National Academy of Opticianry

The Influence of Lens Position on Effective Power

(Approved by the ABO & NCLE)

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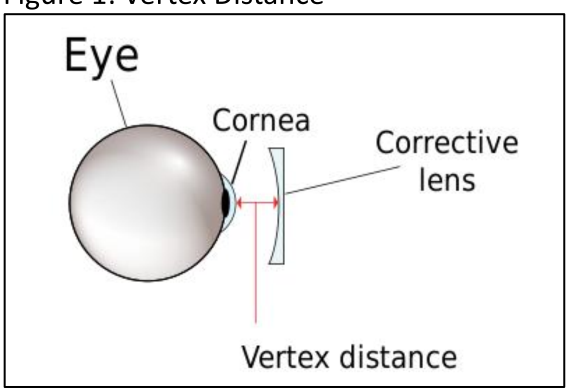
Consider the environment in which the eye examination is performed: the patient is refracted with the phoropter positioned at a vertex distance of 12-14mm (on average), and the lenses at a 90-degree angle to the patient's visual axis, with zero lens tilt in either power meridian. The key factor, here, is the "position" of the lenses – their angle relative to both the incident light rays and the patient's line-of-sight, together with their distance from the cornea. If the lens position, in front of the patient's eyes, is changed in some way – either its vertex distance or angle of tilt, such changes can greatly influence its *effective power.*

This course will discuss the ways in which changes in lens position influence effective lens power, for both glasses and contact lenses alike.

As shown in figure 1, vertex distance is a measure of the distance from the lens to the patient's eyes. As indicated, if the corrective lenses are going to be worn at a vertex distance other than that at which the patient was refracted (on average, 12mm), this can greatly influence their *effective* power. In a nutshell, they will behave differently, when worn. Accordingly, compensation for such changes in vertex distance should be applied when working with lens powers over +/-7D for glasses, and over +/-4D for contact lenses. Why the lower power for contact lenses? Because, generally, the change in vertex distance is greater for a contact lens than it is for glasses, and the magnitude of its change influences the related change in effective lens power.

Figure 1: Vertex Distance



Before diving deeper, let's define a few important terms . . .

- **Prescribed power:** is the refractive power ordered by the doctor or examiner, determined during the "refraction" stage of the eye examination, to correct a patient's refractive error. The prescribed power is what the patient "should" receive in their new eyeglasses.

- **Effective power**: is influenced by lens position. Changes in lens position from those used during examination will result in the lenses, effectively, behaving differently than intended. Basically, the patient will <u>not</u> receive the prescribed powers in their new eyewear, even though the lenses were made precisely as the doctor ordered.

- **Vertex corrected power/compensated power:** is the resultant power ordered, to offset changes in effective powers due to changes in lens position.

Measuring Vertex Distance
A patient's vertex distance can be measured using a simple PD ruler, of necessary. However, while most phoropters provide a means for the examiner to measure the refracted working distance, a Distometer provides the most accurate way for the optician to measure vertex distance for the eyeglasses wearer (figure 2).

The Distometer
A Distometer is a device that precisely measures vertex distance once the frame has been correctly fitted to the patient's face. Eyewear measurements are only as good as the fitting of the eyewear. If the eyewear doesn't fit well to begin with, all related measurements will serve no benefit. Pre-fitting involves adjusting frames to fit the patient's head and facial features, while maintaining certain recommended parameters.

Figure 2: Distometer

Using A Distometer:
- Ask the patient to look straight ahead and close their eyes, with their glasses in place
- Inform them that they will feel a probe against their eyelid
- Position the Distometer between the back surface of the lens and the patient's eye
- Pushing down on a button at the top of the instrument will extend a lever to the back surface of the lens
- The worn vertex distance can then be measured, using the instrument scale
- Remove the instrument from behind the patient's eyewear and let them know they can re-open their eyes.

NOTE: The Distometer factors into its reading, 1mm for lid thickness

Again, vertex distance can always be measured using a PD ruler or other fitting measurement tool provided by many of today's premium lens manufacturers, but a Distometer provides the most accurate method.

