Vertex distance and pantoscopic angle – a review

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1 Vertex distance

Overview
Vertex distance, sometimes referred to as back vertex distance or BVD, is an important, often critical part of ophthalmic optics. Yet it remains largely overlooked or misunderstood, with ‘industry averages’ being used, if remembered at all, instead of accurate measurements. Prior to the almost overnight universal adoption of intraocular lenses by ophthalmologists in the late 1970s (surprisingly IOLs were actually invented in the late 1940s), vertex distance measurements and calculations were common due to high numbers of aphakes; and opticians were accustomed to taking the measurements and making the appropriate adjustments. With the rapid adoption of pseudo phakia (IOLs) came an equal drop in the interest in taking vertex distance calculations or making the necessary adjustments in power. This, despite the continued existence of high myopes and high hyperopes. Optometrists continued to take an interest in vertex distance due to their interest in contact lenses, where, of course, the change is greatest.

Vertex distance is attracting attention once again, partly through the advent and growth of ‘as worn’ progressive and single vision lenses. However, there is also a substantial growth in the prevalence of high myopia (stronger than −5.00 D) around the world, with it expected to reach about 10% of the world’s population by 2050.1

As worn lenses require the measurement of vertex distance, though the calculations are made by the laboratory. High myopia (and the fewer cases of high hyperopia) require both the measurement and the calculation of the adjusted power. Some practice computer programs have an entry for vertex distance but often offer a default value. There is also an assumption that this default or the industry average is good enough. This is similar to saying that 64 mm is the average PD and suitable for all spectacle wearers.

Most phoropters and many trial frames used by optometrists have a ruler on the side for measuring vertex distance. This, or one of the other methods of measuring vertex distance discussed below, should be used by the optometrist for any prescription requiring a test vertex distance. As to what prescriptions require a test vertex distance, some guidance is given by British Standard BS2738-3:2004, where they recommend giving a vertex distance for all prescriptions over +/-5.00 D. The vertex distance conversion calculator shown in Figure 17 also starts at 5.00 D. Therefore, it is good policy to measure and record vertex distance (both the optometrist and the dispensing optician) for powers over 5.00 D and make any necessary adjustments to the power. The importance increases as the power increases. The calculator shows that a change in vertex distance of 4 mm at 5.00 D is likely to require a change of 0.12 D while the same distance at 12.00 D would be about 1.50 D.

There is a belief by some that the vertex distance on the prescription is an instruction to fit the spectacles at the same plane. This is incorrect and likely to lead to spectacles sitting inappropriately; usually too far from the eye (if the nose even permits it to be done). The vertex distance on the
prescription should be taken as an instruction to measure the vertex distance on the adjusted frame and calculate the equivalent power (examples will follow below).

There also appears to be a view among some that new advanced lenses do not require this measurement. This is also not true. All high powered lenses regardless of their form require vertex distance measurement and adjustment of powers.

Guesswork and industry averages should not be the methodology adopted by opticians or optometrists, nor should the term ‘default’ be considered good enough. Heights are regularly ignored for single vision lenses, requiring the laboratory to use their ‘default’ of the horizontal centreline, rather than the correct position of 1 mm below pupil centre for every 2 degrees of pantoscopic angle. There will be more of this particular issue at the end of this paper.

What is vertex distance?

Vertex distance is also incorrectly measured in some cases due to misunderstanding the definition. It is the distance between back vertex and corneal apex along the optical axis. It should be measured with zero pantoscopic angle, as you would to find the height for single vision lenses. That is, instruct the client to tilt his/her head back until the lens plane is perpendicular to the floor (see Figure 1). Then, with the client holding that position measure the distance between the back vertex of the lens and the corneal apex (methods of measuring are discussed below).

An official definition can be found in the Australian and New Zealand Standard AS/NZ ISO 13666 (which is also the international standard). In Clause 5.27 the standard defines vertex distance as the “distance between the back surface of the lens and the apex of the cornea, measured with the visual axis perpendicular to the plane of the front of the spectacle frame”.2

![Figure 1 Vertex distance](image)

Figures 2a and 2b show the correct measurement of vertex distance with zero pantoscopic angle (as explained in Figure 1) and with normal pantoscopic angle. Figure 3 shows the incorrect measurement of vertex distance (along the line of sight with normal pantoscopic tilt).
Figure 2a Vertex distance (shown with zero pantoscopic angle)

Figure 2b Vertex distance (shown with normal pantoscopic angle)

Figure 3 Incorrect measurement of vertex distance
Why is it important
For a lens to work its focus must lie on the far point sphere. For myopes the far point sphere is in front of the cornea and for hyperopes it lies behind the retina. The far point sphere is the surface that is conjugate with the retina. That is, light leaving the far point sphere (in the case of myopia) or converging towards the far point sphere (in the case of hyperopia) will form a focus on the retina.

