The Spectrum of Prism Optics – Part 3

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Intended Audience - Technical Level III

Well, here it is, the conclusion to my 3-part series. Here's where we get into some seriously advanced areas involving prism. It promises to be more thrilling than Splash Mountain at Disneyworld! Ok, enough idol chatter, off we go . . .

Part 3 Objectives

1) Discuss how prism affects steep wrap eyewear, and the compensations to be made
2) Explain how the Progressive Addition Lens (PAL) design can induce vertical imbalance at distance as well as near
3) Discuss Yoked Prism and explain its use to offset vertical imbalance

Prism & Wrap Eyewear

Let's jump right in by discussing how wrapped frames with steep base curves induce a prismatic effect.

Light that enters a lens that has been rotated around either a horizontal (180˚) axis – "pantoscopic tilt", or a vertical (90˚) axis – "face form", induces a prismatic effect. When the rotation is due to pantoscopic tilt, both lenses are tilted in the same direction, so the induced BD prism is equal in each eye (another example of Yoked Prism – more to come, later) and becomes of little consequence.

However, when dealing with wrap eyewear, the lenses are now rotated in opposite directions resulting in a Base Out (BO) prismatic effect induced in each eye. The direction of the prism base is dependent on the angle the incident light rays will enter the wrap lens. For example, the steep face form tilt of the right lens causes light to enter the lens closer to the left side of the direction of gaze causing the base direction to be temporal (BO). The same is true for the left lens; so, it will always be BO for both eyes. In a similar way, increasing pantoscopic tilt causes the light to enter the lens closer to the top of the lens inducing BD prism.

The amount of induced prism is dependent on:

1) Angle of wrap
2) Front lens surface BC: The steeper the BC, the greater the induced prism
3) Refractive Index of the lens material
4) Lens Thickness

Surprisingly, the prismatic effect is independent of the lens power. For my fellow math nerds, the prismatic effect can be calculated using the following equation:

Induced Prism = (100 x tan α) x (Ctr Thickness / Material Index) x Base Curve

Where α = Wrap Angle

To offset this induced prismatic effect with a non-compensated lens, an approximation of the amount of opposing prism required can be incorporated as part of the lens order. However, with a compensated lens design, the lab can incorporate individual "position of wear" measurements (panto, vertex, and wrap) to accurately determine "compensated powers" to not only offset this induced prism, but also to correct for induced cylinder changes from the lens tilt. This should result in a happier patient with the end product.

Location of the Major Reference Points (MRPs), or Distance reference Points (DRPs), is also affected by changes in lens tilt. Obviously, a patient's anatomical PD does not change when using wrap eyewear. However, placement of the MRP, or DRP, must be modified during fabrication to compensate for the narrowing effect of face form tilt. The monocular PD will shrink by an amount proportional to the cosine of the wrap angle as calculated using the following equation:

$$PD_{NEW} = PD_{OLD} / \cos \alpha$$

Where α = Wrap Angle

To avoid induced prismatic effects from misalignment of the MRP, the measured anatomical PDs should be widened, accordingly, prior to ordering. The widened PD should be ordered. The following table, taken from "Wrap Star" by Dr Palmer Cook, provides a quick reference tool for determining the recommended PD modifications based on the degree of wrap.

MRP modification for Wrap eyewear

Measured Half PD	PD to Order Wrap = 6°	PD to Order Wrap = 8°	PD to Order Wrap = 10°	PD to Order Wrap = 12°	PD to Order Wrap = 14°	PD to Order Wrap = 16°
30	30.25	30.25	30.5	30.75	31	31.25
30	31.25	31.25	31.5	31.75	32	32.25
32	32.25	32.25	32.5	32.75	33	33.25
33	33.25	33.25	33.5	33.75	34	34.25
34	34.25	34.25	34.5	34.75	35	35.25
35	35.25	35.25	35.5	35.75	36	36.5

MRP Modification Associated with Prescribed Prism

What does prism do? It shifts image placement. As previously discussed, the primary use of prism is to shift the image placement in the direction of an eye deviation to assist with binocular fusion. The image is always shifted in the direction of the apex and a 2 diopter prism shifts an image approximately 1.0 degree. In addition, 1 Δ = 0.33mm of image shift.

