**The Spectrum of Prism Optics – Part 1**

Andrew S. Bruce, LDO, ABOM, NCLEC

***Intended Audience - Technical Level I***

Ok, with a show of hands, (nobody's watching, really, nobody is), how many Opticians feel the urge to run and hide when presented with a prescription that includes prismatic correction? It's ok, you're not alone. Also, it's nothing that years of immersion therapy and consumption of copious amounts of alcohol can't resolve. All joking aside, prism can be intimidating; usually due to a knee-jerk reaction that results in over-thinking and over-complicating the subject. Taking a deep breathe and taking it step-by-step will remove a great deal of the anxiety that many associate with prism, making it much easier to handle.

There are those crazy, masochistic, optical math nerds out there, like yours truly, who can't get enough of it. However, a large number of Opticians struggle with the topic. The purpose of this 3-part program is to provide a step by step introduction and explanation to the topic of prism and its uses, moving on to more advanced discussions and calculations.

**<u>Part 1 Objectives</u>**

1) Provide an introduction to prism and its connection to ophthalmic lenses
2) Discuss ocular and therapeutic conditions for which prism might be prescribed
3) Discuss frame style considerations and lens material selections / options when working with prism. Also, to present a step-by-step procedure for verifying prism.

Can't wait to get started? Alright then, off we go at on this fun exploration into the world of prism.

So, let's start at the very beginning; I've heard it's a very good place to start!

According to "Geometric Optics," by Fannin & Grosvenor,

*"A prism has the property of changing the direction of an incident light beam without changing its vergence."*

We use the unit of Prism Diopters, or Δ, to measure prism and it is defined as,

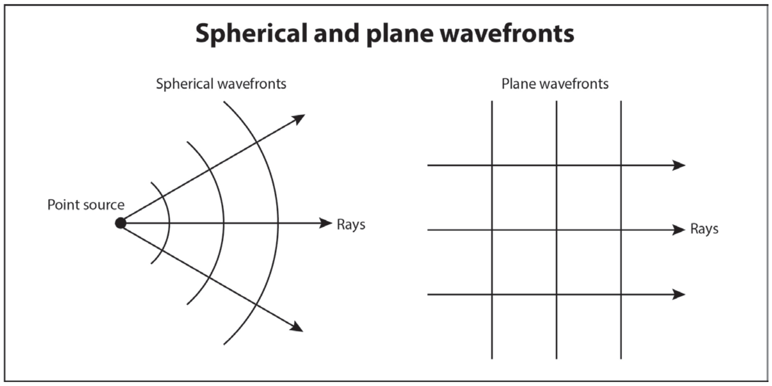
A 1 Diopter prism will displace an image 1cm at a distance of 1meter

Note the distiction between "diopters" and "prism diopters": lens refractive power is measured in diopters, prismatic deviation, in prism diopters.

What is vergence? I hear you ask . . .

Here's where we have to dig into some light theory, but hang in there, I will try to make it relatively painless.

**Figure 1: Light rays and wavefronts**



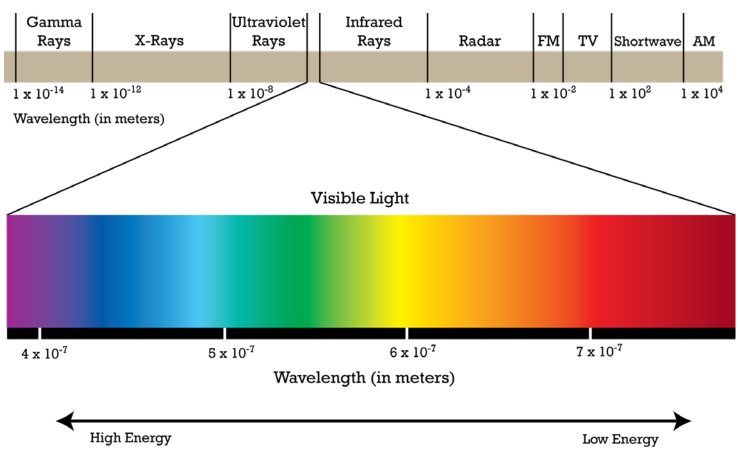

"A light ray is a hypothetical line extending from the origin or focus (point source) of a wavefront and is perpendicular to all wavefronts emanating from the origin or moving toward the focus of the wavefront." *(Clinical Optics, 2nd Ed: Fannin & Grosvenor)*

The curvature of a wavefront is known as its vergence. Diverging wavefronts have negative vergence, converging have positive. Optical systems have the effect of changing the curvature / vergence of these wavefronts, determining where the rays of light come to a focus. In order to have such an effect, the optical system must possess curvature to create refractive power (light bending properties).

