

# WaveLight<sup>®</sup> Contoura topography-guided planning: contribution of anterior corneal higher-order aberrations and posterior corneal astigmatism to manifest refractive astigmatism

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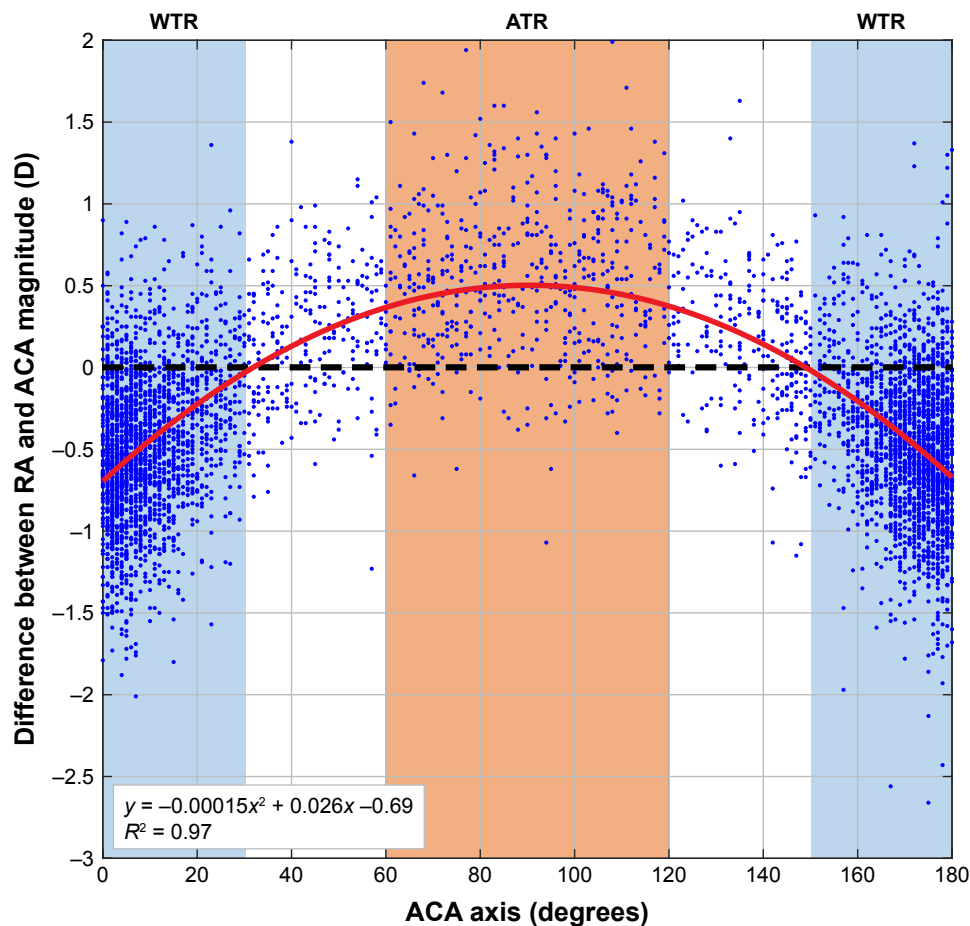
Clinical refractive astigmatism (RA) and topography-measured anterior corneal astigmatism (ACA) are rarely identical in magnitude and axis.<sup>1</sup> This difference, when expressed vectorially, is termed ocular residual astigmatism (ORA).<sup>1</sup> What accounts for this difference remains a topic that needs further research, and has implications as to what refraction to treat with topography-guided excimer laser ablations in order to maximize outcomes.<sup>1</sup> This research letter investigates aspects of two contributing factors: posterior corneal astigmatism (PCA) and anterior corneal higher-order aberrations (CHOAs).

