either Anisometropia, or Antimetropia, will experience different prismatic effects in each eye when looking away from the OC. When looking below the OC, such as when using a multi focal lens design, this difference results in a disparity in image displacement due to the difference in vertical prismatic effects between each eye. We refer to this as Vertical Imbalance.

Vertical imbalance can affect stereopsis (the brain's ability to fuse images from both eyes to form one). When vertical imbalance is present at near when using a multifocal, this makes near tasks difficult, if not impossible. Depending on the amount of imbalance, the patient can occasionally compensate for it. However, over time, this can cause headaches and eye strain, in addition to discouraging patients from reading and similar near related tasks and interests.

<u>Example: Vertical Imbalance at Near due to Antimetropia</u>

OD: -2.00DS Add +2.25
OS: +1.00DS Add =2.25



How Much Is Too Much?

The patients most often affected by vertical imbalance are multifocal wearers with good binocular acuity and an imbalance greater than 1.5D. Every patient's sensitivity is different, however.

To review ANSI standards, tolerance limits are:

Horizontal prism	< 2/3 Δ
Vertical prism	< 1/3 Δ

NOTE: Correcting for vertical imbalance becomes especially critical when it is of recent onset. For example, following monocular cataract, or refractive surgery.

What Options Do We Have Available?

The doctors might be the medical experts, but when it comes to filling the prescription, that's where our expertise comes into play. It's our job to always stay alert and be watching for potential complications in the finished eyewear. When we see a "red flag", we must make the appropriate recommendations and take the appropriate steps to ensure ultimate patient satisfaction. If we drop the ball and miss a potential vertical imbalance issue, the patient is inconvenienced, having to wait for the glasses to be re-made. In addition, their first impression of our skill-set and knowledge is compromised. As the saying goes, "You never get a second chance to make a first impression." This, less than stellar, first impression also has a detrimental effect on our profession's reputation – something we are already struggling to elevate.

If faced with a "red flag" for potential vertical imbalance issues, how do we proceed? Do we run and hide? Do we suddenly have to go to the bathroom and hope a colleague will step up to the tee? No, we're Eye Care Professionals! We step up and embrace the challenge.

There are three main methods we can use to compensate for vertical imbalance at near: single vision lenses, dissimilar segments, and slab-off prism.

Let's discuss these in depth.

First method: Single Vision

As previously discussed, imbalance is induced when viewing through a point in the lens away from the OC. Separate pairs of eyeglasses, for different purposes, virtually eliminate the potential for induced vertical imbalance.

Specifying the OC height in a distance pair ensures no vertical imbalance at distance: patient should be looking through the OC.

When specifying the OC height for a near pair, the patient must assume their normal reading posture, in order to determine the correct placement. For example, is the primary use for reading in bed, or in their recliner? Posture and other preferences will have an effect on where the vertical OC should be placed. However, even if the vertical OC is slightly misplaced from the patient's visual axis, a slight re-positioning of the head should quickly resolve any induced vertical imbalance. Single vision lenses avoid forcing the patient to look down, away from the OC; an unavoidable necessity with a multifocal lens due to the placement of the near segment.

Single vision readers are the simplest and probably the most effective way to correct for vertical imbalance at the near point. However, they are the most inconvenient. The patient always has to switch between pairs and, frequently, misplaces them!