Figure 4 Myopia and the far point sphere
Figure 4 shows the far point sphere (FPS) for a myope. Light diverging from the far point sphere will form a focus on the retina. Any correcting lens, whether it is a contact lens or spectacle lens, must create the same amount of divergence entering the eye for the person to see clearly. Both the power of the lens and its position are very important.

Figure 5 Effect of changing spec plane – minus lenses
In order to create the right amount of divergence the minus spectacle lens must form its virtual focus on the FPS. In Figure 5 the red spectacle lens (the vertical red line in front of the eye) is in the test position and it forms its virtual focus on the FPS as required. However, if we now fit the lens at the blue plane, closer to the eye, we need a lens with a longer focal length. That is, a weaker minus lens. This is why myopes’ contact lenses are weaker than their spectacle correction.

Figure 6 Hyperopia and the far point sphere – plus lens

Figure 6 shows the far point sphere (FPS) for a hyperope. Light converging towards the far point sphere (which, now, lies behind the retina) will form a focus on the retina.

Figure 7 Effect of changing spec plane – plus lens

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A plus spectacle lens must form its real focus on the FPS. In Figure 7 the red spectacle lens (the vertical red line in front of the eye) is in the test plane and it forms its focus on the FPS as required. However, if we now fit the lens at the blue plane, closer to the eye, we need a lens with a shorter focal length. That is, a stronger plus lens. This is why hyperopes’ contact lenses are stronger than their spectacle correction.

How is vertex distance measured?
There are several ways of measuring vertex distance. We will look at some of the methods below. They are in no particular order.

1 Split prism ruler (from Rodenstock)
The split prism at the top of the ruler in Figure 8 is used to bisect the image of the eye horizontally. It is held against the front of the spectacles. The spectacles must be adjusted and the measurement must take place with zero pantoscopic angle as discussed earlier. A later version of this ruler has a built in light source.

Figure 8 Rodenstock split prism ruler
Figure 9 Using the split prism ruler
Figure 10 The image in the split prism ruler

Figure 10 shows the image as seen through the split prism. The arrowhead on the right is lined up with the edge of the iris in the top half of the eye. The bottom part of the rule is then checked against the equivalent side of the iris. In this example it lines up with 13 mm.

The ruler takes into consideration the position of the entrance pupil (about 3 mm behind the cornea) since the reference point, the iris, is actually behind the cornea. That is, the entrance pupil does not lie where the actual pupil lies. This is why the arrowhead is 3 mm below zero. The ruler, however, is resting against the front surface not the back, so this should be considered in the calculation.

The later version with the light source builds the 3 mm into the scale. In that version the edge of the scale is zero and not minus 3 (Figure 11). In this case the black line is lined up with one edge of the iris and a thumb slide is pushed to line the moveable black line with the equivalent point.

Figure 11 The image in the new illuminated split prism ruler

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2 The distometer
Figure 12 shows the distometer. These are callipers that rest on the closed eyelid and when the plunger is pushed measure the distance to the back vertex of the lens. The scale allows for the closed lid (1 mm).

Figure 12 The distometer

Figure 13 shows the distometer being used. Note that the client has her head tilted back to ensure that the lens is perpendicular. Note also that the optician is measuring from below so that his hands are not in the way.

Figure 13 Using the distometer

The round flat pad is gently placed against the closed lid and the plunger on the end pushed in until the other arm of the callipers touches the back surface of the lens.

3 The PD rule
The PD rule is possibly the most widely used tool for measuring the vertex distance, but not the best. Once again, the frame must be adjusted and the measurement taken with zero pantoscopic angle.
One problem with the PD rule is that the position of the back vertex must be estimated. This is made worse if the side of the frame is thick or it is a thick plastic rim.