A prism is, basically, 2 "plane" refractive surfaces of a transparent medium inclined at an angle between them. Opposite this prism angle, known as the apex, is the prism base. A "plane", or "plano" surface describes a surface with no curvature; therefore, no refractive properties; it will have no effect on the vergence of incident rays.

So, if prism can change the direction of an incident light beam without changing its vergence, what processes are involved? Let's discuss the 3Ds of prism . . . Dispersion, Displacement, and Deviation.

**Figure 2: Visible Spectrum and Components**




*Dispersion (1st D),* first described by Newton, is defined as, "The breaking up of white light into its component, or spectral colors – Red, Orange, Yellow, Green, Blue, Indigo, & Violet."

This *"Visible"* white light, as the name suggests, is light that is visible to the naked eye. Respective wavelengths range from approximately 380 nanometers at the violet end, to 760 nanometers at the red. It is also known as the Visible Spectrum; a very small section of the Electromagnetic Spectrum that includes other components such as, x-rays, UV-rays, and Infrared.

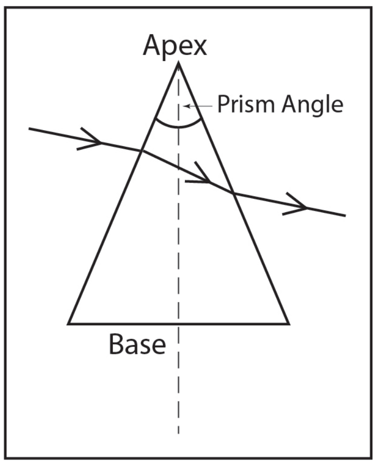
Why does this “breaking up” happen? When light passes from a medium such as air, to a more dense medium, such as glass, it is slowed down. The degree of slowing is determined by both the wavelength of the individual component, and the refractive indices of the mediums involved.

Shorter wavelengths are slowed down more than the longer wavelengths. Dispersion can adversely impact ophthalmic lens performance and its effect varies based on a material’s dispersive and aberration properties - topics that will be discussed in part 2.

*Deviation (2nd D)*, of an incident ray takes place based on the angle of incidence and the prism angle. Ultimately, a ray of light entering a prism is *Displaced (3rd D)* from its original direction. (Angle of incidence and refraction are topics for another day - for more, refer to *Ophthalmic Lenses & Dispensing, 2nd Ed: Mo Jalie).*

Ok, we survived and came out on the other side! That’s some of the science, now let’s look explore how prism affects what we do on a daily basis.

**Figure 3: Prism Construction**




Again, the two “plane” prism surfaces meet at the apex, creating the prism angle, the opposite of which is the base. Prism is always written referencing the direction of its base. The deviating properties of a prism are directly proportional to its prism angle: as the angle increases, as does the degree of deviation. As stated previously, by definition, a 1D prism will displace an image 1cm at a distance of 1 meter.

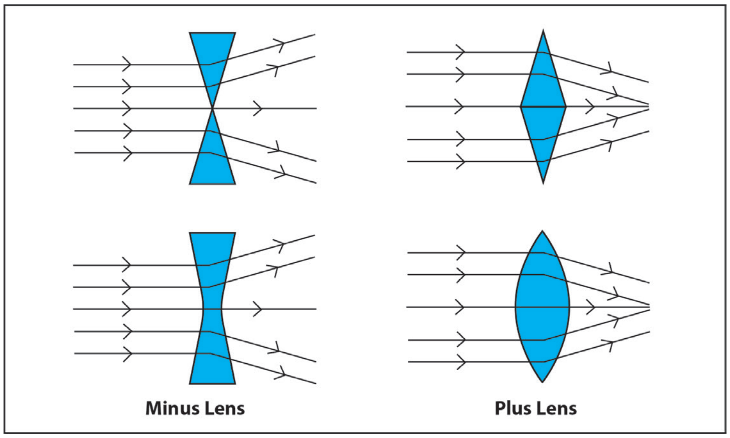
The Rule:

- Light rays are always deviated towards the prism base
- The image is always perceived to shift towards the apex

The simple way to remember this is to visualize the prism as the head of an arrow. The image always shifts in the direction of the arrow head.