The Effects of Changes in Vertex Distance

Changes to the worn vertex distance will influence the lens' effective "plus" power. In that, increasing vertex distance results in an increase in its effective plus power and reducing vertex distance, results in a decrease. For example, moving a "plus" lens closer to the eye, effectively reduces the amount of "plus" power it's providing; moving a minus lens closer to the eye also reduces its effective plus power, increasing the effective minus power it delivers.

NOTE: Industry standard is to reference changes in effective *plus* power, not effective *minus*, because the eye is a hyperopic system.

Typically, changes in vertex distance are more of a concern when fitting contact lenses. For example, the patient may be refracted at a vertex distance of 12mm, but the correction will obviously be applied at the corneal plane. And for general purposes, we can consider the corneal plane to represent a vertex distance of zero. Again, when fitting contact lenses, refractive powers over +/- 4D, in either power meridian, require compensation for changes in vertex distance; referred to as vertex corrected powers.

That said, patients who wear glasses occasionally indicate a preference to wear their them at a vertex distance other than that at which they were refracted (12mm). At which point, if working with traditionally surfaced lenses, vertex corrected powers should also be determined, prior to ordering.

To determine vertex corrected powers, it's first necessary to calculate effective powers at the worn vertex distance – how will the prescribed lens power behave? This can be accomplished using the Effective Power Formula. Of course, for contact lenses, the handy, dandy conversion sheet, available from contact lens manufacturers, is a lot more efficient, but not nearly as much fun!

- Effective Power Formula = $\dfrac{\text{Original Power}}{(1 + (\text{Change in vertex distance x Original Power}))}$

NOTE: Different variations of this formula exist, but in this form, "change in vertex distance" MUST be expressed in meters.

For accurate results, care must also be taken to use the correct sign for both the change in vertex distance and the original power.

For example:

- If vertex distance is increased, change is “-”
- If vertex distance is reduced, change is “+”
- Original power should include its related sign: “+” or “-”

A simple way to remember the sign rule for changes in vertex distance relates to the advice eyeglass wearers are given, with regards to how they wear their eyewear. For optimal vision, do opticians recommended the eyewear being worn closer to, or further from their eyes? Generally, patients are advised to wear them closer, because closer is better. Hence, closer is a “positive” change. So, reducing the vertex distance is “+”.

Let’s work through three examples of how to calculate vertex corrected lens powers using the Effective Power Formula. First with a spherical prescription for a glasses-wearer, and then, both a spherical and sphero-cylinder prescription for a contact lens wearer.

First however, when dealing with formulae such as this, that incorporates multiple operations, compliance with the Order of Operations is vital, for successful outcomes. Here’s a brief review . . .

Order of Operations

When multiple operations are incorporated within a formula, each operation MUST be completed, in a specific order:

- **P**arenthesis
- **Ex**ponents
- **M**ultiplication
- **D**ivision
- **A**ddition
- **S**ubtraction

The acronym, **PEMDAS**, provides a simple way to remember this order of operations, since it stems from the first letters of each operation.

Ok, here we go . . .

Example #1: Glasses Wearer

Consider a nine-diopter myope, refracted at a vertex distance of 12mm, who insists on wearing their glasses at an increased vertex distance of 15mm. How much influence will this 3mm change in vertex distance have on how the lens behaves for the patient - its effective power? And what lens power should be ordered?

Let’s first consider what we *should* expect. Vertex distance is being increased from the original 12mm to 15mm; so, we *should* expect an increased effective plus power (less minus). The question is, how significant will it be, and does it require compensation to ensure the patient sees *as the doctor ordered*?

- Effective Power Formula = $\frac{\text{Original Power}}{(1 + (\text{Change in vertex distance x Original Power}))}$

- Effective Power = -9 / (1+ (-0.003 x -9)) = -9 / (1 + 0.027) = -9 / 1.027 = -8.76D

NOTE: Vertex distance is being increased from 12mm to 15mm, so the change in vertex distance is "-". And this change in vertex distance must be converted to meters (since there are 1000mm in 1 meter, simply divide 3mm by 1000 = 0.003m).

