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Soft toric lens rotation adjustment strategy

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Abstract
Before the fairly recent invention of soft toric contact lenses, astigmats had two lens options outside of spectacles: soft spherical lenses or hard contact lenses. Hard lenses provide great optics but the discomfort of these lenses eliminates them as an option to many. Soft spherical contact lenses provide desirable comfort but lack the cylinder correction needed by astigmats. A hybrid lens having the comfort of a soft lens and the optics of a hard lens would solve this problem. Thus, the toric soft lens was born. It had the comfort of the soft lens and the cylinder correction resulting in hard lens wear. The “flimsy” nature of soft lenses material allows for this comfortable fit, but also allows the lens to rotate freely orienting itself differently from blink to blink. This is of no concern for spherical soft lenses as the power is the same in all meridians, but with soft toric lenses orientation is key as there is both a spherical and a cylindrical correction. In an effort to stabilize the rotation of soft toric lenses, a prism ballast design was developed. This prism ballast results in a lens that is thicker over one end. This thicker end and its interaction with the wearer’s upper lid stabilizes the orientation of the lenses by what has been labeled “the watermelon seed effect.” This “watermelon seed” phenomenon forces the thicker part of the lens inferior. The labeled power on the soft toric lens assume the lens has oriented itself with the thicker portion perfectly perpendicular. In actuality, the lens rarely perfectly aligns this way. To correct for this shift, many clinicians estimate the direction of rotation, from their perspective, and magnitude. Then applying, the LARS (Left Add, Right Subtract) rule they make their correction to the axis. This estimation of rotation is not easy. Even an experience clinician can expect + 5° error in their estimation. 5° of rotation is not that much, just less than 3% (5°/180° ~ 3%) of a full rotation, but can definitely affect and blur the wearer’s vision. A method relying less on the clinician’s subjective estimation would more accurately measure the amount of lens rotation. This strategy will help more accurately estimate the amount and direction of rotation. Very simply: The amount of rotation of the spherocylindrical lens can be more accurately measured with an over-refraction and a few other measurements. First of all, the vertex corrected refractive error from phorometry is needed. From this value, a soft toric lens will be selected with an appropriate base curve. This lens will be as close to the vertex corrected refraction as possible. The fit of the lens is also of utmost importance as a lens that is too flat will be uncomfortable for the patient and will rotate differently and unpredictably with each blink. Once a suitable lens based on comfort, stability, and the patient’s refractive error has been determined, an over-refraction will be performed “over” this lens. This over-refraction value along with the vertex corrected refractive error of the patient can be used to calculate the amount of rotation of the lens. This magnitude of the rotation will then be added or subtracted based on the direction of rotation of the original soft toric lens’ axis. Now a more appropriate lens based on the rotation intrinsic to the wearer can be determined resulting in the most clear vision possible.

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SOFT TORIC LENS ROTATION ADJUSTMENT STRATEGY

BY
JPHAMEL

A THESIS PROJECT SUBMITTED TO THE FACULTY OF THE
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SOFT TORIC LENS ROTATION ADJUSTMENT STRATEGY

JPHamel

Patrick Caroline, COT, FAAO
JPHamel was born in Holyoke, MA on July 9th, 1975. In the late seventies he moved to the Central Valley of California with his parents and two sisters. Here he grew up and graduated from Merced High School in Merced, CA in 1993. After high school, he was awarded three scholarships: Virginia Smith Memorial Scholarship, Bloss Memorial Scholarship, and World Color Press, Roswell Messing, Jr. Four Year Scholarship and enrolled at University of California-Davis (UCD). At Davis, he earned a Bachelor of Science in Nutrition Science in 1997 and was invited into Circle of Honor Alumni Association at UCD and Golden Key National Honor Society. After UCD, he took a year off from school working for Kaplan as a tutor/teacher for various college admission tests including the MCAT, OAT, and DAT. In 1998, he enrolled at Pacific University College of Optometry in Forest Grove, OR and is on his way to earning a degree in optometry in May 2002. He plans on most likely settling down with a private practice somewhere in Central or Northern California near his family.
Before the fairly recent invention of soft toric contact lenses, astigmats had two lens options outside of spectacles: soft spherical lenses or hard contact lenses. Hard lenses provide great optics but the discomfort of these lenses eliminates them as an option to many. Soft spherical contact lenses provide desirable comfort but lack the cylinder correction needed by astigmats. A hybrid lens having the comfort of a soft lens and the optics of a hard lens would solve this problem. Thus, the toric soft lens was born. It had the comfort of the soft lens and the cylinder correction resulting in hard lens wear.

