



A NEW ANGLE ON SOFT TORIC LENSES

Unexpected rotation happens with toric soft lenses.
Learn how to get things back in line.

RICHARD G. LINDSAY, BSCOPTOM

It is now more than 40 years since soft toric lenses were introduced into contact lens practice.^{1,2} Since that time, toric soft lens technology has continued to evolve, with improvements in design and reproducibility and—over the last few decades—the introduction of frequent replacement soft toric lenses (including daily disposable modalities) and the subsequent expansion of this range of lenses. Hence, it is not surprising that contact lens practitioners continue to strongly embrace toric lenses; this is reflected in the fact that over the last 10 years, there has been a commensurate increase in toric lens fitting as a proportion of all soft lenses fitted (Morgan et al, 2017).

As always, the biggest challenge that contact lens practitioners confront in prescribing soft toric contact lenses is determining the extent of lens misalignment if unexpected lens rotation is observed. Lens misalignment occurs when the cylinder axis of the toric soft lens on the eye does not coincide with the cylinder axis of the ocular refraction. It results from the lens rotating by an amount different to that allowed for in the final contact lens prescription. Lens misalignment will result in suboptimal visual acuity because of induced cylindrical error. Note that there is nothing wrong with lens rotation, provided proper allowance is made for this rotation in the final contact lens order.

ESTIMATING LENS ROTATION HAS ITS LIMITATIONS

From the time that toric soft lenses were introduced onto the market, the usual method of determining lens misalignment has been to simply estimate the degree of lens rotation on the eye. This has been facilitated by the toric lenses having markings at one or more specific reference points so that the degree of rotation can be assessed when the lens is on the eye. The markings have

generally been in the form of laser trace, scribe lines, engraved dots, or ink dots. It is important to note that the lens markings do not represent the cylinder axis; they are simply a point of reference for use in assessing lens rotation.⁴ Practitioners will normally estimate the degree of lens rotation, and clinical experience has shown that this is a satisfactory method of assessing lens rotation.⁵

Unfortunately, there are many problems associated with using rotation as the only factor in evaluating the fit of a soft toric lens on the eye.⁶ First, rotation does not provide a direct evaluation of vision performance. Second, rotation can vary between visits, and when there are changes in vision, it may not be clear as to whether they are due to lens misalignment or to other factors. Third, practitioners often mistakenly assess the position of the marker on the cornea rather than its angular orientation when determining lens rotation.⁷ Fourth, errors in estimation of rotation are more likely to occur when evaluating higher amounts of lens rotation.⁵ Finally, it gives us no idea as to whether or not the back-vertex power (BVP) of the lens has been made to specification.

HOW TO DETERMINE LENS MISALIGNMENT USING THE SCO

About 20 years ago, I became increasingly frustrated by the fact that—based purely on assessment of lens rotation—it often required four or more attempts to arrive at the final toric soft lens prescription; and, even then, a successful result was not guaranteed. Effectively, I was relying on what really amounted to educated guesswork, and I reasoned that there had to be a more accurate and reliable method of fitting soft toric contact lenses. Making better use of the spherocylindrical refraction over a mislocating soft toric lens (as advocated by Myers et al⁶) appeared to be the best solution in this regard. The

SPREADSHEET FOR DETERMINING TORIC SOFT LENS MISALIGNMENT
(ADAPTED FROM LINDSAY⁷)