So, a -9.00D lens, refracted at 12mm, will *behave* like a -8.76D lens, if worn at 15mm. Essentially, we've short-changed the patient approximately 0.25D minus power.

It's important to never *just* rely on your calculator. For example, if the vertex distance is being *increased* and your calculated answer indicates that the effective power has NOT changed as you would expect, become more "plus", something went wrong! However, in this case, our calculations agree with our initial expectation, thus, they appear to be correct.

So now, how is this information utilized? Well, if a -9.00D lens is ordered, the patient will be under-corrected by -0.25D. Will they notice? Possibly! So, to determine the vertex corrected lens power to dispense, consider the change that's occurred to the effective power: in this case, it has been reduced by -0.25D. Again, the patient has been short-changed by -0.25D, so it must be returned, in advance.

So, a +-9.25D lens should be ordered. This way, when -0.25D is lost, because of the change in vertex distance, the patient will see *as the doctor ordered* – the optician's objective.

Now, just for the sake of curiosity (watch out, cats), let's see what the outcome would be if we used the *incorrect* sign for the change in vertex distance (minus instead of plus):

- Effective Power = -9 / (1+ (+0.003 x -9)) = -9 / (1 + - 0.027) = -9 / 0.973 = -9.25D

This *incorrect* answer shows an increase in effective minus resulting from an increased vertex distance, which goes against what we'd expect.

NOTE: A major benefit of fitting your patients with a free-form, compensated lens design, besides providing your patients with an enhanced visual experience and increased precision, is that when you provide Position of Wear (POW) measurements (pantoscopic tilt, vertex distance, and wrap), vertex corrected powers are automatically calculated by the proprietary software utilized by the lens design manufacturer. As discussed earlier, the manual compensations discussed above are only necessary when working with traditionally surfaced lens designs.

Let's take a closer look at free-form surfaced lenses and the ways in which they can enhance the patient's visual experience.

Free-form Ophthalmic Lenses

Free-form surfacing technology has given eye care professionals the opportunity to deliver an incomparable visual experience provided by compensated lens designs, fabricated with the utmost precision and accuracy, and customized for every patient. It provides the opportunity to truly personalize the lenses for patients in the form of customized eyewear, not only with progressive addition lenses, but also single vision.

In a compensated free-form lens design, proprietary software algorithms modify the prescribed powers you provide with your order (those written by the doctor), to produce *compensated powers* based on the patient's POW fitting values. These compensated powers are then used during lens design and fabrication, NOT the prescribed powers.

This explains why your lab invoice for a compensated lens will indicate two different sets of powers: one set will reflect the powers you ordered and the other, the compensated powers used during fabrication. It is these *compensated* powers that should be used for verification purposes. And providing the lenses agree with the compensated powers indicated on the invoice, the patient should see "as the doctor ordered", when wearing the lenses in what's referred to as the "as worn" position - the way the frame sits on their face.

Compensated powers allow the patient to experience the prescribed powers intended by the doctor, in real-life wearing conditions. Accordingly, supplying your lab with your patient's *personalized* POW values, measured using *their* selected frames that have been pre-fit and aligned as needed, will best ensure your patient receives lenses that have been truly personalized, from the ground up.

Many things must happen and come together, to result in the best visual experience for the patient. So, while working with them, subtly mention the importance of precise measurements and fitting; talk them through the steps you're taking and discuss how each measurement serves its own purpose. Inform them that you and the doctor are going to use the information they have provided, to personalize the design of their new eyewear and strive to resolve the vision complaints with which they presented. It's even better if the doctor can also do the same while conducting the patient's examination.

There's a common society misconception that all eyewear is the same and the only personalized piece of the equation for great eyewear and best vision is the doctor's written prescription. Now, not to undermine the doctor's role - it goes without saying that great eyewear begins with an accurate prescription; as indicated earlier, the prescription forms the foundation upon which everything else is built. However, most doctors would agree that the prescription is only one component; a vital one, though it may be. That said, *best vision* can only result when many highly skilled professionals collaborate, using premium ophthalmic products, to design and fabricate personalized eyewear solutions.