When working with prescriptions that incorporate ground prism, in order to provide the patient with optimum visual acuity, the MRP should be shifted in the direction of the apex by approximately 1mm for every 4Δ.

For example, consider the following:

OD: PL sph 4BU
OS: PL sph 4BD

OC heights are measured at 20mm OU
OC heights should be ordered as:

OD: 19
OS: 21

If the prescribed prism was lateral, instead of vertical, the horizontal OC should be modified.
Such modifications will result in both improved acuity and visual comfort for your patients.

Prism and PALs

The topic of induced prismatic effects and vertical imbalance was introduced in part 2 of this series. However, its emphasis was on vertical imbalance at the near point. A single vision, or lined multi-focal lens design, has a single point in the lens that represents the distance optical center (OC). However, in a PAL, the distance OC is separated into two different points:

- Distance Reference Point (DRP): Prescribed refractive power for distance
- Prism Reference Point (PRP): Point to accurately verify prism (The actual OC of a PAL)

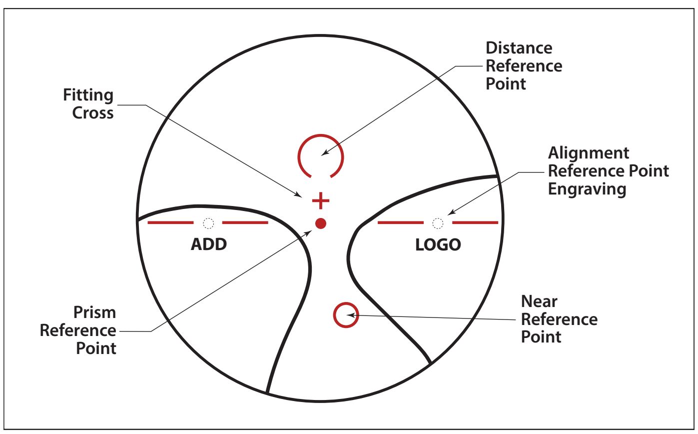
What effect does this separation have on the wearer?

With a single vision lens, or lined multi-focal, the distance OC is, ideally, positioned in line with the patient's visual axis (factoring in lens tilt). This virtually eliminates the potential for induced prism through the distance portion of the lens. Any minor misalignment can be easily rectified with a slight head adjustment. However, this is not as straight forward when working with a PAL.

Contrary to popular belief, the Fitting Cross is NOT the DRP in a PAL. The DRP is actually positioned several millimeters above the fitting cross. The fitting cross is purely an arbitrary point, determined by the manufacturer, positioned somewhere between the PRP and DRP.

To achieve optimum distance viewing, the patient has to move their eyes upward from the fitting cross to the DRP. The same principle that can induce vertical imbalance at the Near Reference Point (NRP) can induce a similar imbalance through the distance portion of the lens. However, it is usually to a lesser degree because the distance the eye has to shift its direction of gaze is less.

Figure 1: Major Reference Points of a PAL



Certain prescriptions can be more prone to induce such prismatic effects at DRP than others. Patients whose prescriptions include the following should raise a red flag:

- Anisometropia or Antimetropia
- Oblique astigmatism
- Prescribed prism

Let's explore in greater detail.

Anisometropia and Antimetropia
To review from part 2, anisometropia is present when there is at least a 1D difference in the spherical equivalent refractive error between each eye and both eyes are either myopic, or hyperopic. Antimetropia exists when, again, there is at least a 1D difference in the spherical equivalent refractive error between each eye, but one eye is myopic and the other, hyperopic.

This difference in refractive error creates a disparity in prismatic shift between each eye of the object being viewed, when looking away from the OC. This makes such conditions more susceptible to induced vertical imbalance at DRP as well as the NRP.