4 A vertex distance rule
These rules, such as the one from Rayner, pictured in Figure 15, can be used in conjunction with a PD rule. In this case the lens inserts are removed. Then with the frame adjusted and the lens perpendicular, the PD rule is held against the front rim and the vertex distance rule slid in until it touches the closed lid. An allowance of 1 mm is then made for the lid thickness.

5 The pupilometer
Some pupilometers allow vertex distance measurements. They will have two vertical lines in each eye. One, the fixed one, is lined up with the apex of the cornea and the other line (the one usually used for measuring PD) is moved until it is in line with the back vertex of the lens. It is important that
the pupilometer be held exactly side on to the client. It also has the same problem as the PD rule of estimating the back vertex of the lens.

Figure 16 Using the pupilometer to measure vertex distance

6 Digital instruments
Digital instruments are widely available. They can normally measure monocular PDs, heights, pantoscopic angle, face from angle and vertex distance. They have been proven to be very precise.³

Figure 17 Digital instruments
How are the calculations made?
As with taking the measurements there are also several ways the adjusted power can be found.

1 The vertex distance conversion calculator
The vertex distance conversion calculator, often referred to as a Rayner card, is an effective means of finding the adjusted power. The inside disc graduations are in millimetres. The outside disc is in dioptres. The steps to follow are:

**Step 1:** There are two arrowheads on the inside disc. Select the one that is appropriate, depending on whether you are measuring a plus or minus lens.

**Step 2:** Turn the inside disc until the vertex distance given by the refractionist lines up with the dioptric power on the prescription.

**Step 3:** Look around the inside disc until you see the spectacle lens vertex distance that you measured and look at the power adjacent to it on the outside disc. This is the adjusted power. Remember, each meridian must be done separately.

Example 1 (method 1)

Prescription \( -10.50/-2.00 \times 180 \) vertex distance at test 14 mm

The spectacle vertex distance measures 9 mm

First work out the adjusted power for the 10.50 D meridian.

**Step 1:** Use the minus arrowhead.

**Step 2:** Turn the inside disc until 14 mm lines up with 10.50 D

**Step 3:** At 9 mm the power reads 10.00 D.

Now calculate the 12.50 D meridian.

**Step 1:** Use the minus arrowhead.

**Step 2:** Turn the inside disc until 14 mm lines up with 12.50 D

**Step 3:** At 9 mm the power reads 11.75 D.

So, the adjusted power at 9 mm is \(-10.00/-1.75 \times 180\)

Example 2 (method 1)

Prescription \( +12.50/-3.00 \times 180 \) vertex distance at test 14 mm

The spectacle vertex distance measures 8 mm

First work out the adjusted power for the 12.50 D meridian.

**Step 1:** Use the plus arrowhead.

**Step 2:** Turn the inside disc until 14 mm lines up with 12.50 D

**Step 3:** At 8 mm the power reads 13.50 D.
Now calculate the 9.50 D meridian.

**Step 1:** Use the plus arrowhead.

**Step 2:** Turn the inside disc until 14 mm lines up with 9.50 D

**Step 3:** At 8 mm the power reads 10.00 D (or just over).

So, the adjusted power at 8 mm is $-13.50/-3.50 \times 180$

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2 **Vertex distance chart**

The vertex distance chart can be found in many textbooks and is also an effective means of finding the adjusted power. The steps to follow are:

**Step 1:** Use the side of the chart describing what is happening. In Example 1 it is a minus lens fitted closer to the eye. That is, the left hand side of the chart.

**Step 2:** Look down the centre column to find the power and then look across to the column showing how far you have moved from the test vertex distance to the spectacle vertex distance (5 mm in Example 1 and 6 mm in Example 2). This is the adjusted power. Remember, each meridian must be done separately. If the power falls between the powers on the chart (i.e. an 0.25 step) look up the power above and the one below and find the average.

If the new vertex distance does not fall exactly on a power, select the nearest 0.12 D power. If only 0.25 D steps are available then round to the nearest 0.25. And, if the power is exactly half way between two 0.25 powers then round down for plus powers and up for minus, since the spectacles are likely to slide forward.
Example 1 (method 2)

Prescription $-10.50/-2.00 \times 180$ vertex distance at test 14 mm

The spectacle vertex distance measures 9 mm

First work out the adjusted power for the 10.50 D meridian.