So, why do we need to know about prism? It’s the very foundation of what we use in our day-to-day practice: ophthalmic lenses.

**Figure 4: Ophthalmic Lens Construction**




A plus lens is basically 2 prisms arranged base to base, and a minus lens is basically 2 prisms arranged apex to apex. If you move a plus lens in front of your eye, you will see “against motion”. Do the same with a minus lens, you’ll see “with motion.” The rules mentioned above explain this prismatic deviation and why lenses function the way they do.

**Prism Convention**

There are 2 conventions for use with prism. Polar coordinates and Rectangular coordinates. Opticians in the USA typically use rectangular; optical labs and European countries, polar.

**Rectangular Coordinates**

Base In (BI), Base Out (BO), Base UP (BU), and Base Down (BD).
When prescribed, prism will be combined in very specific ways, between each eye, in order for it to be effective. This very specific way of combining prism introduces the topic of ***Compounding and Cancelling*** prism.

**Working with horizontal, or lateral prism:**

*Compounding Effect* (prismatic effects of each eye are additive): Prism must be ground in the same direction OU. For example, BI OU

*Cancelling Effect* (prismatic effects are subtractive): Prism must be ground in opposite directions OU. For example, BI and BO.

**Working with vertical prism**

*Compounding Effect:* Prism must be ground in opposite directions OU. For example, BU and BD

*Cancelling Effect:* Prism must be ground in the same direction OU. For example, BU OU

**Polar Coordinates**

Although rarely necessary, rectangular coordinates can be converted to polar coordinates. What follows are the steps for conversion:

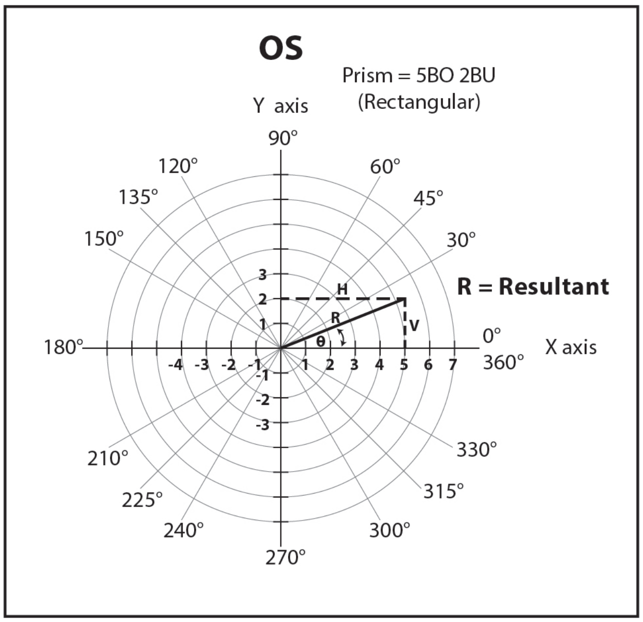
Example: OS 5BO 2BU (Figure 5)

1) Create a grid showing 0° to 360°
2) Visualize which eye from the patient’s perspective
3) Mark a point on the grid at 5BO and another at 2BU
4) Draw a vertical line from the “5BO” point and a horizontal line from the “2BU” point

5) The point of intersection of these two lines is the resultant of the 2 combined
6) Now, draw a line from this point to the center of the grid
7) Using a mathematical equation known as The Pythagorean Theorem, the length of this resultant line can be calculated:
   $\text{Resultant}^2 = 5^2+2^2$
   $\text{Resultant} = \sqrt{29} = 5.39$
8) Now, using geometry, the angle between the resultant and the horizontal (x-axis) can be calculated:
   $\text{Sin angle} = 2 \div 5.39 = 0.371$
   So, angle = 21.8°
   Resultant polar coordinates of 5BO and 2BU OS = 5.39Δ @ 21.8°

Don't be concerned if this is too much math for comfort, or your wondering what on earth is "Sin angle". The point to note is that prism can be ordered in either polar coordinates or rectangular coordinates, depending on preference. Both are correct. 5BO and 2BU for the left eye is the same as 5.39Δ @ 21.8°.