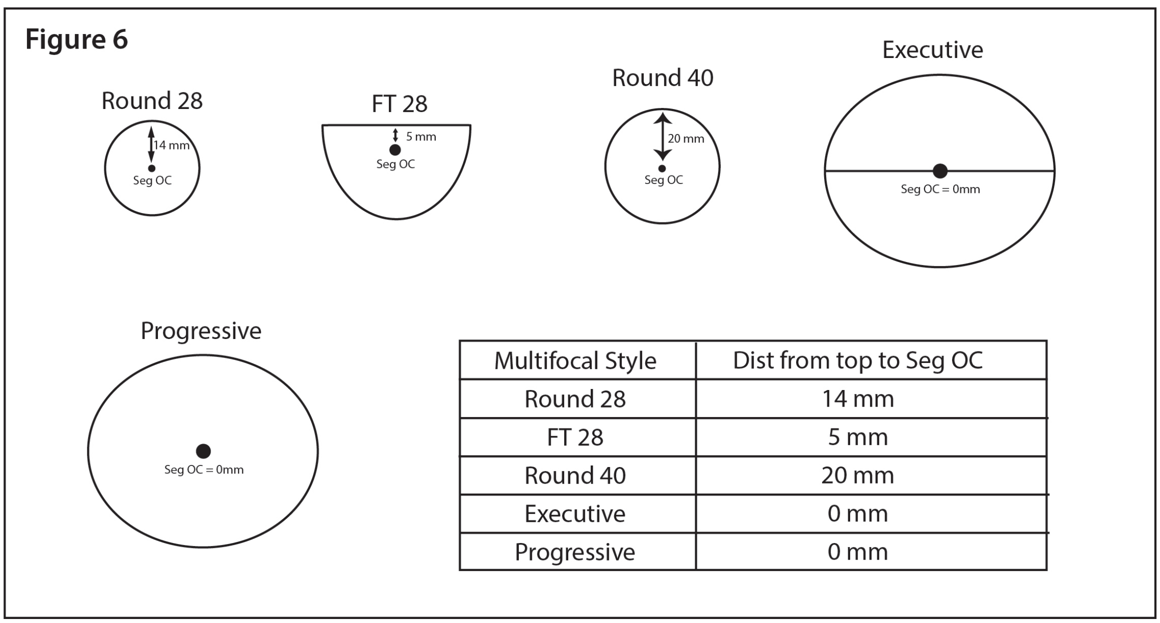
Second method: Dissimilar Segments

An alternative option, though rarely used today, involves using dissimilar segments. As the name suggests, different lined bifocal styles are used for each lens. This method uses the prismatic effect induced by the bifocal segment to offset small amounts of vertical imbalance induced by the distance lens, when performing near tasks.

Imagine a lined bifocal segment as a miniature lens with its own OC. As with any other lens, when viewing through a point away from its OC, a prismatic effect is induced. When this "miniature" lens is combined with a distance lens – for example, a bifocal – this prismatic effect is separate from any induced by the distance lens. When both lenses incorporate the same bifocal style, the same power, and both are positioned at the same height, any prismatic effect induced by the bifocal will obviously be the same for each lens and, thus, neutralized. Since we are attempting to offset vertical binocular imbalance induced by the distance power when viewing below its OC and through the bifocal, both bifocal segments will offset an equal amount. Therefore, the bifocal segments will have no net effect on correcting for vertical imbalance at near.

The following graphic illustrates how different lined bifocal styles have OCs at different locations, relative to their upper edge, depending on their design. This can be used to our advantage.

Figure 1: Bifocal styles and their OC placement



Multifocal Style	Dist from top to Seg OC
Round 28	14 mm
FT 28	5 mm
Round 40	20 mm
Executive	0 mm
Progressive	0 mm

Example

Consider a patient with the following prescription:

OD: -6.00 DS Add: +1.75

OS: -3.50 DS Add: +1.75

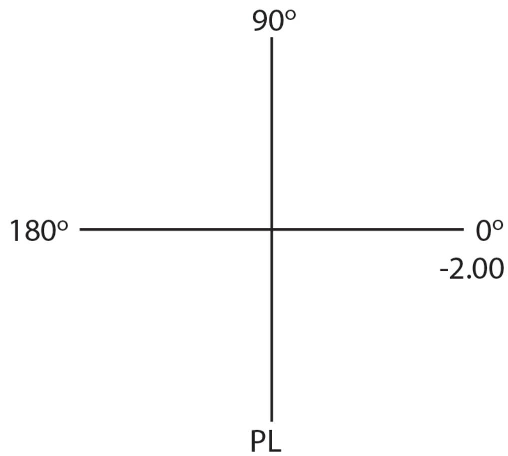
Such a prescription should raise a red flag for potential vertical imbalance at near due to the 2.50D of anisometropia.

Determining meridian powers with sphero-cylinder prescriptions

A lens for a spherical prescription has the same power in all meridians, whereas a lens for a sphero-cylinder prescription has its sphere & cylinder powers ground at 90˚ to one another.