We compared RA to ACA magnitude in 5,403 eyes to reveal that 87% with-the-rule (WTR) corneal cylinder eyes had less RA magnitude than ACA magnitude, and 89% against-the-rule (ATR) corneal cylinder eyes had RA magnitude greater than ACA magnitude (Figure 1). Published data show that 87% of corneas have ATR posterior corneal astigmatism,<sup>5</sup> which, if additive to ACA, could explain the decreased RA seen in most WTR corneal cylinder eyes, and the increased RA in most ATR corneal cylinder eyes (Figure 1). Furthermore, our data show that the ACA axis location correlates to the amount of difference between RA and ACA (Figure 1), supporting the notion that the interaction between ACA and PCA impacts RA by modifying the total corneal astigmatism.

A recent paper<sup>2</sup> claimed that PCA does not contribute significantly to RA, while other publications have reported that PCA compensates between 22% and 31% of the ACA.<sup>3,4</sup> A large cohort study revealed that PCA accounts for more than  $-0.5$  D in 9% of eyes.<sup>5</sup> This magnitude of PCA cannot be taken as clinically negligible, particularly for eyes with a greater amount of cylinder. It is also why PCA is now used for intra-ocular lens surgical planning, with improved outcomes.<sup>6</sup> With topography-guided treatments, only treating the Contoura-measured ACA could allow the PCA to manifest as RA post-operatively, as can be seen with TORIC IOL surgery that ignores PCA.<sup>6</sup>

A recent series examined six eyes with significant ORA and theorized that anterior CHOAs were the cause of the discrepancy between RA and ACA.<sup>2</sup> For illustrative purposes, the author characterized CHOAs as creating an ovalization of the central cornea, interacting with an ovalization produced by ACA.<sup>2</sup> Depending on how these two ovals are aligned, the net RA will summate or negate.<sup>2</sup> To objectively investigate

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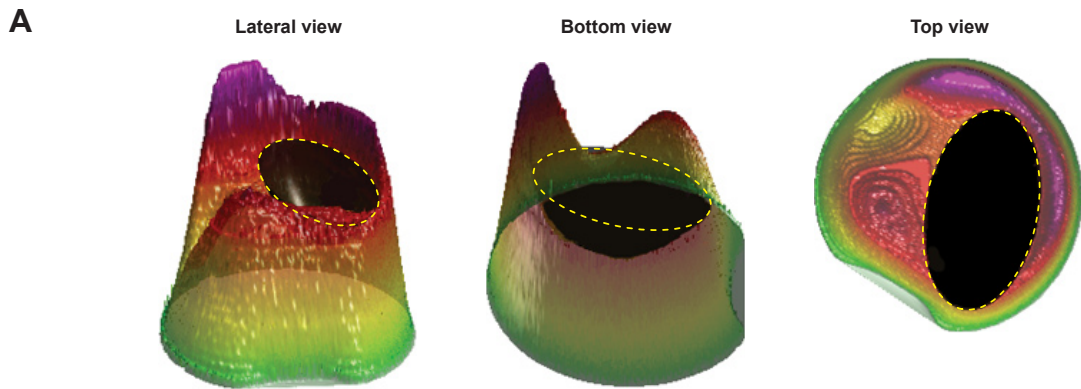
**Figure 1** Difference between RA and ACA magnitude (ie, RA magnitude – ACA magnitude) in relation to the ACA axis and quadratic fitting of this relationship (red curve). Data points (blue dots) above the black dashed line indicate eyes where the ACA is smaller than the RA magnitude, and below show eyes where the ACA is greater. Blue-shaded area: WTR-ACA eyes; red-shaded area: ATR-ACA eyes.