**Figure 5: Conversion Grid**




Now, how does the brain handle prism?

When prismatic correction is placed in front of one eye, the brain applies the effect binocularly, splitting the power between each eye. How is this relevant? If the brain splits it, we can do the same, leading us to the topic of splitting prism.

**Splitting Prism**

Why do we want, or need to split prism, and how is this beneficial?

Let's look at the following the prescription example:
OD: -4.00 DS 8BD
OS: -2.00 DS

First, before even considering the prism, the right eye is going to obviously be thicker at both the upper and lower edges. It's twice the power of the left!

Now, consider prism construction, it has a wide base. Prism will always add thickness in the direction of the base. Taking this into consideration, returning to the above example, 8 BD is going to add additional thickness to the lower edge of the right lens. This will exacerbate the thickness disparity between each lens, degrading lens cosmetics, and increasing the potential for distortion in the lens periphery.

Here's where splitting prism power can be beneficial. It allows us to "split" the prescribed prism power between each eye. Applying 4BD in the right eye and 4BU in the left eye will "share" the added thickness caused by the prescribed prism between the two lenses. However, it will add thickness to the upper edge of the left eye. Important note: the prismatic effect will be the same as if all the prism had been applied to the right eye.

**<u>Important Rules for Splitting Prism</u>**

- Always stay with appropriate compounding / cancelling conventions.
- Always make sure the direction of the prism power in the eye it was originally prescribed remains unchanged.

  For example, OD: 16BD OS: PL

  OK to split as OD: 8BD and OS: 8BU **NOT** OD: 8BU and OS: 8BD

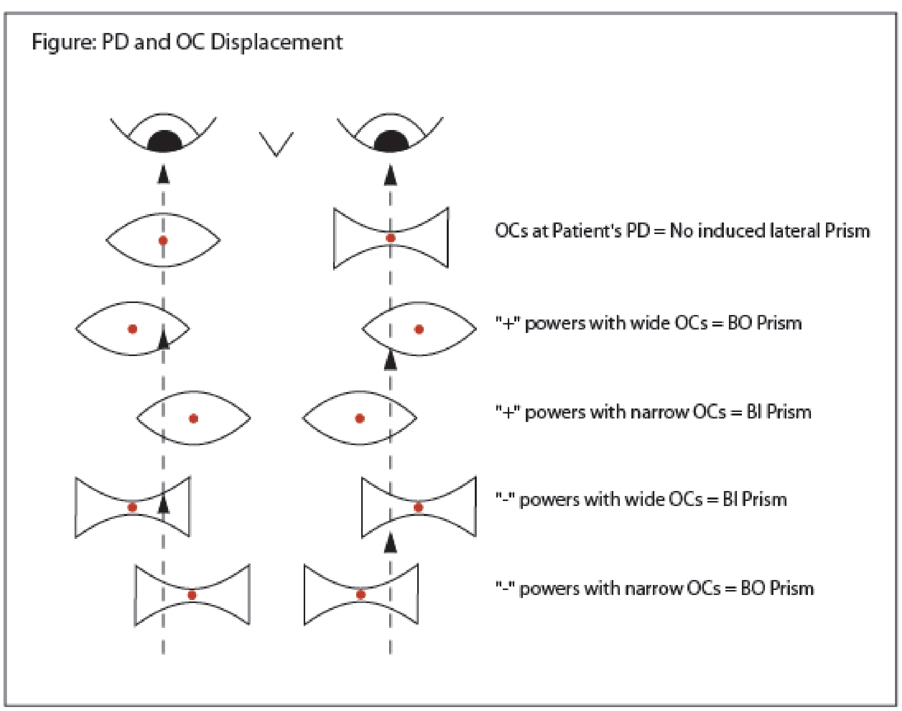
**<u>Prism: Good or Bad?</u>**

What does prism do for our patients? It can be both beneficial, if prescribed, but also can be detrimental, if mistakenly induced, or poorly managed by the optician.

How can prism be mistakenly induced?