FIGURE 1

	A	B	C	D	E
1		SPHERE	CYLINDER	AXIS	
2					
3	Oc Rx	-1	-2.25	90	=D3/57.2958
4	MATRIX	=B3+C3*(SIN(E3)^2)	=C3*SIN(E3)*COS(E3)		
5		=-C3*SIN(E3)*COS(E3)	=B3+C3*(COS(E3)^2)		
6	OR	0.5	-1	51.5	=D6/57.2958
7	MATRIX	=B6+C6*(SIN(E6)^2)	=-C6*SIN(E6)*COS(E6)		
8		=-C6*SIN(E6)*COS(E6)	=B6+C6*(COS(E6)^2)		
9	SUM	=B4-B7	=C4-C7		
10		=B5-B8	=C5-C8		
11	TRACE	=B9+C10			
12	DET	=(B9*C10)-(B10*C9)			
13	BVP _{in situ}	=(B11-C13)/2	=SQRT((B11^2)-4*B12)	=IF(57.2958* ATAN((B13-B9)/ C9)>0, 57.2958* ATAN((B13-B9)/C9), 180+57.2958* ATAN((B13-B9)/C9))	
14	BVP _{in situ}	-1.00	-2.25	103	

problem was how to use the information obtained from a sphero-cylindrical over-refraction (SCO) to determine what modifications to the back vertex power were required to arrive at the appropriate prescription for the soft toric lens.

Going back to first principles, for a patient to be corrected appropriately with a toric soft contact lens, the BVP on the eye (BVP_{in situ}) should be equal to the patient's refraction at the ocular plane (Oc Rx). Where lens rotation is observed, the cylinder axis of the BVP_{in situ} will differ from the cylinder axis specified in the contact lens prescription by an amount equal to the degree of lens rotation. The specified cylinder axis should incorporate an allowance for this rotation to ensure that the cylinder axis of the lens on the eye will coincide with the cylinder axis of the ocular refraction.

When a toric soft lens mislocates on the eye (i.e., the rotation observed is different from what is expected), the BVP_{in situ} will be different from that required. Cylindrical error will be induced as a result, and this can be determined by performing an SCO with the soft toric lens. The combination of the BVP_{in situ} and the SCO will be

equal to the patient's ocular refraction (Oc Rx):

$$BVP_{in\ situ} + SCO = Oc\ Rx$$

This formula can be rearranged to solve for BVP_{in situ}:

$$BVP_{in\ situ} = Oc\ Rx - SCO$$

The BVP_{in situ} will not only indicate whether the lens is misaligning, but also whether the lens has been made to the correct specifications. Calculating the BVP_{in situ} will require obliquely crossed cylinders to be resolved, and this is best accomplished by matrix optics^{8,9} using the following method:¹⁰

1) Express both the sphero-cylindrical ocular refraction and the SCO in dioptric power matrix form:

$$F = \begin{vmatrix} S+C\sin^2\theta & -C\sin\theta\cos\theta \\ -C\sin\theta\cos\theta & S+C\cos^2\theta \end{vmatrix}$$

where S is the sphere power, C is the cylinder power

and θ is the axis (in radians) of the cylinder.

2) Subtract the dioptric power matrix for the over-refraction from the dioptric power matrix for the ocular refraction to obtain the dioptric power matrix, F_r , for the BVP_{in situ}:

$$F_r = \begin{vmatrix} S_r + C_r \sin^2 \theta_r & -C_r \sin \theta_r \cos \theta_r \\ -C_r \sin \theta_r \cos \theta_r & S_r + C_r \cos^2 \theta_r \end{vmatrix}$$

3) Convert the matrix form of the BVP_{in situ} back to sphero-cylindrical notation using the following formulas:

$$\text{Lens power matrix is } \begin{vmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{vmatrix}$$

$$\text{trace } (t) = a_{11} + a_{22}$$

$$\text{and determinant } (d) = (a_{11}a_{22}) - (a_{12}a_{21})$$

To convert the matrix form of the BVP_{in situ} back to sphero-cylindrical notation, S_r , C_r and θ_r (the sphere power, cylinder power, and cylinder axis, respectively, of the BVP_{in situ}) can be determined as follows:

$$S_r = \frac{(t - C_r)}{2}$$

$$\theta_r = \text{atan} \left(\frac{(S_r - a_{11})}{a_{12}} \right) \times \frac{180}{\pi}$$

(where θ_r is in degrees)

$$C_r = -\sqrt{t^2 - 4d}$$

(The minus sign prior to the radical symbol simply means that the final solution will be in minus cylinder form.)