The "flimsy" nature of soft lenses material allows for this comfortable fit, but also allows the lens to rotate freely orienting itself differently from blink to blink. This is of no concern for spherical soft lenses as the power is the same in all meridians, but with soft toric lenses orientation is key as there is both a spherical and a cylindrical correction. In an effort to stabilize the rotation of soft toric lenses, a prism ballast design was developed. This prism ballast results in a lens that is thicker over one end. This thicker end and its interaction with the wearer's upper lid stabilizes the orientation of the lenses by what has been labeled "the watermelon seed effect." This "watermelon seed" phenomenon forces the thicker part of the lens inferior. The labeled power on the soft toric lens assume the lens has oriented itself with the thicker portion perfectly perpendicular. In actuality, the lens rarely perfectly aligns this way. To correct for this shift, many clinicians estimate the direction of rotation, from their perspective, and magnitude. Then applying, the LARS (Left Add, Right Subtract) rule they make their correction to the axis.

This estimation of rotation is not easy. Even an experience clinician can expect $\pm 5^\circ$ error in their estimation. $5^\circ$ of rotation is not that much, just less than 3% ($5^\circ/180^\circ \sim 3\%$) of a full rotation, but can definitely affect and blur the wearer's vision. A method relying less on the clinician's subjective estimation would more accurately measure the amount of lens rotation.

This strategy will help more accurately estimate the amount and direction of rotation. Very simply: The amount of rotation of the spherocylindrical lens can be more accurately measured with an over-refraction and a few other measurements. First of all, the vertex corrected refractive error from phorometry is needed. From this value, a soft toric lens will be selected with an appropriate base curve. This lens will be as close to the vertex corrected refraction as possible. The fit of the lens is also of utmost importance as a lens that is too flat will be uncomfortable for the patient and
will rotate differently and unpredictably with each blink. Once a suitable
lens based on comfort, stability, and the patient’s refractive error has been
determined, an over-refraction will be performed “over” this lens. This
over-refraction value along with the vertex corrected refractive error of the
patient can be used to calculate the amount of rotation of the lens. This
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direction of rotation of the original soft toric lens’ axis. Now a more
appropriate lens based on the rotation intrinsic to the wearer can be
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ACKNOWLEDGMENTS

I would like to thank everyone who helped with this thesis project. First off, I would like to thank Pat Caroline, COT, FAAO, for helping me come up with the idea for this project. I would also like to thank Dr. Karl Citek for his help and his Ophthalmic Optic (OPT 601) notes on the optics aspect of the project. Finally, I would like to thank Blake Sweeney, a computer science engineer, who will help turn this project into software.
SOFT TORIC LENS ROTATION ADJUSTMENT STRATEGY

The first part of this soft toric lens rotation adjustment strategy is a reliable refraction. This refraction will be used to decide the most appropriate soft toric lens. To determine the most suitable lens power, a vertex correction to the plane of the cornea must be calculated in both meridians. The equation is below.

**Vertex Correction**

\[ P' = \frac{P}{1-dP} \]

- \( P \) = original power in diopters
- \( d \) = distance in meters to new position where power will be calculated
  - If the new position is closer to the eye, \( "d" \) is positive.
  - If the new position is further from the eye, \( "d" \) is negative
- \( P' \) = vertex corrected power in diopters

Note: \( P' \) is rounded to the nearest quarter diopter as contact lenses are available in quarter diopter increments.

**Example: Refractive error from phorometry**

- \(-5.00 -2.00 \times 180 \text{ @ } 13\text{mm in front of the cornea}
- \(-7.00 @ 090\)

After vertex correction and rounded to the nearest quarter diopter, we have:

- \(-4.75 -1.75 \times 180\)
- \(-6.50 @ 090\)
- \(-4.75 @ 180\)
A soft toric lens with this lens power or as close as possible should be chosen.