**Step 1:** Use the left side of the chart.

**Step 2:** Look down to 10.50 D and across to 5 mm (the difference between 14 and 9). The result is 9.98.

Now calculate the 12.50 D meridian.

**Step 1:** Use the left side of the chart.

**Step 2:** Look down to 12.50 D and across to 5 mm. The result is 11.76.

So, the adjusted power at 9 mm is $-9.98/-1.78 \times 180$

Rounded this becomes $-10.00/-1.75 \times 180$

Round the powers to the nearest 0.12 D. Again, if only 0.25 D steps are available then round to the nearest 0.25. And, if the power is exactly half way between two 0.25 powers then round down for plus powers and up for minus, since the spectacles are likely to slide forward.

Example 2 (method 2)

Prescription $+12.50/-3.00 \times 180$ vertex distance at test 14 mm

The spectacle vertex distance measures 8 mm

First work out the adjusted power for the 12.50 D meridian.

**Step 1:** Use the right side of the chart.

**Step 2:** Look down to 12.50 D and across to 6 mm (the difference between 14 and 8). The result is 13.51.

Now calculate the 9.50 D meridian.

**Step 1:** Use the right side of the chart.

**Step 2:** Look down to 9.50 D and across to 6 mm. The result is 10.07.

So, the adjusted power at 8 mm is $+13.51/-3.44 \times 180$

Rounded this becomes $+13.50/-3.44 \times 180$

Round the powers to the nearest 0.12 D. Again, if only 0.25 D steps are available then round to the nearest 0.25. And, if the power is exactly half way between two 0.25 powers then round down for plus powers and up for minus, since the spectacles are likely to slide forward.
Modified powers for change in vertex distance

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3 The formula
A simple formula will also enable you to calculate the adjusted power. The formula is:

\[ F_e = \frac{F}{1 - dF} \]

Where:
- \( F_e \) = the compensated power
- \( d \) = the test vertex distance minus the spectacle vertex distance in metres (NB it will be negative if the specs fit further from the eye than the test distance)
- \( F \) = the test power

Example 1 (method 3)
Prescription \(-10.50/-2.00 \times 180\) vertex distance at test 14 mm
The spectacle vertex distance measures 9 mm

First work out the adjusted power for the 10.50 D meridian.

\[ F_e = \frac{F}{1 - dF} \]
\[ F_e = \frac{-10.50}{1 - 0.005 \times -10.50} \]
\[ F_e = -9.98 \text{ D} \]

Now calculate the 12.50 D meridian.

\[ F_e = \frac{F}{1 - dF} \]
\[ F_e = \frac{-12.50}{1 - 0.005 \times -12.50} \]
\[ F_e = -11.76 \text{ D} \]

So, the adjusted power at 9 mm is \(-9.98/-1.78 \times 180\)
Rounded this becomes \(-10.00/-1.75 \times 180\)

Once again, round the powers to the nearest 0.12 D. Again, if only 0.25 D steps are available then round to the nearest 0.25. And, if the power is exactly half way between two 0.25 powers then round down for plus powers and up for minus, since the spectacles are likely to slide forward.

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Example 2 (method 3)

Prescription +12.50/–3.00 × 180 vertex distance at test 14 mm

The spectacle vertex distance measures 8 mm

First work out the adjusted power for the 10.50 D meridian.

\[ F_e = \frac{F}{1 - dF} \]

\[ F_e = \frac{+12.50}{1 - 0.006 \times +12.50} \]

\[ F_e = +13.51 \, \text{D} \]

Now calculate the 9.50 D meridian.

\[ F_e = \frac{F}{1 - dF} \]

\[ F_e = \frac{+9.50}{1 - 0.006 \times 9.50} \]

\[ F_e = +10.07 \, \text{D} \]

So, the adjusted power at 8 mm is +13.51/–3.44 × 180

Rounded this becomes +13.50/–3.50 × 180

If the prescription includes an addition, then this should not be changed (form bifocals and progressives). This assumes that the object is moved the same distance as the lens. That is, if the lens is 6 mm closer to the eye then so too would be the object. Since the object remains at the same distance from the lens then it requires the same addition to collimate the light.

Also, it is possible for the spectacles to fit further from the eye (as in a diving mask).

What is meant by ‘as worn’ spectacle lens design?