Oblique Astigmatism
Consider the example: PL -4.00 x 045

- Along the cylinder axis (045) there is no effective power
- 90˚ to its axis, 100% of the cylinder power is effective (135) = -4.00D

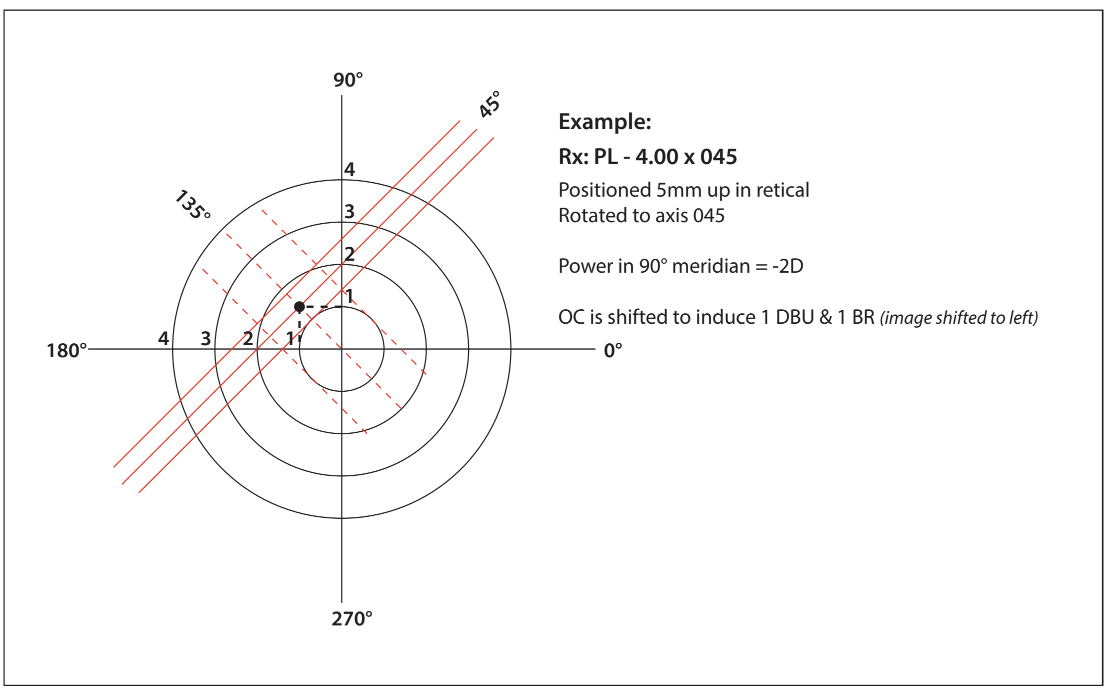
In a PAL, the eye must shift its gaze vertically (along a 90˚ axis) from the fitting cross to view through the DRP. Using the Oblique Meridian Table, as illustrated in part 2, the 90˚ meridian is halfway between axis 045 and axis 135. Therefore, 50% of the cylinder power will be effective in the 90˚ meridian = -2.00D.

To visualize the prismatic effect induced by this 2D in the vertical meridian, use Prentice's rule: P = dD

We'll assume a vertical shift in gaze of 5mm from fitting cross to DRP, for our purposes here: P = 0.5cm x 2 = 1Δ

When the axis is oblique, however, because a cylinder contributes its power to any optical system in every meridian but its axis, this induces both lateral and vertical prism. Viewed through a lensometer, the OC will be displaced by 1Δ both horizontally and vertically, displaced to the left of the axis – resulting in obliquely induced prism.

Figure 2: Induced Prism by Oblique Astigmatism



Once again, being mindful of prescriptions with oblique astigmatism, and having this knowledge of its potential effect, will enable the optician to take proactive steps.

Prescribed Prism

Here's where we need to remember to differentiate between prescribed and induced prism. Prescribed prism must be maintained at DRP and NRP. Induced prism must be managed and, to the best of our ability, eliminated by the optician.

So, when calculating vertical imbalance, care must be taken to factor in the prescribed prism, leaving it unaltered.

DRP Vertical Imbalance Calculations in a PAL

Procedure

- Determine the distances between PRP, Fitting Cross, & DRP for specific PAL
- Calculate vertical imbalance at DRP based on distance from PRP
- Apply compensations to how the order is placed such as incorporating yoked prism

Let's put this procedure to work, but first, as promised, more about Yoked Prism.