Power is not the only key feature of the lens; an appropriate base curve is necessary. The fit of the lens is also of utmost importance as a lens that is too flat will be uncomfortable for the patient and will rotate differently and unpredictably with each blink. A fit that is tight enough to provide comfort for the patient with a stable amount of rotation, but loose enough to provide the necessary amount of tear and oxygen exchange is the goal.

Now that we have a lens with an appropriate base curve and the vertex corrected power, an over-refraction with this lens is the next step. An accurate over-refraction is important, as it will be used to calculate the amount of rotation of the lens.

At this point we have the original refraction, the vertex corrected soft toric lens power and axis, and the over-refraction. This is all we need to determine how much the lens has moved.

**Obliquely Crossed Cylinders**

The calculation of the rotation is based on obliquely crossed spherocylinder formula:

\[
\text{Spherocylinder A} + \text{Spherocylinder B} + \text{Spherocylinder C}
\]

In this instance, the three spherocylinders are the refractive error from the original refraction, the soft toric lens (but now vertex corrected back to the plane of the phoropter where the other two values were calculated), and the over-refraction.

\[
\text{Soft toric lens vertex corrected to the plane of the phoropter} + \text{Over-refraction over the soft toric lens} + \text{Refractive Error of the patient}
\]

A vector analysis of cylinders will determine how much the soft toric lens has rotated:

Basically, what two cylinder vectors from the 1) soft toric lens and 2) the over-refraction will equal the cylinder component of the patient’s refraction.
Example #1

<table>
<thead>
<tr>
<th></th>
<th>Soft toric lens vertex corrected to the plane of the phoropter (CL)</th>
<th>Over-refraction over the soft toric lens (ORE)</th>
<th>Refractive Error of the patient (RE)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-4.75-2.25X005</td>
<td>+1.50-1.00X040</td>
<td>-5.00-2.00X010</td>
</tr>
</tbody>
</table>

First step is to subtract the over-refraction vector from the refractive error vector to determine where the axis of the soft toric lens has oriented itself. To subtract vectors one simply adds the opposite of the vector, which is the vector rotated $180^0$.

To make things simpler, we start off by setting the RE vector at angle $0^0$.

![RE magnitude=2.00 direction 0°](image1)

We then insert the ORE vector at an angle twice the difference between the axis of the refractive error and the over-refraction because we are only dealing with axis values between 0-180.

$40^0 - 10^0 = 30^0$

$30^0 \times 2 = 60^0$

![ORE magnitude=1.00 direction 60°](image2)

Since we are actually, subtracting ORE from RE, we need to rotate the vector by $180^0$.

![Rotation](image3)
The resultant of the addition of these two vectors will locate the position of the cylinder of the toric soft contact lens.

Resultant describes the position of the cylinder of the soft toric lens (CL)

Vector analysis
Vertical component of RE vector = 0
Horizontal component of RE vector = 2.00

Vertical component of ORE vector \( \rightarrow \sin 60^\circ (1.00) = 0.87 \)
Horizontal component of ORE vector \( \rightarrow \cos 60^\circ (1.00) = 0.50 \)

Therefore, Vertical component of CL vector \( \rightarrow 0.87 \)
Horizontal component of RE vector \( \rightarrow 2.00 - (0.50) = 1.50 \)
Thus the angle of the resultant equals $\Rightarrow \tan^{-1}(0.87/1.50) \sim 30^0$

Next we divide this value by 2 in order to accommodate for the earlier doubling of the angle. This results in a value of $15^0$.

This is the position of the axis of the soft toric lens cylinder relative to the refractive error. Since the over-refraction axis value was greater than the axis of the refractive error $40^0$ to $10^0$, this tells us that the axis of the soft toric lens rotated below the axis of the refractive error. In this case, the value of the rotation value must be subtracted from the axis of the refractive error to correct for and locate the position of the soft toric lens axis.

Note: if the over-refraction axis value was less than the axis of the refractive error this value would have been added to the axis of the refractive error.