The concept of as worn is similar to the adjustment for vertex distance discussed above. Essentially the position of the spectacles is what is referred to as the as worn position. In the case of as worn progressives and single vision lenses not only is vertex distance factored in but also pantoscopic angle and face form angle. The laboratory needs the original prescription, the monocular PDs, monocular heights, the vertex distance, face form angle and pantoscopic angle. They will then calculate an adjusted power, just as was done for just vertex distance above, and they will supply the spectacles together with a form indicating the adjusted power against which the spectacles should be checked.
What are the confounding factors?
The base curve chosen can have an effect on the vertex distance. Each 1.00 D change in base curve from the measured lens equates to a 0.6 mm change in vertex distance.\textsuperscript{6} Thus, any variation from the lens insert, or whatever lens is in the frame when the vertex distance is being measured, should make this allowance. This makes the methods in which there is no lens insert or it is difficult to judge the back vertex (methods 3, 4 and 5) even less accurate.

![Figure 19 The effects of base curve](image)

Thick sides on frames and thick rims also present problems when measuring vertex distance. They are less of a problem for the distometer, where you can approach from below, or the split prism.

Conclusion
Measuring vertex distance and making the appropriate calculations of the adjusted power is a very important part of the work of an optician, and measuring the vertex distance at test an important part of the work of an optometrist. Laboratories will not do the calculations for you, though they will make all necessary calculations for as worn lenses. Ignoring vertex distance in high powers can result in providing the client with spectacles that differ substantially from their real prescription, causing blurred vision. In Example 1 above the person would be over-minused by $-0.50$ D in one meridian and by $-0.75$ D in the other. In Example 2 above the person would be over-plussed by $+0.50$ D in one meridian and by $+1.00$ D in the other. This is even worse since it will fog the person’s vision. In the minus case the person could use any amplitude of accommodation to overcome the excess minus, however it would leave them with less accommodation for near.

2 Pantoscopic angle

Overview
As with vertex distance this is a measurement that is often misunderstood. For example, many believe that the back of the traditional PD rule can be used to measure pantoscopic angle (also called pantoscopic tilt): it cannot. All it will measure is the angle between the front and the sides. This could be referred to as the lens angle but it is not a measurement that relates directly to lens design. Pantoscopic angle is the angle between the optical axis of the lens and the visual axis. It depends on the habitual posture of the wearer, the position of their ears and the lens angle of the frame. While the angle between the front and sides as measured on a PD rule will contribute to the pantoscopic angle, one frame worn by two separate people is likely to create two different pantoscopic angles, because it will be affected by their respective posture and the positions of their ears.
What is pantoscopic angle?
The definition given in the Australian and New Zealand Standard AS/NZS ISO 13666 is, the “angle in the vertical plane between the optical axis of a spectacle lens and the visual axis of the eye in the primary position, usually taken to be the horizontal.”

Figure 20 Pantoscopic angle

If the tilt is backwards it is referred to as retroscopic angle. This is rare, except in cases such as snooker/billiard specs. In this case the optical centre must be moved up above pupil centre by 1 mm for every 2 degrees of tilt.

Why is it important
In addition to being required by laboratories for as worn lenses, all lenses should be fitted with pantoscopic angle in mind. Lenses should be fitted with the optical centres dropped 1 mm for every 2 degrees of pantoscopic angle. This should be done for all single vision lenses, aspheric or normal best form. It should also be done for the distance section of bifocals. Indeed, this is the recommended method by the manufacturers of high plus aspheric bifocals. In the case of progressive lenses it has already been done in the lens design. The fitting cross is positioned at the centre of the pupil but the optical centre is the prism reference point (normally about 4 mm below the cross).

Figure 21 Measuring single vision heights
If you do not have the instruments discussed below the easiest way to take this measurement is to zero the pantoscopic angle by asking the client to tilt his head back, as in the left side of Figure 21, until the lens is perpendicular. Then find pupil centre. This will be the optical centre position and it will drop as he adopts his normal posture (right photo).

**How is it measured?**  
As with vertex distance, several instruments have been created to take this measurement. Again, they are in no particular order. And, again, digital instruments would be the ultimate choice. It is important that the frame be adjusted to its final fit position to make an accurate measurement. This will be repeated in each instruction below.