RULE: A cylinder exerts 100% off its power, 90˚ to its axis, and 0% along its axis.

A **power cross** is the best way to visualize this concept:
Example: PL – 2.00 x 090



Effective Power in the vertical (90˚) meridian = PL DS (0% of cylinder is present along its axis)

Effective Power in the horizontal (180˚) meridian = -2.00 DS (100% of cylinder is present 90˚ to its axis)

It's very easy when dealing with axes are at 90˚ and 180˚, but how often does that happen in our real world? Rarely! So, what if we're presented with axes other than 90˚ and 180˚?

Our first option is to perform complicated and time-consuming calculations using the *Oblique Meridian Equation*.

Oblique Meridian Equation: $Dt = Ds + Dc \sin^2 \alpha$

Where Dt = Total power in desired meridian
Ds = Sphere power
Dc = Cylinder power
α = Angle between cylinder axis and meridian of interest

Consider the following Rx: +2.50 -1.00 x 045 Add +2.00

Dt = +2.50 + -1.00 x sin2 (90˚-45˚ = 45˚)
= +2.50 + -1.00 x 0.7072
= +2.50 + -1.00 x 0.5
= +2.50 – 0.50
= +2.00D in 90˚ meridian

An alternative is to approximate using the following Oblique Meridian Table, which, for our purposes, is perfectly adequate. We can have the lab do the precise calculations, later.

Determining Lens Power in Oblique Meridians
A cylinder exerts 100% of its power 90° from its axis
A cylinder exerts 75% of its power 60° from its axis
A cylinder exerts 50% of its power 45° from its axis
A cylinder exerts 25% of its power 30° from its axis
A cylinder exerts 0% of its power on axis

Using this, we can determine the effective power in all meridians between 0˚ and 180˚. Obviously, cylinder axes don't always align perfectly with the table. However, as opticians, we don't always need to precisely calculate the effective power in a specific meridian. We do, however, need to be able to spot "red flags." As lens experts, it's our responsibility to identify and manage prescriptions that have the potential to cause vision problems under certain situations.

Example: Consider the following Rx: +1.00 -2.00 x 068
Suppose we need to determine the power in their vertical (90˚) meridian.

NOTE: When using the oblique meridian table, we use the angle between the cylinder axis and the meridian of interest (90˚ meridian, for purposes of vertical imbalance calculations)

- So, angle needed = 90˚ – 68˚(cylinder axis) = 22˚
- It's this "22" that we're going to use in the table.

Referring to the table, "22˚" is closest to 30˚ than any other entry
So, we estimate approximately 25% of the cylinder power will be effective in the 90˚meridian
= 25% of 2.00D = 0.50D
Power in vertical (90˚) meridian = +1.00 – 0.50 = +0.50D

This allows us to quickly approximate meridian powers to proactively manage vertical imbalance issues, if necessary.

Let's first calculate the vertical imbalance present at near . . .

Step 1: When dealing with vertical imbalance, we are concerned with the power in the vertical (90˚) meridian ONLY. Since this is a spherical prescription, the power is the same in all meridians.

So, power in vertical meridian = OD: -6.00 DS and OS: -3.50DS
(Refer to side bar for determining meridian powers with sphero-cylinder prescriptions)

Step 2: Industry standard for estimated drop from distance OC to the point in the lens used when viewing through a bifocal is, conveniently, 10mm = 1cm

Step 3: Use Prentice's Rule to calculate the induced prism at this point: P = dD
For the right eye: P = dD = 1cm x 6 = 6 Δ
Since viewing below the OC of a minus lens = Base Down Prism

For the left eye: P = dD = 1cm x 3.50 = 3.5 Δ
Since also viewing below the OC of a minus lens = Base Down Prism

Step 4: Calculate net imbalance at near using rules for compounding and cancelling prism:
Resulting vertical imbalance at near = 6 – 3.5 = 2.5 Δ

Compensation using Dissimilar Segments

Use a FT28 for the right lens and a Round 28 for the left (Refer to figure 1)

- For the right lens: Segment OC is located 5mm below its top edge
- For the left lens: Segment OC is located 14mm below its top edge
- Both segments are fit at the same height = 5mm below distance OC

When patient looks down to read through the bifocal, 10mm below the distance OC, they will be looking through a point in each segment, 5mm below their top edge.

