CORRESPONDENCE

Topography-guided excimer treatment planning: Contribution of anterior corneal coma to ocular residual astigmatism

Manifest refractive astigmatism and anterior corneal astigmatism rarely agree in magnitude and axis. When expressed vectorially ($\overrightarrow{RA} - \overrightarrow{ACA}$; where **RA** is the refractive astigmatism and **ACA** is the anterior corneal astigmatism), the discrepancy between refractive astigmatism and anterior corneal astigmatism is called ocular residual astigmatism (ORA).[1] Corneal higher-order aberrations (HOAs) are thought to contribute to refractive astigmatism and therefore to ORA in highly aberrated keratoconus corneas and in irregular corneas post-laser in situ keratomileusis flap complications and excimer laser ablation–related complications.[2] The contribution of corneal HOAs to ORA in primary unoperated eyes is less certain and has been described in a single small sample (6 eyes).[3] Of the various types of corneal HOAs, anterior corneal coma is the most likely significant contributor to ORA.[2] We describe anterior corneal coma and ORA in a large cohort of preoperative laser vision correction eyes. Correlations between anterior corneal coma magnitude and axis to ORA magnitude and axis are also investigated.

Anterior corneal astigmatism and vertical and horizontal anterior corneal coma (Zernike C7 and C8) data in 37 454 eyes were reviewed. All eyes were imaged with the Vario Topolyzer and analyzed with WaveLight Contoura software (both Alcon Laboratories, Inc.). Eyes with no anterior corneal astigmatism, defined as Contoura-measured anterior corneal astigmatism magnitude of 0.10 diopter (D) or less (385 eyes [1.0%]) with a clinical refractive astigmatism of 0.25 D or more (101 eyes [0.3%]), were selected from this group. In these eyes, ORA had virtually no contribution from anterior corneal astigmatism and therefore equaled the refractive astigmatism (ORA ≈ refractive astigmatism). Vertical and horizontal anterior corneal coma values were converted into total anterior corneal coma root-mean-square values. The anterior corneal coma axis was derived using the arctangent and reported between 0 and 180 degrees. The correlation coefficient was used to assess relationships between variables. Positive cylinder notation was used. Ocular residual astigmatism was calculated at the corneal plane.

Results reveal a mean refractive astigmatism = 0.50 D ± 0.26 (SD), anterior corneal astigmatism = 0.06 ± 0.02 D, ORA = 0.51 ± 0.25 D, and anterior corneal coma = 0.27 ± 0.13 µm. Table 1 shows the characteristics of 10 randomly selected ORA ≈ refractive astigmatism eyes. Ocular residual astigmatism and refractive astigmatism were found to be equal ($P = .9998$). No significant relationship and a quasi-null correlation coefficient were found between anterior corneal coma magnitude and ORA magnitude ($R = 0.025$, $P = .8042$) (Figure 1, *A*) and between anterior corneal coma axis and ORA axis ($R = 0.019$, $P = .8453$) (Figure 1, *C*). Similarly, no clinically meaningful magnitude or axis correlations were found between anterior corneal coma and ORA when including all 37 454 eyes with quasi-null correlation coefficients ($R = 0.030$ and $R = 0.017$; Figure 1, *B* and *D*, respectively), although the magnitude correlation was statistically significant because of the very large sample of eyes. The ORA was against-the-rule (ATR) in 85% of ORA ≈ refractive astigmatism eyes (Figure 1, *E*, *orange-shaded region*) and 86% in the entire cohort (Figure 1, *F*). The anterior corneal coma was ATR in only 27.6% of ORA ≈ refractive astigmatism eyes (Figure 1, *E*) and 28.3% in the entire cohort (Figure 1, *F*).

Because no meaningful correlation was found between anterior corneal coma and ORA in ORA ≈ refractive astigmatism eyes as well as in the entire cohort, anterior corneal coma cannot be a significant cause of the observed discrepancy between anterior corneal astigmatism and refractive

Table 1. Refractive, corneal, and ocular variables for a sample set of eyes.