Yoked Prism

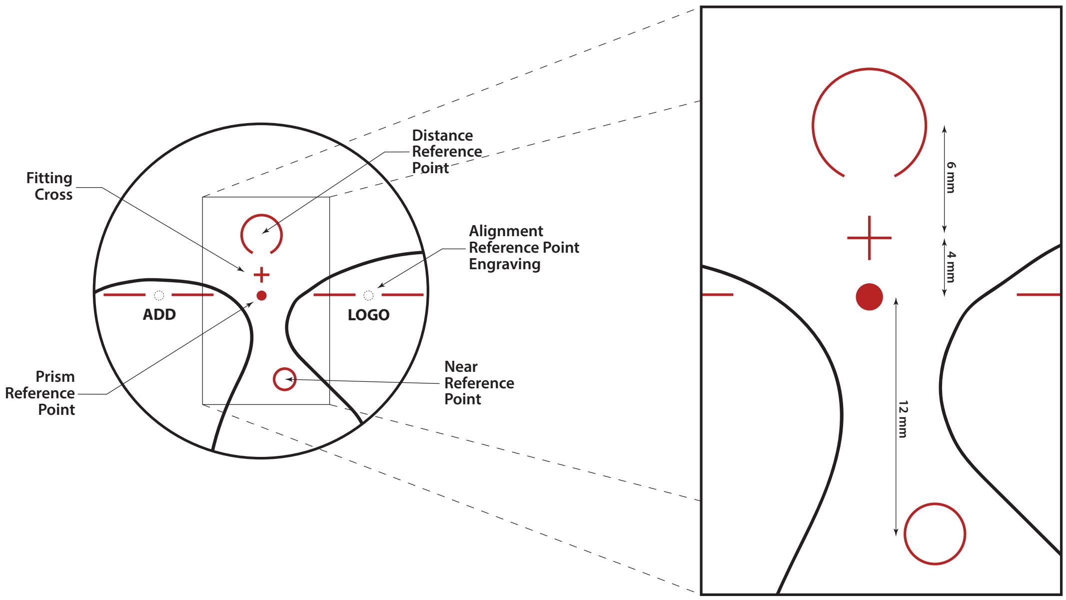
Yoked Prism is non-prescribed prism ground to result in no net binocular imbalance from its application. I'll demonstrate its use to offset an imbalance between each eye; however, it is frequently used for Prism Thinning in a PAL. *Prism Thinning* uses BD prism to provide a thinner center thickness (hence its name) while ensuring sufficient edge thickness at the bottom of the lens for the steepening curvature needed for the increasing add power. High minus lenses can also be thinned at the bottom using the same principle but using BU prism. In such circumstances, verification of prism at the PRP may indicate prism has been ground, despite none being ordered. Further investigation should reveal an equal amount, in the same direction, has been ground in each eye to result in no net binocular imbalance. Patients can typically tolerate up to 3Δ of yoked prism. Of course, every patient is different.

Ok, here we go . . . a practical example . . .

Calculating Vertical Imbalance at DRP and NRP in a PAL

Example: OD: +4.00 DS OS: +2.00 DS Add +2.50

Figure3: PAL Measurements for Vertical Imbalance Example



Measurements: DRP located 6mm above Fitting Cross
PRP located 4mm below Fitting Cross
NRP located 16mm below Fitting Cross

From these we can determine:

PRP to DRP = 6mm + 4mm = **10mm**
PRP to NRP = 16mm – 4mm = **12mm**

NOTE: The Red flag here for potential imbalance issues is the 2D of anisometropia

First, let's order conventionally with no compensations . . .

Vertical Imbalance at DRP would be:
OD: 10mm (1cm) x 4 = 4Δ BD
OS: 10mm(1cm) x 2 = 2Δ BD
Net Vertical Imbalance at DRP = 2Δ

Vertical Imbalance at NRP would be:
OD: 12mm (1.2cm) x 4 = 4.8Δ BU
OS: 12mm(1.2cm) x 2 = 2.4Δ BU
Net Vertical Imbalance at NRP = 2.4Δ

This resultant imbalance at distance and near can result in visual discomfort for the patient, in addition to potential diplopia at both distance and near. To compensate for the imbalance at distance, the patient could always tilt their chin upwards. However, this would result in compromised acuities.

How to Proceed

Instead of ordering the prescription as written, one approach would be to order as follows . . .