As illustrated in Figure 6, misaligned PDs or OCs can induce unwanted prism which can potentially cause vision problems and discomfort. These problems can present as distortion, headaches, a pulling sensation, eye strain & fatigue, and, in severe cases, diplopia (double vision).

**<u>Figure 6: Prismatic Effect from Misaligned OCs</u>**



When I ask my audiences of Opticians how many routinely measure OC heights for single vision and lined multi-focal lens designs, I am surprised to find a large number who do not.  Let's explore why vertical OCs are always important.

**How Much Is Too Much?**

The patients most often affected by imbalance are those with good binocular acuity. When a patient's best corrected visual acuity (BCVA) is compromised, for whatever reason, the need for compensation is usually reduced; however, every patient's sensitivity is different.

ANSI standards indicate the following tolerance limits:

Horizontal prism < 2/3 Δ

Vertical prism < 1/3 Δ

Patients can frequently tolerate more horizontal prism than vertical, reinforcing the importance of always measuring vertical OC placement, in addition to horizontal pupillary distances.

A quick review of current frame styles reveals how deep "Bs" are regaining popularity. Such frames, with large vertical dimensions, make vertical OC measurements even more necessary; also, when lined multi-focal designs are fit differently than "textbook." Why, you may ask?

**Importance of Vertical OC Measurements**

If vertical OCs are not provided with a SV lens, the lab will default to placing the MRP at the datum line (mid line).

Consider a frame with a high temple attachment and a B of 40mm. The lab will default to placing MRP at 20mm. If patient is actually looking through a point 10mm above datum, it will result in the patient looking through induced vertical prism. If the patient also has unequal powers in the 90 ˚meridian for each eye, (anisometropia), the patient will also experience vertical imbalance at distance, which can result in diplopia. The subject of imbalance will be discussed in greater detail in part 2.

**Importance of Vertical OC Measurements with Lined Multi-Focals**

Now, consider a patient who likes their FT28 bifocal sitting lower than "textbook". In such a situation, it is necessary to not only provide segment height measurements, but also vertical distance OC placement. This can be ordered either relative to the top of the segment, or the bottom of frame.

If vertical distance OC measurements are not provided, the lab will default to placing the distance OC 5mm above segment line of a FT28, for example.

Assume the patient likes the bifocal positioned 10mm below the standard lower eyelid. This would result in an inaccurate distance OC placement, if the lab positions it at default. Again, this could result in the patient experiencing induced vertical prismatic effects at distance.

Other scenarios where non-prescribed prism can be mistakingly induced include . . .

- Lenses are fabricated incorrectly
- Lenses are ordered incorrectly
- Transcription errors

In order to avoid these situations, we must be very disciplined in both providing the lab with all the necessary measurements and ensuring accuracy in our ordering procedures. Thankfully, most practice management software auto-populates fields for data such as Rx and PDs, helping reduce the risk of transcription errors.

Now that we've discussed scenarios where prism can be induced in error, under what conditions would prism intentionally be prescribed by the doctor?

First, what does prism do? It shifts the image in the direction of the apex, making the object appear to be shifted in the same direction. Prism does NOT straighten eyes that are misaligned, only strabismus surgery can do that.

Strabismus is a broad, medical term referring to misalignment, or deviations of the eyes, typically due to a muscular imbalance. The extra-ocular muscles of our eyes need to be able to maintain parallel alignment of each eye, regardless of gaze. They control eye movement, in tandem, to ensure only a tolerable amount of difference between the images each eye is receiving. By doing so, both eyes capture a slightly dissimilar image. This enables the brain to blend, or fuse, the images from each eye to form a single image – a process called binocular fusion.

When the extra-ocular muscles cannot maintain this alignment, the patient is determined to have a strabismus.

The most common use of prescribed prism is to compensate for a strabismus. As mentioned earlier, this is a broad medical term describing eye deviations that can be broken down into . . .