		RA*		ACA*		ORA*		ACC		Total ACC	
ID	Eye	Mag	Axis	Mag	Axis	Mag	Axis	C7	C8	RMS	Axis
4	OD	0.75	1	0.03	133	0.75	178	0.06	0.13	0.143	25
17	OS	0.50	164	0.02	133	0.49	15	−0.36	0.13	0.383	110
35	OS	0.25	155	0.06	143	0.20	21	−0.02	0.08	0.082	166
42	OD	1.00	1	0.03	004	0.97	179	−0.35	0.30	0.461	131
56	OD	0.50	108	0.10	140	0.46	78	0.21	−0.22	0.304	136
61	OS	0.25	3	0.03	20	0.23	179	−0.06	0.20	0.209	163
74	OS	0.50	171	0.05	22	0.48	12	0.31	−0.32	0.446	136
82	OS	0.50	180	0.05	86	0.55	180	−0.45	−0.06	0.454	82
91	OD	1.00	12	0.10	130	1.06	14	0.23	0.26	0.347	41
100	OS	0.75	180	0.07	47	0.76	177	0.01	0.04	0.041	14

ACA = anterior corneal astigmatism; ACC = anterior corneal coma; C7 = vertical coma (Zernike); C8 = horizontal coma (Zernike); Mag = magnitude; ORA = ocular residual astigmatism; RA = refractive astigmatism; RMS = root mean square
*Reported using the positive cylinder notation

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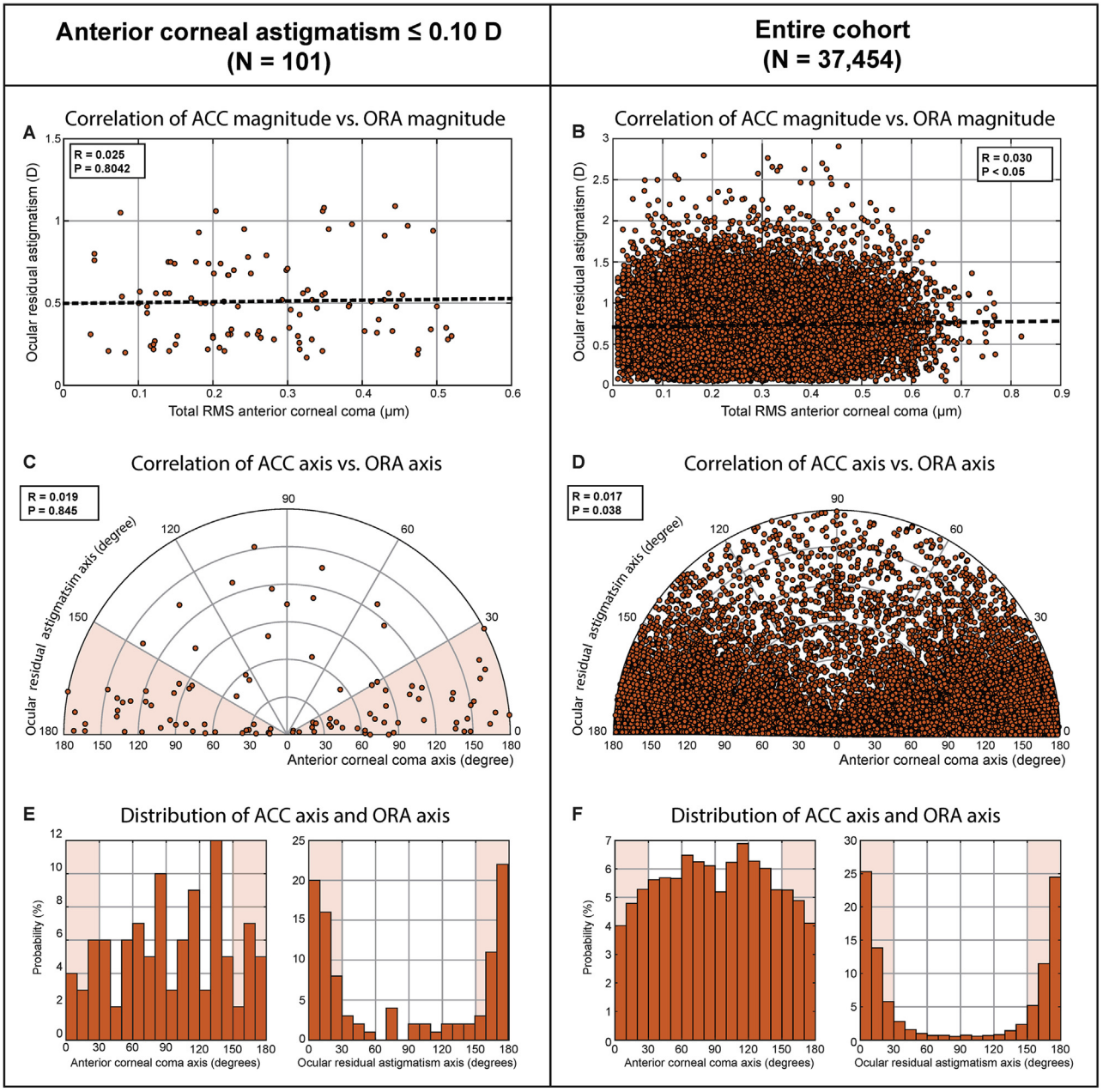

