

Solving the Problem of Toric Soft Lens Misalignment

A common challenge that the contact lens practitioner confronts in prescribing toric soft 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, and is due to 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.

The usual method of determining lens misalignment is to simply estimate the degree of lens rotation on the eye. However, calculation of the effective back vertex power of the contact lens on the eye ($BVP_{in situ}$), by utilizing the patient's ocular refraction (Oc Rx) as well as the spherocylindrical refraction obtained over the mislocating lens (SCO), is a more accurate technique that can be used to calculate the degree of lens misalignment.

When a toric soft lens axis mislocates on the eye, the $BVP_{in situ}$ will differ from the ocular refraction hence inducing significant cylindrical error. The combination of the $BVP_{in situ}$ and the SCO should be equal to the patient's ocular refraction.

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

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

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

Given the over-refraction with the lens and the patient's ocular refraction, we can resolve these obliquely crossed cylinders and calculate $BVP_{in situ}$ using matrix optics and the following method:

- Express both the spherocylindrical ocular refraction and the spherocylindrical over-refraction 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.

- 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 $BVP_{in situ}$.

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

- Convert the matrix form of the $BVP_{in situ}$ back to spherocylindrical notation using the following formulae:

If the lens power matrix is $\begin{vmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{vmatrix}$

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

To convert the matrix form of the $BVP_{in situ}$ back to spherocylindrical 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:

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

$$\theta_r = \text{atan} \frac{(S_r - a_{11})}{a_{12}} \times \frac{180}{\pi} \text{ (where } \theta_r \text{ is in degrees)}$$

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

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

These formulae can easily be incorporated into the following spreadsheet which can then be quickly utilized in clinical practice.

	A	B	C	D	E
1		SPHERE	CYLINDER	AXIS	
2					
3	Oc Rx	-3	-2	180	=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	37.5	=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))	

For example, consider a toric soft lens being fitted to a patient's *right* eye. The patient's ocular refraction is $-3.00/-2.00 \times 180$. The specified BVP of the contact lens is $-3.00/-2.00 \times 170$, hence this prescription incorporates an allowance for 10° nasal rotation. A SCO with this lens yields $+0.50/-1.00 \times 37.5$ (note that over-refractions incorporating oblique cylinders are often indicative of lens mislocation). Solving for BVP_{in situ} gives $-3.00/-2.00 \times 165$. The specified cylinder axis was 170, however the effective cylinder axis on the eye is 165. Therefore the lens is exhibiting 5° temporal rotation on the eye (instead of the expected 10° nasal rotation). To allow for this 5° temporal rotation, the contact lens would now have to be reordered with a cylinder axis of 5 to achieve the target cylinder axis on the eye of 180.

The BVP_{in situ} calculated using the previous formulae will not only indicate if the lens is misaligning, but also if the lens has been made to the correct specifications. A toric soft lens mislocating on the eye but incorporating the appropriate power will produce an over-refraction with a spherical equivalent equal to zero. Where the sphere or cylinder power is also incorrect, the spherical equivalent of the over-refraction will not equal zero. In the previous example, the spherical equivalent of the SCO ($+0.50/-1.00 \times 37.5$) was zero, indicating that the misaligned lens did have the appropriate spherical and cylindrical powers.

Some practitioners and contact lens laboratories advocate adding the SCO to the BVP of the contact lens to determine lens misalignment. However, what does this really achieve? Well, 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 is a method proposed whereby the SCO is added to the effective BVP of the contact lens on the eye (BVP_{in situ}), with the latter being determined by observing the degree of lens rotation and then making the appropriate adjustment to the cylinder axis in the BVP. (Note in this case, you must use right add and left subtract for nasal rotation as we are adjusting for lens rotation that has already occurred.) However, this simply results in the ocular refraction (remember the formula $BVP_{in situ} + SCO = Oc Rx$), which we obviously already know. The appropriate allowance is then made for the observed rotation (using left add and right subtract for nasal rotation) to determine the required back vertex power. A variant on this method is where an adjustment is made to the cylinder axis in the SCO (using left add and right subtract for nasal rotation) and then this modified SCO is added to the original contact lens BVP to determine the contact lens BVP that now needs to be ordered. Both of these methods require an accurate estimation of the amount of lens rotation and they also assume that the contact lens BVP has been made to the specifications outlined by the practitioner.

References

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