**Abbreviations:** ACA, anterior corneal astigmatism; ATR, against-the-rule; RA, refractive astigmatism; WTR, with-the-rule.

this claim, we developed an advanced algorithm that analyzed the Contoura (WaveLight® EX-500; Alcon Laboratories, Inc., Fort Worth, TX, USA) CHOA ablation profile in 3D, accurately detailing the CHOA ellipse (Figure 2A). We then studied the vectorial relationship between the calculated CHOAs and ACA ellipses in 12 eyes (Figure 2B). While we found six of 12 cases that supported the summation notion, we also found six contradictory cases, and could therefore not validate this theory (Figure 2B). This was illustrated in cases 2, 6, 9, and 12, where ellipses with similar orientations should have summated and increased the RA, but did not. For case 11, the ellipses with perpendicular orientation should have partially canceled each other, but did not. Case 1 is an example that could not be fitted by an ellipse as the pattern was circular. While we agree that CHOAs also affect RA, a concept previously reported by Zhou et al,<sup>7</sup> the claim that ORA is mainly accounted for by anterior CHOAs in the large majority of eyes<sup>2</sup> is not

supported by the current research letter's findings or by previous literature.<sup>1,3-6</sup>

The difference between RA and ACA is thought to be attributed to several factors, including anterior CHOAs, PCA, anterior and posterior lenticular astigmatism, refractive index variability, decentration of the crystalline lens, as well as from retinal tilt and cortical perception.<sup>1</sup> Contoura topography-guided software determines the anterior CHOAs and the true ACA from a high resolution Placido disc topographer. The Contoura-measured ACA does not consider the manifest RA and does not supply information on how anterior CHOAs influence RA. RA encompasses all sources of astigmatism, from the anterior cornea to the brain. Since Contoura treatments partially remove anterior CHOAs, to produce a more accurate nomogram for topography-guided ablations, one would need to fully elucidate – possibly using ray tracing technology – the contribution of anterior CHOAs to manifest RA, as well as the effects of PCA and the remaining internal optics.