Example 1 Consider a soft toric lens being fitted to the left eye of a patient. The ocular refraction is $-1.00 -2.25 \times 90$. The specified BVP of the contact lens is $-1.00 -2.25 \times 95$, so this prescription incorporates an allowance for 5° of nasal rotation. An SCO with this lens yields $+0.50 -1.00 \times 51.5$. Solving for BVP_{in situ} results in $-1.00 -2.25 \times 103$. The specified cylinder axis was 95° ; however, the effective cylinder axis on the eye is 103° . Therefore, the lens is exhibiting 8° of temporal rotation on the eye (rather than the expected 5° of nasal rotation). To allow for this 8° of temporal rotation, the contact lens would now have to be reordered with a cylinder axis of 82° to achieve the target cylinder axis on the eye of 90° .

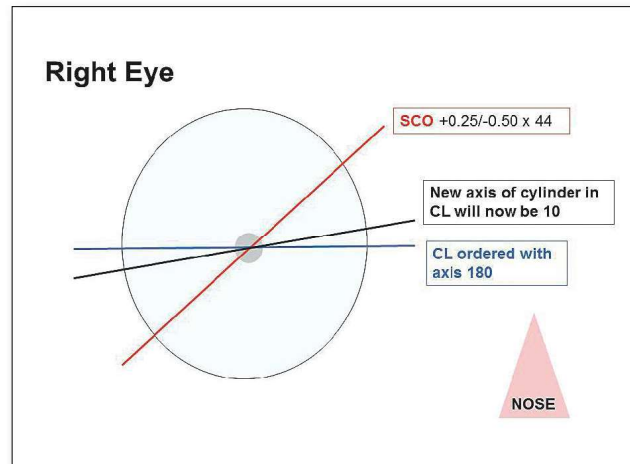


Figure 2. Diagram showing how the new cylinder axis is determined in Example 2.

Figure 1 shows this example in a spreadsheet. This spreadsheet also incorporates all of the formulas required to calculate the BVP_{in situ} and can be quickly utilized in clinical practice. (Note that the values shown for the BVP_{in situ} in row 14 are superfluous to this spreadsheet; they have simply been included to show what would be obtained in row 13 by application of the formulas.)

There are many problems associated with using rotation as the only factor in evaluating the fit of a soft toric lens on the eye.

FREQUENT REPLACEMENT SOFT TORIC LENSES ALLOW US TO KEEP IT SIMPLE

While it is nice to have access to these formulas (and the spreadsheet) to calculate the degree of lens misalignment, practitioners usually like to keep things fairly simple in the clinical setting. Thankfully, we can do this as a result of the popularity of frequent replacement soft toric lenses and the fact that these lenses generally have a restricted parameter range. Presently, most toric soft contact lenses are prescribed on a frequent replacement basis, with a recent survey revealing that only 1% of new soft contact lens fits or refits were prescribed on an unplanned replacement basis globally.³

Virtually all frequent replacement soft toric lenses are produced as a stock range of lenses encompassing a certain number of cylindrical powers (such as $-0.75D$,

−1.25D, and −1.75D), a set choice of spherical powers (for example, from +6.00D to −9.00D), and cylinder axes in 5° or 10° steps—most commonly the latter—usually encompassing the complete spectrum from 0° to 180°. The fact that we are generally limited to ordering our cylinder axes in 10° steps means that it is quite acceptable to approximate when adjusting for lens misalignment in clinical practice.