While advanced POW measurements can further enhance the patient's visual experience, when done correctly, basic measurements such as monocular PDs and vertical OC heights for single vision, as well as seg or fitting heights for lined multifocals and progressives, respectively, are equally as important. So, don't forget the basics!

Horizontal placement of the lens optical center (OC) is determined by the patient's PD measurements. Such measurements direct the lab as to where it should be positioned, horizontally, to best ensure the patient is looking through this point in the lens when in primary gaze. Of course, the lab also needs to know where to position the OC vertically. Otherwise, their default placement will be at the midline or datum. Similar consequences to those caused by inaccurate horizontal alignment of the OCs can also result from inaccurate vertical placement. In fact, any displacement from its ideal location will result in the patient experiencing an induced prismatic effect.

In addition, if any type of multifocal lens is made using incorrect PD measurements, this will influence the near inset:

- An inset that is too narrow will compromise the width of the near zone - especially with a PAL
- An inset that is too wide can result in binocularity issues at near - one eye may be clear when the other is not.

Correct placement of the OC is vital for providing your patients with best vision.

NOTE: if making single vision glasses for a closer working distance than infinity, the patient's OC placement should be adjusted, accordingly.

<u>PD Modification for Near Working Distances</u>

Calculation of near inset can do done using D.R. Gerstman's "*Three-Quarter Rule*'.

- **Three-Quarter Rule:** For every diopter of dioptric demand, the OC of each reading lens should be inset by 0.75mm.
- Dioptric demand = 1/reading distance in meters[1]

NOTE: Dioptric demand is independent of the ADD power.

Example: A patient's monocular PDs for distance are 32/30. The patient wants to read at 40cm and is prescribed an ADD power of +1.00D. What near PDs should be used for a pair of single vision readers?

1. First, calculate dioptric demand, based on the working distance:
   Dioptric demand = 1/working distance in meters = 1/0.40m = +2.50D
2. Now, multiply the dioptric demand by 0.75 for the near inset = 2.50 x 0.75 = 1.9mm/eye
3. Since it's the same for both eyes, near PDs should be 30.1/28.1 (factoring the 1.9mm inset, OU)

Again, the prescribed ADD power does not influence the calculation in any way.

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[1] Brooks, C.W. OD., Irvin M. Borish, OD. System for Ophthalmic Dispensing. 3rd Edition.

OC Height Modification for Near

- Hand the patient something to read
- Ask them to read it while assuming their normal reading posture
- Spot the pupil location, accordingly
- This indicates the OC height to order.

Example #1: Contact Lens Wearer – Spherical Rx

Consider a nine-diopter hyperope, refracted at a vertex distance of 12mm, who is being fit with a contact lens. How much influence will this 12mm change in vertex distance have on how the lens behaves for the patient - its effective power? And what contact lens power should be dispensed?

Let's first consider what we *should* expect. Vertex distance is being reduced from the original 12mm to zero; so, we *should* expect a reduced effective plus power. Again, the question is, how significant will it be, and does it require compensation to ensure the patient sees *as the doctor ordered*?

- Effective Power Formula = $\frac{\text{Original Power}}{(1 + (\text{Change in vertex distance x Original Power}))}$

- Effective Power = +9 / (1+ (+0.012 x +9)) = +9 / (1 + 0.108) = +9 / +1.108 = +8.12D

NOTE: Vertex distance is being reduced from 12mm to zero, so the change in vertex distance is "+".

The result indicates a loss in "plus" power of 0.88D due to this change in vertex distance, which also agrees with our initial expectation. Again, our calculations appear to be correct.

Now, if this patient is fit with a +9.00D contact lens, they will be under-corrected by +0.88D. Will they notice? Most definitely! Accordingly, to determine the vertex corrected lens power to dispense, consider the change that's occurred to the effective power: in this case, it has been reduced by +0.88D. The patient has been short-changed by +0.88D. So, once again, it must be returned, in advance.

