Sources of 

- Corneal astigmatism measurements
- Methods of calculation
- Corneal surgically induced astigmatism (SIA)
- Toric IOL misalignment

Unexpected residual astigmatism!

Single-angle vs. double-angle plots for astigmatism data

Commercial Toric IOL calculators

- Toric IOL cylinder power at the corneal plane is calculated by using a fixed ratio:
  - Alcon
  - Oculentis
  - PhysIOL
Toric IOL cylinder power at the corneal plane is calculated by using the estimated ELP.

- AMO
- Medicontur
- Rayner
- Zeiss
- Holladay, ASSORT, Barrett

Q: Does the ELP make a difference?
Commercial Toric IOL calculators

Q: Does the ELP make a difference?
A: Yes, but...mostly for extreme cases

Q: What is the reason for this phenomenon?

Errors in Predicted Residual Astigmatism

2. Abulafia et al, J Refract Surg 2015; accepted for publication
Posterior Corneal Astigmatism

Standard keratometric and topography machines tend to yield inaccurate results in assessing the net corneal astigmatic power.


Posterior Corneal Astigmatism

715 eyes of 434 patients


Posterior Corneal Astigmatism

What is the effect of the posterior corneal astigmatism?

- Most posterior corneas are steep vertically
- The posterior cornea acts like a negative lens
- It creates a net plus power along the horizontal meridian
- ATR astigmatism

Koch et al., J Cataract Refract Surg 2012; 38:2080-2087

Errors in Predicted Residual Astigmatism

| 68 eyes | Ein-Tal |
|--------|--
| 81 eyes | LEI |

What is the reason for this phenomenon?

1. Abulafia et al., J Cataract Refract Surg 2015; 41:936-944
2. Abulafia et al., J Refract Surg 2015; accepted for publication

Solutions:

- Intraoperative aberrometry
- Standard toric IOL calculators + Nomogram (Baylor)
- Barrett Toric IOL calculator
- Standard toric IOL calculators + Direct measurements of the PCA (Scheimpflug, OCT, Cassini)
- Standard toric IOL calculators + AK (Abulafia-Koch) formula
Baylor Nomogram:

<table>
<thead>
<tr>
<th>Effective IOL Cylinder Power at Corneal Plane (D)</th>
<th>WTR (D)</th>
<th>ATR (D)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>≤ ±1.49</td>
<td>&lt; 1.00</td>
</tr>
<tr>
<td>1.00</td>
<td>1.76-2.19</td>
<td>0.40-0.79</td>
</tr>
<tr>
<td>1.50</td>
<td>2.26-2.50</td>
<td>0.80-1.29</td>
</tr>
<tr>
<td>2.00</td>
<td>2.75-3.10</td>
<td>1.30-1.79</td>
</tr>
<tr>
<td>2.50</td>
<td>3.20-3.79</td>
<td>1.85-2.39</td>
</tr>
<tr>
<td>3.00</td>
<td>3.80-4.79</td>
<td>2.50-3.29</td>
</tr>
<tr>
<td>3.50</td>
<td>4.40-5.50</td>
<td>2.80-3.59</td>
</tr>
<tr>
<td>4.00</td>
<td>5.00-</td>
<td>3.50-3.79</td>
</tr>
</tbody>
</table>

\( \text{ATR} = \text{against the rule; IOL = intraocular lens; PCE = peripheral corneal intersecting} \)
\( \text{WTR = with the rule; } 5\text{ spectacles have zero ATR} \)

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**The Barrett Toric Calculator**

SEq \( \rightarrow \) Universal II formula

ELP \( \rightarrow \) IOL cylinder power correction at the corneal plane

**Mathematical model \( \rightarrow \) Net corneal astigmatism**

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**Errors in Predicted Residual Astigmatism**

59 eyes

- LEI
- IOLMaster & Holladay
- Pentacam & Holladay
- IOLMaster-Pentacam & Holladay
- IOLMaster & Barrett

Each ring = 0.50 D
The Abulafia-Koch (AK) formula

The AK formula calculates the estimated net corneal astigmatism, by using anterior corneal based measurements!

AK Formula – ATR astigmatism

AK Formula – WTR astigmatism
AK Formula – oblique astigmatism

<table>
<thead>
<tr>
<th>Rn</th>
<th>Tilt</th>
<th>Pher_aaxis</th>
<th>Spast</th>
<th>Strop_aaxis</th>
<th>Average</th>
<th>Lg</th>
<th>Ave</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.125</td>
<td>43.15</td>
<td>-126</td>
<td>.96</td>
<td>45</td>
<td>48.35</td>
<td>0.5</td>
<td>46</td>
</tr>
</tbody>
</table>

Measured P's

Central Total Corneal Power (CTCP)

43.15 126 .96 45

Abulafia et al, accepted as an abstract, Barcelona, ESCRS 2015

Centroid Error in Predicted Residual Astigmatism

WTR  ATR

Abulafia et al, accepted as an abstract, Barcelona, ESCRS 2015
Example: WTR Astigmatism

- 61 years old female
- Ref: -7.75, -0.75x161°
- AL = 27.21mm, mean K = 43.02 D, ACD = 3.19 mm

Primary and secondary supporting instruments determining the steep meridian

Use primary and secondary supporting instruments power difference between meridians
Toric IOL Calculation

![Toric IOL Calculation Diagram]

Toric IOL Calculation

![Toric IOL Calculation Diagram]

Toric IOL Calculation

![Toric IOL Calculation Diagram]
Error in predicted residual astigmatism

LE uneventful cataract extraction, SN6AT4, 11.5 D
Post op refraction (cyl): 0.25D x 155° cyl

- Alcon: 0.61 D x 167°; Holladay: 0.68 D x 168°
- Holladay (pentacam) TCRP: 0.80 D x 166°
  - Posterior astigmatism: 0.53 D x 167°
- Alcon + AK: 0.14 D x 114°
- Holladay + AK: 0.14 D x 133°
- Barrett: 0.16 D x 142°

Summary

The outcome of toric IOL implantation can be optimized by using -

Appropriate methods of calculation