OD: +4.00 DS 2BU *(Notice: prism was not included in the original prescription)*
OS: +2.00 DS
Add + 2.50

Why did I order the job with the additional prism, you might ask? Here's why . . .

The addition of the 2 diopters of BU prism in the right eye reduces the vertical prismatic effect induced in that eye at the DRP and, subsequently, the vertical imbalance at the DRP.

Now, at DRP:

OD = 1cm x 4 = 4BD – 2BU = **2Δ BD** (Factoring in the additional 2BU ordered)
OS = 1cm x 2 = **2Δ BD**
Result: Yoked prism of 2BD OU at DRP
Net Vertical Imbalance at DRP = 0

The addition of the 2 diopters of BU prism OD must also be considered when calculating the vertical prismatic effects induced at NRP.

Notice, it does increase the vertical prismatic effect in the right eye at NRP.

Now at NRP:

OD: 12mm (1.2cm) x 4 = 4.8BU + 2BU = **6.8Δ BU** (Factoring in the additional 2BU ordered)
OS: 12mm(1.2cm) x 2 = 2.4BU = **2.4Δ BU**

Result: Net Vertical Imbalance at NRP 6.8Δ - 2.4Δ = 4.4Δ

This can easily be corrected with 4.4Δ Slab Off OS

The finished eyewear should now provide your patient with uncompromised acuities and no vertical imbalance at DRP or NRP.

NOTE: Another tool to keep in mind . . . to minimize vertical imbalance at NRP, a short corridor PAL can always be selected. This will reduce the drop from the fitting cross to the NRP.

IMPORTANT: When any modifications to the prescription are made in a patient's eyewear, always clearly document in a patient's record, or chart notes. In addition, it never hurts to provide the patient with documentation showing the modifications made, in case they need to visit a different ECP in the future. With modifications such as those illustrated here, where prism is added to offset vertical imbalance, documentation should include directions to verify the prism at the DRP, not the PRP. This will be very helpful to any future ECP; ultimately, in your patient's best interest. It's important to remember that we're all in this together and, if we help each other out, we'll ALL be more successful and better equipped to provide our patients with the best possible care and service.

Scope of Practice
I understand the idea of modifying a prescription from that written might appear questionable behavior and outside the scope of practice of an optician. I can hear some of you thinking, “Is this guy nuts?!” Anyone who knows me knows the answer to that question is a resounding, “Yes!” However, that’s a topic of discussion for a psychology thesis, not this one! However, let me ask you this . . . Is it the role of an optician to provide the patient with the prescription determined by the doctor? Obviously, that it is our main objective.

With the prevalence of digital and free-form lens technology, the majority of us are very familiar with the concept of Positional Power Effects and how Position of Wear (POW) changes the effective power of a lens. When the doctor refracts the patient, the lenses in the phoropter are aligned vertically, with zero wrap, perpendicular to the patient’s line of sight. When the lenses are in an eyeglass frame, the lenses are now frequently tilted around both the vertical and horizontal axes. This tilt will change the effective power the patient “sees”.

When ordering digital and free-form lens designs, providing the lab with a patient’s individual POW measurements for wrap, pantoscopic tilt, and lens vertex distance, will enable them to use this personalized data to modify the prescription, making sure the patient “sees” through the actual prescription the doctor intended. These Compensated Powers are often included with your lab invoice, for such designs.

Modifying the prescription to prevent vertical imbalance is no different. We have seen the consequences of not doing so – potential problems – and the patient ends up experiencing unintended prismatic effects at DRP and NRP. So, by modifying the prescription as shown, we are actually fulfilling our role more effectively – thinking outside the box as true eye care professionals. Having this knowledge and skill set will also set you apart from your competition. If the patient is new to your office and has a history of failed experiences with PALs, perhaps due to anisometropia, or oblique astigmatism, incorporating these tools to make them a pair of PALs that actually work will win them over for life!

How to Order
Looking at the steps we just went through might, at first, seem a little complex and intimidating. I can hear some of you thinking, “What if I miscalculate the imbalance?” “What if I miscalculate the power in the vertical meridian?” “So much pressure! Ahhhhh!”

Breathe! It’s ok. I’m about to make it really simple. The best way to order the job is provide the lab with all the measurements and then ask them to. . .