The result is a positioning of the soft toric cylinder axis at $\Rightarrow 10^0 - 15^0 = -5^0$

Adding $180^0$ to correct for the negative value $\Rightarrow (-5^0) + 180^0 = 175^0$.

The package states that the soft toric lens is located at $5^0$. A rotation from the package labeled and designed value of $5^0$ to the actual $175^0$ tells us that this lens design on this patient’s eye rotates $10^0$. A rotation from $5^0$ to $175^0$ constitutes is a rotation to the left. Applying the LARS (Left Add, Right Subtract) pneumonic, the $10^0$ rotation must be taking into account by subtracting this value from the packaged listing to correct for the lens’ intrinsic orientation on this patient’s eye. For this lens design to align properly with the refractive error of the patient’s eye of $10^0$, this patient should wear a lens with the packaged listed axis of $20^0$. 
Example #2

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soft toric lens vertex corrected to the plane of the phoropter (CL)</td>
<td>-4.75-2.25X005</td>
</tr>
<tr>
<td>Over-refraction over the soft toric lens (ORE)</td>
<td>+0.25-0.50X160</td>
</tr>
<tr>
<td>Refractive Error of the patient (RE)</td>
<td>-5.00-2.00X010</td>
</tr>
</tbody>
</table>

First step is to subtract the over-refraction vector from the refractive error vector to determine where the axis of the soft toric lens has oriented itself. To subtract vectors, one simply adds the opposite of the vector, which is the vector rotated 180°.

To make things simpler, we start off by setting the RE vector at angle 0°,

\[ \text{RE magnitude}=2.00 \quad \text{direction}=0° \]

Here, again, we then insert the ORE vector. But since there is > 90° difference between the two angles, we first need to correct for this difference by subtracting 180° from the angle to get a difference of equal or less than 90°.

Corrected over-refraction value \( \rightarrow 160°-180° = -20° \)

Now, we insert ORE vector at an angle twice this difference between the axis of the refractive error and the over-refraction because we are only dealing with axis values between 0-180.

\[ -20°-10° = -30° \]

\[ -30° \times 2 = -60° \]
Since we are actually subtracting ORE from RE, we need to rotate the vector by $180^\circ$.

The resultant of the addition of these two vectors will locate the position of the cylinder of the toric soft contact lens.

Resultant describes the position of the cylinder of the soft toric lens (CL)

Vector analysis

Vertical component of RE vector = 0
Horizontal component of RE vector = 2.00

Vertical component of ORE vector $\rightarrow \sin 60^\circ (0.50) = 0.42$
Horizontal component of ORE vector $\rightarrow \cos 60^\circ (0.50) = 0.25$
Therefore, Vertical component of CL vector → 0.42
Horizontal component of RE vector → 2.00 - (0.25) = 1.75

Thus the angle of the resultant equals → \( \tan^{-1} \left( \frac{0.42}{1.75} \right) \approx 13.5^0 \)

Next we divide this value by 2 in order to accommodate for the earlier doubling of the angle. This results in a value of ~7°.

This is the position of the axis of the soft toric lens cylinder relative to the refractive error. Since the corrected over-refraction axis was less than the axis of the refractive error, -20° to 10°, this tells us that the axis of the soft toric lens rotated above the axis of the refractive error. In this case, the value of the rotation must be added to the axis of the refractive error to correct for and locate the position of the soft toric lens axis.

Note: if the corrected over-refraction axis value was greater than the axis of the refractive error this value would have been subtracted to the axis of the refractive error).

The result is a positioning of the soft toric cylinder axis at → 10° + 7° = 17°

The package states that the soft toric lens is located at 5°. A rotation from the package labeled and designed 5° to the actual 17° tells us that this lens design on this patient’s eye rotates 12°. A rotation from 5° to 12° constitutes a rotation to the right from the observer’s perspective. Applying the LARS (Left Add, Right Subtract) pneumonic, the 12° rotation must be taken into account by adding this value to the packaged listing to correct for lens’ intrinsic orientation on this patient’s eye. For this lens design to align properly with the refractive error of the patient’s eye, this patient should wear a lens with the packaged listed axis of 178° (178° + 12° = 190°).