There are also three useful rules-of-thumb that we can utilize to quickly determine whether a toric soft lens is misaligning on the eye.¹⁰ First, a lens made to specification but mislocating on the eye will produce an over-refraction with a spherical equivalent equal to zero.¹¹ Where the sphere or cylinder power is also incorrect, the spherical equivalent of the over-refraction will not equal zero. Second, if a lens is mislocating on the eye, the axis of the cylinder in the over-refraction will be oblique with respect to the prescribed cylinder axis in the contact lens. Third, the direction of the lens misalignment is always opposite to the axis of the over-refraction, relative to the prescribed cylinder axis. This means that to allow for this lens misalignment so as to obtain the new (required) cylinder axis of the contact lens, we need to move the lens cylinder axis in the direc-

The BVP_{in situ} will not only indicate lens misalignment, but also whether the lens has been made to the correct specifications.

tion of the axis of the cylinder in the over-refraction.

Example 2 Consider a frequent replacement soft toric lens that is being fitted to the right eye of a patient. The ocular refraction is $-3.00 -1.25 \times 005$. The specified BVP of the contact lens is $-3.00 -1.25 \times 180$, so this prescription incorporates an allowance for 5° of nasal rotation. An SCO with this lens yields $+0.25 -0.50 \times 44$. Solving for BVP_{in situ} using the spreadsheet and the formulas results in $-3.00 -1.25 \times 173$. The specified cylinder axis was 180°; however, the effective cylinder axis on the eye is 173°. Therefore, the lens is exhibiting 7° of temporal rotation on the eye (rather than the expected 5° of nasal rotation—hence, 12° of mislocation). To allow for this 7° of temporal rotation, the contact lens would now have to be reordered with a cylinder axis of 12° to achieve the target cylinder axis on the eye of 5°.

However, we are fitting this patient with a frequent replacement toric soft lens in which the cylinder axes are

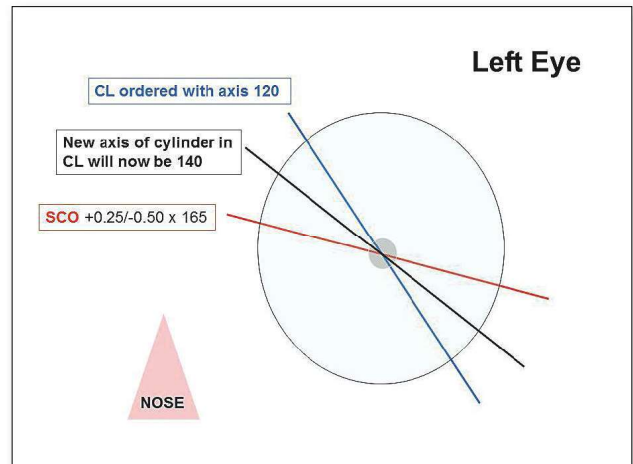


Figure 3. Diagram showing how the new cylinder axis is determined in Example 3.

available only in 10° steps. Hence, it is acceptable here to approximate. Using our three rules, we can confirm that there is lens mislocation and then determine the new contact lens prescription. First, the SCO ($+0.25 -0.50 \times 44$) has a spherical equivalent of zero. Second, the axis of the cylinder in the SCO (44°) is oblique with respect to the specified cylinder axis in the contact lens (180°). Based on these two observations, we can therefore conclude that there is lens mislocation. The third rule states that to obtain the new cylinder axis of the contact lens, we need to move it in the direction of the cylinder axis in the SCO. Hence, we need to change the cylinder axis in the contact lens to 10° (moving from 180° toward 44° [Figure 2]), which approximates well to the 12° axis we would have ordered based on the formulas and calculation.

Given that we will generally be prescribing frequent replacement soft toric lenses that have cylinder axes in 10° steps, there is the issue here of how much modification (i.e., 10°, 20°, or more) needs to be made to the cylinder axis when we approximate rather than calculating the actual amount of lens misalignment based on the previously outlined formulas. To help in this regard, Table 1 shows the resultant cylinder expected from axis misalignment for the different amounts of cylinder power and lens mislocation. Note that this table does not show expected SCO; rather, it has been simplified to show just what would be the expected cylindrical component of the SCO.