1 **Zeiss pantoscopic gauge**  
For this measurement the frame is adjusted and then the inserts removed. The client is told to sit comfortably and the gauge is placed against the top and bottom rims. The weighted needle will then point to the pantoscopic angle (10 degrees in Figure 23).

![Figure 22 Zeiss pantoscopic angle gauge](image1)  
![Figure 23 Using the Zeiss gauge](image2)

2 **Essilor Rule**  
This works in a similar way. The frame is adjusted and the inserts removed. When the rule is placed against the rims the angle can be measure by the position of the centre of the air bubble. In this example it is 4 degrees here as seen in the magnified inset in the photo.

The Essilor and Zeiss gauges are not as well suited to rimless or nyltag frames since the inserts cannot be removed for the measurement. If left in the gauges tend to rock on the curved insert.
3 Rodenstock pantoscopic angle gauge
Once again, adjust the frame first. The gauge is then clipped on the side and the black line on the left hand side of the small triangle in Figure 24 is aligned with the spectacle lens plane. The angle is then read as the centre of the small ball bearing in the curved groove.
4 Digital instruments
The digital instruments shown in Figure 16 above can also measure pantoscopic angle. As with other measurements they take they have been proven to be the most precise.³

What are the effects of tilting a lens?
If a lens is not fitted according to the optical axis/centre of rotation rule, that is, 1 mm below pupil centre of every 2 degrees of pantoscopic angle, then unwanted astigmatic error will be created.

This is easily demonstrated and calculated. The formula is:

\[
NS = F \left(1 + \sin^2 \frac{a}{2n}\right) \quad \text{Where } NS \text{ is new sphere, IC is induced cyl, } a \text{ is angle of tilt and } n \text{ is refractive index}
\]

\[
IC = NS \tan^2 a
\]

For example:
If a −5.00 D sphere (made in n = 1.500) is tilted 25 degrees it becomes

\[
NS = F \left(1 + \sin^2 \frac{25}{3}\right) \quad IC = NS \tan^2 25
\]

\[
NS = -5.30 \quad IC = -1.15 \, \text{D}
\]

So the lens would read as −5.30/−1.15 × 180 (the axis assumes pantoscopic angle and not face form)

Try tilting a strong lens (over 5.00 D) in the focimeter.

Conclusion
Pantoscopic angle appears to be a somewhat controversial measurement, though it shouldn’t be. It is made worse by claims that you don’t need to bother adjusting heights to compensate for pantoscopic angle (the optical axis/centre of rotation rule) in new advanced lens designs. These new lens designs, while great, are not magical. In fact the reverse is probably true, as suggested by Atchison below. He found that it was more important in aspheric lenses, not less.

Comments from lens experts: the comments below come from some of the leading experts in lens design and spectacle dispensing. Their advice should be heeded.

Prof David Atchison, DSc, School of Optometry and Vision Science, Queensland University of Technology - “In response to poor fitting in the form of tilt or decentration, lenses with aspheric form surfaces were found to have greater off-axis power errors than best-form lenses with spherical surfaces.”⁷

Prof David Atchison, DSc, School of Optometry and Vision Science, Queensland University of Technology - “It is most important that aspheric lenses be correctly fitted which means that each 2° of pantoscopic tilt should be accompanied by approximately 1 mm decentration.”⁷
The optical axis/centre of rotation rule (also known as the centre of rotation requirement) is not a new idea, either: Here are some older quotes dating back to 1941.

**Dr H Goersch Handbook of Ophthalmic Optics (Zeiss) 1983 p 144** - “To meet the centre of rotation requirement, the centration point must be 0.5 mm further below zero visual point for each degree of tilt.”

**Stimson, RL Ophthalmic Dispensing. Whiting Press. Los Angeles 1951 p 181** - “Therefore, if the lens center is dropped about half as many millimetres as the lens is angled to the face-plane, no distortion or power change is induced by a tilted lens.”


**Professors Brooks and Borish, School of Optometry, Indiana University,** “1 mm is subtracted from the height of the OC for every 2 degrees of pantoscopic tilt.”

A final caution: be wary of views that are unique; pet theories and comments such as “I do it this way and I don’t have any problems”. The above quotes all come from peer reviewed journals or internationally recognised authors. All are leading academics in the field. I think that it is wise to take their advice.

Finally, remember, short cuts are not a key to success.

**References**

1 Holden, B. A. et al. in Association for Research in Vision and Ophthalmology.