- Phorias: a tendency for eye deviation when one eye is disassociated, or cut off, from the other
- Tropias: a permanent eye deviation

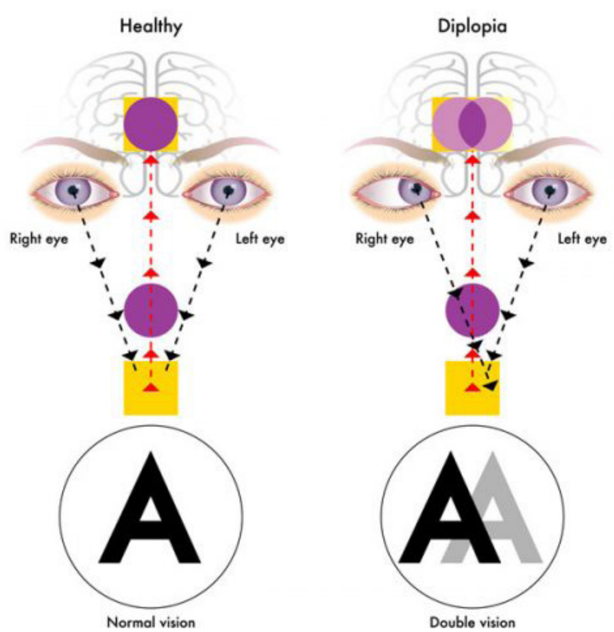
Eye deviations fall into two main categories . . .

- Commitant – The most common in children. Deviation is constant, regardless of direction of gaze
- Incommitant – Deviation is always changing, depending on direction of gaze

The direction of deviation is indicated by a pre-fix, all of which can be used for both phorias and tropias:

ESO = In
Exo = Out
Hyper = Up
Hypo = Down

**Figure 7: Strabismus Graphic**



A strabismus can often result in diplopia. As stated earlier, extra-ocular muscles need to collaborate to make binocular fusion possible. If a muscular imbalance is present, resulting in a strabismus, there can be excessive disparity between the image each eye is sending to the brain for binocular fusion to take place. Ultimately, the brain "sees" and "reports" two separate images; hence, diplopia (double vision). When this happens during the years of eye development, the brain will often suppress (turn off) the weaker eye. The fully functioning eye takes over and the macula of the weaker eye ends up being delayed in development – a condition called Amblyopia, or lazy eye.

Prescribing prism has the effect of shifting the image in the direction of the eye deviation, reducing the disparity, enabling binocular fusion. This is primary use of prescribed prism – to aid binocular fusion. Prism will be prescribed with its base directed opposite to the direction of eye deviation.

Example: Patient with esotropia OD (inward deviation) would be prescribed base out prism OD.

Prism can also be prescribed, unconventionally, to help improve quality of life for patients experiencing vision loss in areas of their vision (visual field defects) due to neurological diseases such as a stroke, or brain injury. These blind spots are known as a Scotoma. Brain injuries, or aneurysms, can occasionally impact the occipital lobe of the brain, the area responsible for visual processing. These can result in visual field defects in specific quadrants, depending on the specific location of the injury.

**Figure 8: Hemispatial Defect, or Homonymous Hemianopsia**

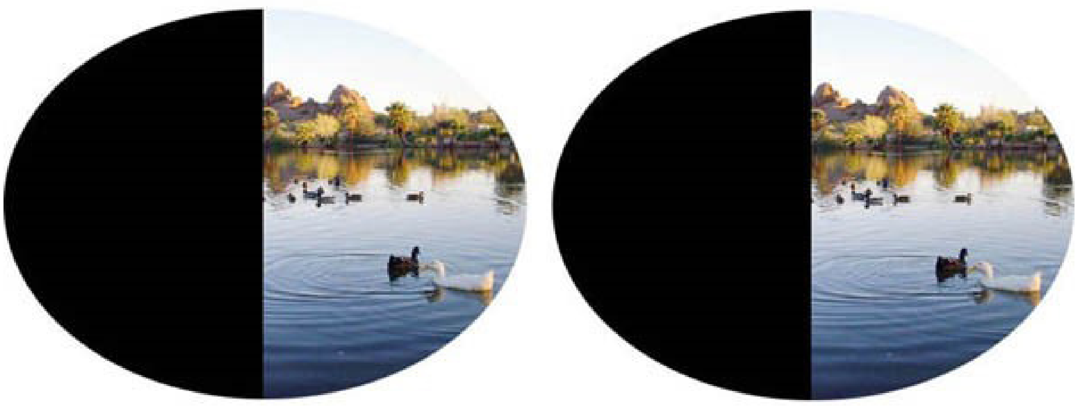


Figure 8 illustrates the visual field defect a patient experienced after a stroke. As you see, the patient has lost vision in one half of their field of vision in each eye. When prism is used to treat such conditions, the conventional rules for compounding and cancelling prism are no longer employed. The objective, here, is to "shift" the patient's gaze in a direction to attempt to "look around" the defect and perceivably "widen" their field of vision, improving their quality of life.