Example 3 Consider a disposable toric soft lens that is being fitted to the left eye of a patient. The ocular refraction is $-1.00 -0.75 \times 130$. The specified BVP of the contact lens is $-1.00 -0.75 \times 120$, so this prescription incorporates an allowance for 10° of temporal rotation. An SCO with this lens yields $+0.25 -0.50 \times 165$. Solving for BVP_{in situ} using the spreadsheet and the formulas

RESULTANT CYLINDER FROM AXIS MISALIGNMENT

TABLE 1

Lens Cylinder Power	0.75	1.25	1.75	2.25
5° mislocation	0.12	0.20	0.29	0.38
10° mislocation	0.25	0.41	0.58	0.75
15° mislocation	0.37	0.61	0.87	1.13
20° mislocation	0.50	0.82	1.16	1.50

results in $-1.00 -0.75 \times 110$. The specified cylinder axis was 120° ; however, the effective cylinder axis on the eye is 110° . Therefore, the lens is exhibiting 10° of nasal rotation on the eye (rather than the expected 10° of temporal rotation—hence, 20° of mislocation). To allow for this 10° of nasal rotation, the contact lens would now have to be reordered with a cylinder axis of 140° to achieve the target cylinder axis on the eye of 130° .

Now if we use our three rules, the SCO ($+0.25 -0.50 \times 165$) has a spherical equivalent of zero, and the axis of the cylinder in the SCO (165°) is oblique with respect to the specified cylinder axis in the contact lens (120°). Based on these two observations, we can confirm that there is lens mislocation. We then need to move the lens cylinder axis in the direction of the axis of the cylinder in the SCO, so we need to move it from 120° toward 165° . Table 1 shows us that for a cylinder power of 0.75D, a 20° mislocation will lead to a resultant cylinder (in the SCO) of 0.50D; hence, we need to change the cylinder axis in the contact lens to 140° (Figure 3). Once again, this is in concordance with what we would have ordered based on calculating the actual amount of lens misalignment.

As always, if the visual acuity is not improved by the SCO, we need to determine whether the cause of the reduced visual acuity is a poorly fitting lens, a lens of poor quality (possibly due to significant deposition on the lens surface), or some form of ocular pathology.⁶

WHAT ABOUT SOFT TORIC LENS CALCULATORS?

Can you use toric soft lens calculators? The answer is basically yes—with some qualifications. Initially, some practitioners and contact lens laboratories advocated simply adding the SCO to the BVP of the contact lens to determine lens misalignment. However, what does this really achieve? Not much, actually, as adding the SCO to the specified BVP of the lens will yield a useless and irrelevant piece of information, as lens rotation generally causes the effective BVP of the contact lens on the eye to be different from the specified BVP.

There have been a number of good soft toric lens calculators proposed by practitioners,^{12,13} and companies have also developed useful programs that allow you to adjust the BVP of a toric soft contact lens when lens misalignment is observed. Most of these calculators still have the limitation of requiring clinicians to estimate the degree of lens rotation and/or they do not provide any idea as to whether or not the toric soft contact lens has been made to the correct specification.¹⁴

Given the potential error—and the lack of information—of estimating the degree of rotation of the soft toric lens on the eye, I would argue that calculating the effective BVP of the contact lens on the eye ($BVP_{in\ situ}$), by utilizing a patient’s ocular refraction and the sphero-cylindrical refraction obtained over the mislocating contact lens, is a more accurate technique that can be used to calculate the degree of lens misalignment. For frequent replacement toric soft lenses especially—given their limited parameters for cylinder power and axes—using the $BVP_{in\ situ}$ obtained from the SCO in combination with the three rules outlined in this article is an acceptable and accurate way of adjusting the BVP of the contact lens when lens misalignment is observed. **CLS**

Richard Lindsay is a Fellow of the American Academy of Optometry and a Diplomate of its Cornea and Contact Lens Section. Presently, he manages his own specialist contact lens practice in East Melbourne, Australia.

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