Figure 1. *Left column*: Results in 101 eyes with anterior corneal astigmatism of 0.10 diopter (D) or less and refractive astigmatism of 0.25 D or more. *Right column*: Results in entire cohort of 37 454 eyes. *A*: Ocular residual astigmatism in relation to total RMS anterior corneal coma and linear fitting of this relationship (*black dashed line*). *B*: Ocular residual astigmatism in relation to total RMS anterior corneal coma and linear fitting of this relationship (*black dashed line*). *C*: Polar plot of the ORA axis (angle coordinates in the polar plot) in relation to total RMS anterior corneal coma axis (radius coordinates in the polar plot). *D*: Polar plot of the ORA axis in relation to total RMS anterior corneal coma axis. *E*: Probability histograms of the RMS anterior corneal coma axis and ORA axis. *F*: Probability histograms of the RMS anterior corneal coma axis and ORA axis. Pearson correlation coefficient *R* and associated *P* value are given in the text boxes. The orange-shaded regions highlight against-the-rule oriented ORA or anterior corneal coma (ACC = anterior corneal astigmatism; ORA = ocular residual astigmatism; RMS = root mean square).

astigmatism or ORA. The main contributors to the difference must therefore stem from the posterior cornea, other internal ocular factors, and cortical perception.

In theory, when topography-guided excimer ablations are used to correct both anterior corneal HOAs and refractive astigmatism simultaneously, anterior corneal coma might modify refractive astigmatism, resulting in less predictability and greater number of postoperative surprises.[2] As such, recent topography-guided protocols disregard refractive astigmatism and recommend treating the topography-measured anterior corneal astigmatism together with anterior corneal HOAs in primary eyes.[4,5] This guidance wrongfully assumes that corneal HOAs are the main cause of the discrepancy between refractive astigmatism and anterior corneal astigmatism (ORA). If that were valid and the corneal HOAs were treated, the anterior corneal astigmatism would equal the refractive astigmatism and then only anterior corneal astigmatism need be

corrected. Although we agree that anterior corneal HOAs might affect refractive astigmatism in highly aberrated eyes with anterior corneal coma-dominant corneal optics,[2] this is not the case in primary eyes, as shown here.

The absence of a correlation between anterior corneal coma and ORA might be explained if posterior corneal or internal HOAs compensated for anterior corneal HOAs. More likely, anterior corneal HOAs simply do not induce enough clinically meaningful cylinder to significantly affect refractive astigmatism in primary healthy corneas, in which refractions are measured with small pupils. This explanation also supports a recent excimer decentration study[6] in which total anterior corneal coma did not affect lower-order refractive astigmatism errors. In a previous large cohort study,[7] posterior corneal astigmatism was ATR in 87% of corneas. Given that the current study found that ORA was also ATR in 86% of eyes, posterior corneal astigmatism likely contributes more to ORA than anterior corneal coma in primary eyes and should be considered if one elects to treat solely on the topography-measured anterior corneal astigmatism.[8,9]

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