Example: In Figure 8, the following may be prescribed . . .

OD: BO

OS: BI

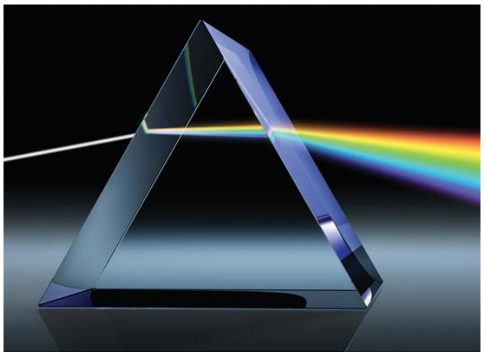
Generally, however, to accomplish the desired outcome, very high prism powers are required which, not only creates cosmetic problems, but also a confusing visual environment in which objects, unexpectedly, appear and disappear from view.

**The Frame Selection**
As a professional Optician, always try to visualize the end product prior to fabrication. In a similar way to how lens thickness can be affected by PD, OC placement, frame dimensions, and cylinder axis orientation, the base direction of prescribed prism will also add thickness to the finished lens.

For example:
Presented with the following prescription:
OD: PL sph 5BI
OS: PL sph 5BI

The thickest part of the lens will always be in the direction of the base. Why?

**Figure 9: Visualize a prism**



The base is the thickest part – makes sense?
In the previous example, the lenses will be thickest at the nasal edge (BI OU)

Knowing this helps with frame selection:

- Keep frame PD as close as practically possible to the patient's anatomical PD to minimize the necessary horizontal decentration
- Fitting the patient in a zyl frame, without nose pads, will not only cover up some of the lens edge, improving the cosmetics, but also eliminate the need to adjust the nose pads around the thick nasal edges.
- If anatomical features necessitate nose pads, application of an edge roll at the nasal edge might help remedy the adjustment dilemma, while also improving cosmetics.

Current frame styles with deep "B" dimensions can also exacerbate induced prism as the patient will often feel inclined to look further away from the primary gaze position. Occasionally, I'm faced with a moderate to high prescription and a patient electing to go "bigger" in frame size, despite my begging and pleading, "No! Don't do it! Please!"

As I stumble up from the begging position, sometimes, all I can do is reiterate my recommendations and fore worn them of the distortion they may initially experience in the periphery, and the necessary adaptation. This, at least, hopefully helps prepare them and avoid a negative first impression of their new eyewear. Aspheric designs can definitely help reduce the effect, due to a flatter edge profile, but sadly, are not a "fix-all".

**Material Selection**
Now, what about lens material selection? We've just determined that prism adds thickness to the finished lens, so, we should simply default to using the thinnest material we can to make the patient's glasses as thin and cosmetically pleasing as possible, right? WRONG!!! Resist this urge, my friends and fellow ECPs.

To explain why, let's travel back in time to my section on dispersion. Remember what prisms do? They deviate light and, in doing so, disperse visible white light into its component colors. This dispersion can lead to compromised acuities from chromatic aberration in the lens periphery – colored fringes appear around objects and letters due to the component colors of "white light" being focused at different points along the visual axis after undergoing refraction by the lens.

A material's Abbe value determines its dispersive properties:

Dispersive Value = 1 / Abbe Value

From this, we can deduce that a material with a low abbe value is going to have high dispersive properties, and vice versa. And remember, dispersion is <u>BAD!!!</u>

Ok, but how does refractive index factor into the equation?

A material's refractive index is inversely related to its abbe value. So, although a material with a high refractive index will reduce lens thickness, it will increase its dispersive properties due to its reduced abbe value.

So, especially when working with prescribed prism, always attempt to use materials with high abbe values and low dispersive properties, to reduce the potential for chromatic aberration. Materials such as CR39 or Trivex are always preferred options. Most high index 1.60 materials actually have an abbe value of 41, making this also a suitable option for patients with strong prescriptions and / or large amounts of prism.