1st: Apply prism at PRP to result in no vertical imbalance at DRP
2nd: Apply slab off to correct for any vertical imbalance at NRP

Having the lab do the calculations ensures computerized accuracy. They will also have access to the specifications of the PAL being used, in terms of the relative placement of the DRP, PRP, NRP, and fitting cross. In addition, their computers will precisely calculate the power in the vertical meridian for oblique axes, as well as factoring in any prescribed prism.

NOTE: Slab-off prism cannot be ordered with all PALs, especially digital designs. Consult with your lab for recommendations. With regards to slab line placement, typically it is placed about 4mm below PRP. Again, consult with your lab for their recommendation based on the specific PAL design.

To close this program, and this series, let’s briefly discuss a few other uses of prism.

Visual Neglect

In a case where a patient has a visual field defect, but is unaware of the defect, this is referred to as Visual Neglect. For such patients, out of sight is, quite literally, out of mind. These patients may be prone to tripping over things, or bumping into people on their blind side. Prism can occasionally be used to help increase their awareness of the missing area in their field of vision. The amount of missing visual field shifted into view is proportional to the prism power prescribed. If you recall from earlier, a 2 diopter prism shifts an image approximately 1˚. Care must be taken in the selection of the prism power, however. Larger prism powers induce a more abrupt image jump for the patient and often require a longer adaptation time.

Eyewear incorporating prism to increase visual field awareness, as with visual neglect, can yield different subjective responses on the part of the patient. Some patients will continue to wear the eyewear on a permanent basis; others may indicate the eyewear worked for a while and then stopped working. Typically, this indicates the prism awareness device helped the patient develop effective techniques to no longer require the prism, prompting them to scan from side to side for normal functioning.

Reading Glasses for Inferior Visual Field Loss

Patients with inferior visual field loss can sometimes find benefit in reading glasses with yoked BD prism. This enables a more normal head/eye position when reading because it shifts the text upwards instead of having to tip the head way down. The necessary prism is usually between 5 and 10 diopters.

Nystagmus and Null Point

Nystagmus is an eye condition exhibiting constant oscillating eye movements. Such patients can usually find a head position that stops, or reduces the oscillation to a minimum, known as the Null Point. However, sometimes, the null point is not a very comfortable head position. Yoked prism can be used to allow the patient to achieve a null point that is more comfortable.

Apparent Alignment

When patients have no useful vision in a deviated eye, there is no benefit from trying to use prism in an attempt to shift the object in the direction of the deviation. The patient is, effectively, monocular. However, prism can be used to help improve cosmetic appearance. Prism with its base oriented toward the deviation (contrary to the conventional use when correcting for eye deviations) can result in the eyes appearing more aligned. For example, BI prism can make an esotropic eye appear to turn in less. Approximately, 8 Δ will cause an apparent shift in the eye of approximately 1mm.

Other Miscellaneous Uses

- Tonometer probes on slit lamps used in *Goldmann Tonometry* to measure IOP utilize prisms
- Single Lens Reflex cameras use pentaprisms to make what is seen through the viewfinder “normal”. If it weren’t for the pentaprism, the photographer would see an image that is inverted and laterally reversed.
- Glasses for therapeutic purposes: Benefit patients who must stay in a certain position for extended periods – those with back injuries, or those with retinal detachments treated with gas bubbles, for example. Such glasses, incorporating specially placed prisms, enable them to perform tasks such as watching tv without looking directly at it.

Conclusion

Well, as a famous rabbit once said, "That's all folks!" For those of you who started this series with both a fear and hatred of prism, I hope I helped dispel some of the horror. I truly hope I provided some tools and steps to take, to make the topic less intimidating. I hope it makes more sense. Those of you, like myself, who can't get enough of the topic, I hope you enjoyed reading it as much as I enjoyed writing it. Perhaps you even picked up a new thing, or two, to incorporate into your daily routine.

Ultimately, however, whether we love it, or hate it, remember, prism is the main component of what we use every day as opticians - ophthalmic lenses. We must fully understand its effects, both good and bad. In doing so, we can make sure we manage it appropriately and provide our patients with the ultimate in patient care, service, and vision correction.