For the right lens: Patient is looking through the segment OC of the FT28 – no prism is induced
For the left lens: Patient is looking through a point in the segment 9mm above the round segment OC.

As always, using Prentice's Rule with an add power of +1.75D OU, this would equate to:

Prismatic effect of OS segment at near point = Distance from OC x Lens Power
= 0.9cm x 1.75D = 1.58 $\triangle^{D}$ (Point in the segment is above its OC, so prismatic effect is Base Down)

If you recall, original prismatic effect induced at near due to the distance power =

OD: 6BD
OS: 3.5BD

Now, in addition to the BD prism from the distance lens for the left lens, an additional 1.58BD prism is induced from the segment.

Total prism present at near OS = 3.5BD + 1.58BD = 5.08BD
Resulting net imbalance is now = 6BD – 5.08BD = 0.92 Δ

This is still greater than ANSI tolerance. However, the above example is more intended to illustrate the concept.

<u>**NOTE:**</u> When ordering dissimilar segments to offset vertical imbalance at near, place the bifocal style with the highest OC on the most minus, or least plus lens, in the vertical meridian.

Clearly, the above illustrates how dissimilar bifocal styles can be used to offset small amounts of vertical imbalance. Although this option may not be as appealing, cosmetically, it can be a more affordable alternative to slab-off, the next topic up for discussion.

Third method: Slab -off Prism

The most common method of compensating for vertical imbalance is to use a method referred to as *slab-off* prism or bi-centric grinding. Slab-off can be used to correct for imbalance amounts ranging from 1.5D to 6D. It provides BU prism in the lower half of one lens to offset excessive BD. Slab-off is always applied to the most minus, or least plus lens in the vertical meridian, and can be ordered in either a glass, or plastic lens, although each is manufactured in a different way. The main difference in manufacturing is that a glass lens has the slab-off ground on the front surface, since the bifocal is fused into the lens; whereas, a plastic lens has it ground on the back surface, due to the molded bifocal segment on the front.

A similar option, referred to as Reverse Slab-off, are molded, or cast lenses, with BD prism in the lower segment area, rather than having BU prism generated using bi-centric grinding. The advantage here is that reverse slab-off lenses can be kept in inventory in a semi-finished form, facilitating normal surfacing techniques, resulting in a faster delivery time. Because reverse slab-off provides BD prism instead of BU, it is always used on the most plus, or least minus lens in the vertical meridian.

If dealing with very large amounts of vertical imbalance at near, for example, greater than 6D, both slab-off and reverse slab-off can be used, in combination.

<u>The Slab-off Manufacturing Process</u>
(Modified from "Clinical Optics" By Fannin and Grosvenor)

> A slab-off lens is made using a procedure called bi-centric grinding. After the front surface of the lens is finished in the usual manner, a dummy, or cover lens manufactured to match the base curve of the required lens is then cemented onto the front surface. The front surface is then reground using the tool originally used for that surface, but ground in a way that the dummy is ground away in the upper portion while leaving it attached to the lower portion. The back surface is then finished with the remaining dummy considered as an integral part of the blank. The blank is now an equal thickness at the top and bottom unless the prescription calls for prism in the distance. When the lens is finished, the remaining dummy on the lower portion is removed. The dummy is base down prism resulting in the addition of base up prism in the lower portion of the lens.
>
> This procedure also results in an upward displacement of the center of curvature of the front surface of the lens in the lower portion, resulting in the front surface having two centers of curvature, one for the upper portion and for the lower, but both having the same curvature. This produces a unique optical axis for each of the two portions of the lens.
>
> Bi-centric grinding can be done on either the front surface in the case of a fused lens such as a glass flat top bifocal, or on the back surface in the case of a lens where the multi-focal segment results in a wedge on the front surface such as a plastic bifocal.

<u>Recommended steps for ordering:</u>

- Calculate how much vertical imbalance is induced by the distance lens at near and determine if sufficient enough to create visual discomfort or problems for the patient
- Order the lenses with the slab-off, or reverse slab, on the appropriate lens (See Table 1), with the slab line placed at the appropriate position based on lens style (See Table 2)
- Have the lab calculate the exact amount of slab off required, based on precise power in vertical meridian.