## <u>Lens Options</u>

As stated earlier, prisms deviate light. It's their job! Our real world presents the eyeglasses wearer with omnidirectional light entering their lenses. As we have already learned, prisms are the foundation of all ophthalmic lenses. Oblique light entering an uncoated lens is going to be scattered in all directions. When prescribed prism is present, this effect can be exacerbated. The application of an anti-reflective treatment will minimize these effects, reducing eye strain and fatigue, and enhancing clarity and acuity – our primary objective.

In addition, supplementing the AR with a 10% grey or brown tint will also help reduce light scatter.

## <u>Prism Verification</u>

Ok, you've set the ground work in selecting the perfect frame and lens material, with the appropriate options. Now, the job comes back from the lab and it's time to verify their accuracy. I know our labs are wonderful, but everyone is human; everyone makes mistakes. It's imperative we verify completed lenses prior to delivery to the patient. You notice "prism" in the Rx and are immediately filled with anxiety and despair, and you ask yourself, "why is it my day to check in jobs?" Have no fear, it's ok. It's just a matter of breaking it down into steps.

Take a deep breath, and here we go . . .

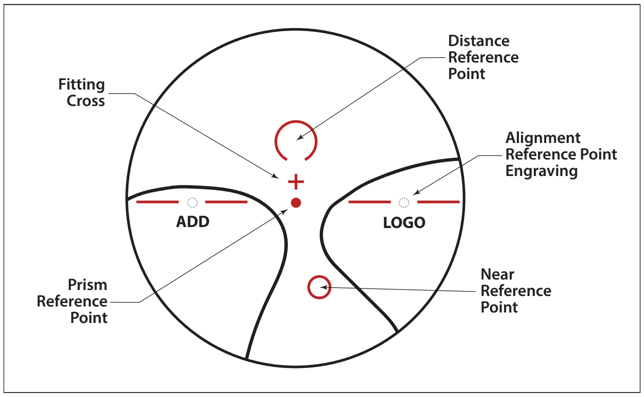
- Mark up lenses with both the vertical and horizontal location of the OC, based on the patient's anatomical PDs and measured OC heights
- Using a lensometer, verify the prism through this point, starting with the highest powered lens, first
- <u>Very important</u> Set Platform Position & <u>DO NOT</u> move it
- Record vertical and horizontal prism present at this point – the point of intersection of the middle line of the lensometer mires in each meridian
- Switch to opposite lens keeping lensometer platform height unchanged

- Verify prism through this point
- Record vertical and horizontal prism
- Calculate net prism using rules for compounding and cancelling prism

NOTE: The above procedure work for single vision and lined multi-focal designs

**Verifying Prism in a Progressive Addition Lens (PAL)**

Figure 10: Reference points in a PAL




In a PAL, ground prism can only be accurately verified through the Prism Reference Point (PRP) – the point below the fitting cross, 17mm from each engraved circle. This actually makes verifying prism in a PAL much easier than other lens designs – it's definitive!

- Locate engraved circles and mark them
- Position lens over PAL cutout template (or locate mid-point between each)
- Mark center position – (The dot below the fitting cross)
- Read vertical and horizontal prism through this point (PRP) for both lenses and calculate net imbalance.

NOTE: Lens power reading at the PRP will be incorrect; this must still be verified at the Distance Reference Point (DRP).

Do not be surprised, if you determine vertical prism has been ground at the PRP, despite not being prescribed. However, it should be an equal amount in each eye. This is known as Prism Thinning. *Prism Thinning* is a technique utilizing equal amounts of vertical prism in the same direction in each eye, usually base down, to create additional thickness in the lower portion of a PAL to accommodate the steepening base curves necessary to provide the add power. It can also be used to reduce edge thickness in a high minus PAL. Since it is equal in both magnitude and direction and, relatively minimal, it does not adversely affect a patient's acuity. Ground prism resulting in no net effect is known as Yoked Prism and will be discussed in greater detail in part 3.

**Conclusion**

So, that's the basic introduction to the world of prism. That's the foundation for what's to follow in parts 2 and 3. I hope part 1 leaves those of you who dread seeing prescribed prism feeling less intimidated, and those of you who can't get enough of it, eagerly anticipating more. Either way, I hope you'll all join me next time for the next thrilling installment.

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