<p><b>Case 1: non-supported</b></p> <ul style="list-style-type: none"> <li>• RA: <math>-2.75 \times 5</math></li> <li>• ACA: <math>-3.26 \times 180</math></li> <li>• ACA &gt; RA (JRA)</li> <li>• CHOA ellipse axis: none</li> <li>• ACA ellipse axis: 180</li> <li>• Prediction: 0% (none)</li> </ul>			<p><b>Case 7: supported</b></p> <ul style="list-style-type: none"> <li>• RA: <math>-1.75 \times 125</math></li> <li>• ACA: <math>-2.36 \times 146</math></li> <li>• ACA &gt; RA (JRA)</li> <li>• CHOA ellipse axis: 76</li> <li>• ACA ellipse axis: 146</li> <li>• Prediction: <math>-32\%</math> (JRA)</li> </ul>		
<p><b>Case 2: non-supported</b></p> <ul style="list-style-type: none"> <li>• RA: <math>-2.75 \times 12</math></li> <li>• ACA: <math>-3.16 \times 9</math></li> <li>• ACA &gt; RA (JRA)</li> <li>• CHOA ellipse axis: 67</li> <li>• ACA ellipse axis: 9</li> <li>• Prediction: <math>+6\%</math> (JRA)</li> </ul>			<p><b>Case 8: supported</b></p> <ul style="list-style-type: none"> <li>• RA: <math>-3.00 \times 35</math></li> <li>• ACA: <math>-3.42 \times 24</math></li> <li>• ACA &gt; RA (JRA)</li> <li>• CHOA ellipse axis: 113</li> <li>• ACA ellipse axis: 24</li> <li>• Prediction: <math>-97\%</math> (JRA)</li> </ul>		
<p><b>Case 3: supported</b></p> <ul style="list-style-type: none"> <li>• RA: <math>-1.50 \times 167</math></li> <li>• ACA: <math>-1.74 \times 169</math></li> <li>• ACA &gt; RA (JRA)</li> <li>• CHOA ellipse axis: 61</li> <li>• ACA ellipse axis: 169</li> <li>• Prediction: <math>-38\%</math> (JRA)</li> </ul>			<p><b>Case 9: non-supported</b></p> <ul style="list-style-type: none"> <li>• RA: <math>-0.75 \times 157</math></li> <li>• ACA: <math>-1.44 \times 168</math></li> <li>• ACA &gt; RA (JRA)</li> <li>• CHOA ellipse axis: 118</li> <li>• ACA ellipse axis: 168</li> <li>• Prediction: <math>+29\%</math> (JRA)</li> </ul>		
<p><b>Case 4: supported</b></p> <ul style="list-style-type: none"> <li>• RA: <math>-2.00 \times 87</math></li> <li>• ACA: <math>-1.11 \times 88</math></li> <li>• RA &gt; ACA (JRA)</li> <li>• CHOA ellipse axis: 77</li> <li>• ACA ellipse axis: 88</li> <li>• Prediction: <math>+96\%</math> (JRA)</li> </ul>			<p><b>Case 10: supported</b></p> <ul style="list-style-type: none"> <li>• RA: <math>-1.25 \times 3</math></li> <li>• ACA: <math>-1.96 \times 12</math></li> <li>• ACA &gt; RA (JRA)</li> <li>• CHOA ellipse axis: 114</li> <li>• ACA ellipse axis: 12</li> <li>• Prediction: <math>-58\%</math> (JRA)</li> </ul>		
<p><b>Case 5: supported</b></p> <ul style="list-style-type: none"> <li>• RA: <math>-2.25 \times 99</math></li> <li>• ACA: <math>-1.52 \times 99</math></li> <li>• RA &gt; ACA (JRA)</li> <li>• CHOA ellipse axis: 107</li> <li>• ACA ellipse axis: 99</li> <li>• Prediction: <math>+98\%</math> (JRA)</li> </ul>			<p><b>Case 11: non-supported</b></p> <ul style="list-style-type: none"> <li>• RA: <math>-1.50 \times 85</math></li> <li>• ACA: <math>-0.49 \times 79</math></li> <li>• RS &gt; ACA (JRA)</li> <li>• CHOA ellipse axis: 149</li> <li>• ACA ellipse axis: 79</li> <li>• Prediction: <math>-32\%</math> (JRA)</li> </ul>		
<p><b>Case 6: non-supported</b></p> <ul style="list-style-type: none"> <li>• RA: <math>-0.25 \times 9</math></li> <li>• ACA: <math>-1.65 \times 176</math></li> <li>• ACA &gt; RA (JRA)</li> <li>• CHOA ellipse axis: 176</li> <li>• ACA ellipse axis: 176</li> <li>• Prediction: <math>+100\%</math> (JRA)</li> </ul>			<p><b>Case 12: non-supported</b></p> <ul style="list-style-type: none"> <li>• RA: <math>-0.00 \times 180</math></li> <li>• ACA: <math>-0.45 \times 177</math></li> <li>• ACA &gt; RA (JRA)</li> <li>• CHOA ellipse axis: 5</li> <li>• ACA ellipse axis: 177</li> <li>• Prediction: <math>+98\%</math> (JRA)</li> </ul>		

**Figure 2 (A)** Objective algorithm-based identification of a 3D ellipsoid in a representative Contoura CHOA ablation profile visualized at different angles. The CHOA's ellipse axis was calculated using the top view. **(B)** Case series of 12 eyes used to test Motwani's claim. Left column, eye parameters; middle column, topographical corneal astigmatism where the ovalization is indicated by a black ellipse; right column, CHOA's profile where the ovalization is indicated by a black ellipse as in Motwani's work.<sup>2</sup> Vectorial analyses were used to predict the effect of the interacting ellipses on RA as a positive or negative percentage change, setting both ellipses at equal magnitude. "Supported" and "Non-Supported" identify cases where Motwani's claim is validated or not, respectively.

**Abbreviations:** ACA, anterior corneal astigmatism; RA, refractive astigmatism; CHOA, corneal higher-order aberrations.

## Disclosure

The authors report no conflicts of interest in this work.

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