Ideally, a +9.88D contact lens should be dispensed. However, assuming the patient is being fit with a stock soft lens, the closest lens power to the required +9.88D (exercising care not to "over-plus"), would be +9.75D. So, a +9.75D lens should be dispensed. This way, when +0.88D is lost as a result of the change in vertex distance, the patient will see *as the doctor ordered* (or at least as close as possible with a stock lens).

Example #2: Contact Lens Wearer – Sphero-cylinder Rx

Consider a patient with the following Rx: -5.50 -3.00 x 180

- Refracted vertex distance = 12mm
- Patient is being fit with a soft toric (non-custom)

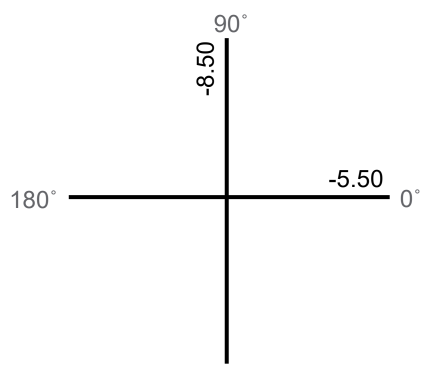
How much influence will this 12mm change in vertex distance have on how the lens behaves for the patient - its effective power? And what contact lens power should be dispensed?

Once again, let's first consider what we *should* expect. Vertex distance is being reduced from the original 12mm to zero; so, we *should* expect a reduced effective plus power (increased minus). The question, once again, is how significant will it be, and does it require compensation to ensure the patient sees *as the doctor ordered*?

Since this patient is both myopic and astigmatic, both power meridians must be taken into consideration.

Transferring the Rx to a power cross, best illustrates the powers in both meridians (figure 3).

Figure 3: Power Cross



From this . . .

- Lens power in the spherical 180˚ meridian = -5.50D @ 12mm *(sphere only along prescribed axis)*
- Lens power in the cylinder 090˚ meridian = -8.50D @ 12mm *(combined sphere and cylinder)*

Each power meridian must be handled separately using the Effective Power Formula:

- Effective Power Formula = $\dfrac{\text{Original Power}}{(1 + (\text{Change in vertex distance x Original Power}))}$

Spherical power meridian:

- Effective Power = -5.50 / (1+ (+0.012 x -5.50)) = -5.50/ (1 + - 0.066) = -5.50 / +0.934 = **-5.88D** *(round to -5.75D)*

Cylinder power meridian:

- Effective Power = -8.50 / (1+ (+0.012 x -8.50)) = -8.50 / (1 + - 0.102) = -8.50 / +0.898 = **-9.47D** *(round to -9.50D)*

From this, at the corneal plane:

- Effective power in the spherical meridian = -5.88D
- Effective power in the cylinder meridian = -9.50D

So, the vertex corrected lens power to dispense must reflect the changes in effective power:

- Spherical power meridian: decreased in effective plus by 0.38D (more minus)
- Cylinder power meridian: decreased in effective plus by 0.97D (more minus)

This effective increase in minus for each power meridian must be factored in:

- <u>Spherical power meridian:</u>
  Original @ 12mm = -5.50D
  Effective @ 12mm = -5.75D (approx.)
  Vertex corrected power at the corneal plane = -5.25D

- <u>Cylinder power meridian:</u>
  Original @ 12mm = -8.50D
  Effective @ 12mm = -9.50D (approx.)
  Vertex corrected power at the corneal plane = -7.50D

- Vertex corrected contact lens power to dispense**: -5.25 -2.25 x 180** *(Original: -5.50 -3.00 x 180)*

When fitting toric lenses, correcting for changes in vertex distance for both power meridians is often overlooked. Oftentimes, only the spherical component is factored into the calculation and the cylinder is assumed to have a negligible effect. However, as demonstrated, considering both spherical and cylinder power meridians is vital to provide your patients a more efficient fitting process, resulting in their increased satisfaction – our primary objective.