Remember, although the prescribing doctor will, occasionally, indicate the need for slab-off, ultimately, it's the Optician's responsibility to identify its necessity.

Table 1: Lens Selection for Slab-off / Reverse Slab

Lens Combination	Slab-off	Reverse Slab
Two Minus Lenses	Most minus	Least minus
Two Plus Lenses	Least plus	Most plus
One plus, one minus	Minus lens	Plus lens

It should be noted that although slab-off can be used on any lens, cosmetically it works best on a flat top bifocal due to the slab line forming a continuation of the top of the segment. In addition, the wider the bifocal used, the less noticeable the slab line will be.

Table 2: Placement of Slab Line

Multi-Focal Lens Style	Slab Placement
Flat Top Bifocal	Slab line should be in line with the top of the bifocal
Trifocal	Slab line should be in line with the bottom of the intermediate portion
Progressive Addition Lens	Slab line should be positioned slightly above the near verification circle

Now, let's explore a real-world example of using slab-off to compensate for vertical imbalance, and how to verify its properties in the finished lens.

Consider the same prescription used previously with dissimilar segments:

OD: -6.00DS Add +1.75
OS: -3.50DS Add +1.75

Fitting data:

Lens style: FT 28 OU
Assumed drop from distance OC to reading height through bifocal segment = 10mm (1cm)
Segment placed 5mm below distance OC
Segment OC = 5mm below top of seg (10mm below distance OC, in this scenario)

To determine if vertical imbalance is present at near, we have to first of all calculate the vertical prismatic effect present at the near point for each eye.

As always, we use Prentice's Rule: P = dD

For OD: P = 1cm x 6 = 6Δ
For OS: P = 1cm x 3.50 = 3.50Δ

Net prismatic effect at near (vertical imbalance) = 6 – 3.50 = 2.50Δ
We apply 2.50D of slab-off to the most minus lens = OD

This generates 2.50D BU prism in the lower half of the right lens to offset the excessive BD induced at near due to the anisometropia. Simple enough!

Verification Procedures:

There are two basic ways to verify slab-off:

Lensometry Method
Compare the vertical prismatic effects of the two lenses through the lensometer and check for actual image displacement at the reading level. The amount of the slab-off is the difference between the calculated amount of vertical imbalance and the amount found using lensometry. *("Clinical Optics" by Fannin & Grosvenor)*

For example:

- Calculated vertical imbalance from Rx = 3D
- Image displacement at near point observed using lensometry = 1D
- Slab-off prism applied = 3-1 = 2D

Lens Clock Method

- First, position the lens clock horizontally across the lens center in the distance portion paralleling the slab line and record this base curve.
- Second, rotate the lens clock 90 ˚ with the pins perpendicular to the slab line and the central pin directly on the line - record this base curve. The difference between these two base curves indicates the slab-off applied.

Fresnel Prism
Although, seldom used, I feel a program about prism would be incomplete without at least touching on Fresnel Prism:

Uncut Fresnel Film

- It's an inexpensive way to temporarily correct prism in a patient's eyewear, if the doctor anticipates the prism power changing in the near future, or is slowly dialing in the required amount in a series of steps
- It's much more affordable than making new lenses every few weeks
- Simply cut film to the shape of the lens and apply in the prescribed direction

Unfortunately, it provides poor optics, but is only short term.

Conclusion
That concludes part 2 of this 3-part trilogy. Who is brave enough to return for the grand finale? By this point, I know you're sucked in and have to know how it ends, right? Just like a good book. Will we explore further to the core of advanced prism, including its relevance in high wrap eyewear, its effect on the major reference point, and the topic of yoked prism? Will we discuss the effect of oblique astigmatism on induced prism in a PAL, together with potential vertical imbalance problems at the Distance Reference Point (DRP) in a PAL under certain conditions? Perhaps, it will even provide additional "red flags" for vertical imbalance such as prescribed prism and oblique astigmatism. You'll just have to return to find out. All will be revealed very soon in Spectrum of Prism Optics – Part 3.