time can answer this question. It is worth mentioning that a case of post-photorefractive keratectomy ectasia has been reported 16 years after the original procedure.[1]

Regarding the title of my case report, it is mentioned that the case was diagnosed as subclinical keratoconus/forme fruste keratoconus; however, there is no global consensus on these nomenclatures and this could lead to some confusion. After reviewing previously published case reports of ectasia after a laser vision correction procedure, it has been noted that the preoperative corneal topography conclusions were not included in the title.[2–4]—*Mohamed Tarek El-Naggar, MD, FRCS*

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Effect of corneal asphericity and spherical aberration on intraocular lens power calculations

The effect of corneal asphericity on intraocular lens (IOL) power calculations found by Savini et al.[1] is a direct consequence of the variation in corneal spherical aberration. The asphericity (Q-value), however, is only the minor component of the 2 variables needed to calculate spherical aberration; the most important variable is the corneal radius of curvature (r). de Ortueta and Arba Mosquera[2] have independently shown that the formula for computing spherical aberration is proportional to the Q-value and inversely proportional to the third power of the corneal radius ($1/r^3$). With the same Q-value, a steep cornea has much more spherical aberration than a flat cornea (my Table 1). Using the Q-value alone is why their findings with the Placido-disk topographer only explain 15% to 26% (R^2) of their data and with the Scheimpflug and Scheimpflug–Placido 3% to 10%. The Q-value alone is a poor indicator of corneal spherical aberration and therefore of the residual ocular spherical aberration. If they had used the Zernike Z(4,0) value determined over a 6.0 mm zone, which is available on each of the devices used, their correlations and R^2 values for prediction error would have been much higher.

Table 1. Longitudinal marginal spherical aberration* in diopters for typical apical K value and asphericity quotient (Q-value) of anterior cornea assuming surface is an aspheric conic.

	Q-Value			
Apical K Value (D)	−0.53	−0.26	0.00	+0.26
36.00	0.00	0.57	1.14	1.74
40.00	0.00	0.78	1.58	2.43
44.00	0.00	1.05	2.13	3.29
48.00	0.00	1.37	2.81	4.37
52.00	0.00	1.76	3.64	5.70

*Determined using corneal stromal index of refraction of 1.376 and a perfect aspheric conic surface with a Q-value for a corneal zone diameter of 6.0 mm

The authors mistakenly state, "It is logical to expect a myopic outcome in prolate corneas, where the central curvature is higher than the paracentral curvature." This is a common misconception that corneal refractive power is greatest where the corneal curvature is steepest; however, this is not true for normal Q-values from −0.53 to 0.00 (normal range) due to Snell's law. For all prolate corneal Q-values greater than −0.53, the corneal refractive power is lowest at the apex even though the apical curvature is steepest. The average cornea has an apical radius of 7.71 mm, a Q-value over a 6.0 mm zone of −0.26 (prolate), and results in +1.03 diopters (D) longitudinal marginal spherical aberration as seen in my Table 1. The power at the apex (apical power at visual axis) is lowest (43.77 D) even though the apical radius is the steepest. The refractive power increases progressively by +1.03 to 44.80 D at the 6.0 mm diameter. As described by René Descartes in the 1620s, the Q-value that eliminates spherical aberration is −0.53 for the perfect aspheric cornea for any

Table 2. Zernike Z(4,0) spherical aberration term* in microns for typical apical K value and asphericity quotient (Q-value) of anterior cornea assuming surface is an aspheric conic.

	Q-Value			
Apical K Value (D)	−0.53	−0.26	0.00	+0.26
36.00	0.00	0.10	0.20	0.31
40.00	0.00	0.14	0.28	0.44
44.00	0.00	0.19	0.39	0.60
48.00	0.00	0.26	0.52	0.81
52.00	0.00	0.34	0.69	1.08

*Determined using corneal stromal index of refraction of 1.376, a perfect aspheric conic surface with a Q-value for a corneal zonal diameter of 6.0 mm and wavelength of 587.6 μm corneal apical radius. This is the only Q-value for which the corneal refractive power is constant over the entire optical zone with no spherical aberration. That the linear regression in Savini et al.'s Figure 1 crosses at a Q-value of −0.19 for the Placido-disk topographer is simply a result of the optimization of the IOL constant for this device. The authors will find that the zero prediction error will occur at the mean Q-value for each device with all formulas.

The IOL used was a spherical Acrysof SA60AT (Alcon Laboratories, Inc.). Today, most surgeons realize that the best visual outcome in normal and post-myopic refractive surgical corneas is with an aspheric IOL because it compensates for the positive spherical aberration in the cornea.[3] The positive spherical aberration of the cornea can be measured directly with each of the topography or tomography devices used in their study using the Zernike Z(4,0) term over a 6.0 mm zone, for which the measured human average is +0.27 μm and accounts for all factors causing spherical aberration (my Table 2).[3] Abbott Medical Optics, Inc. (−0.27 μm), Alcon Laboratories, Inc. (−0.18 μm), and Bausch & Lomb (0.0 μm) all have aspheric IOLs that can be matched to the patient's measured corneal Zernike spherical aberration to achieve the minimum ocular spherical aberration.[4] Wang and Koch[4] also found that adding the Z(6,0) improved their results even further.

Finally and most important, the recommendation should be to use aspheric IOLs, not spherical IOLs, and then there is no need to compensate for the small portion of the prediction error from corneal asphericity. Matching the corneal spherical aberration to the closest available aspheric IOL will not only avoid the prediction error but also will significantly improve the quality of vision for visual acuity, contrast sensitivity, and nighttime driving as well as reducing patient reports of halos and glare.[5,6]

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Reply: We thank Dr. Holladay for his thoughtful analysis and attention to our study. We agree with him that the effect of corneal asphericity (ie, of the Q-value) on the refractive outcomes of IOL implantation might be a consequence of the variation in spherical aberration; that is, the Z(4,0) Zernike coefficient. We therefore reanalyzed our data following his suggestions. For this purpose, we relied on the measurements of the Scheimpflug–Placido topographer, which can evaluate both the anterior and posterior corneal surfaces. Using a 6.0 mm diameter, the mean Z(4,0) coefficient was 0.28 μm ± 0.11 (SD) when measured from the anterior corneal surface and 0.30 ± 0.11 μm when measured from both corneal surfaces. As expected, the Q-values were correlated with the Z(4,0) values from the anterior corneal surface ($r = 0.4465$, $R^2 = 0.1993$, $P < .0001$), as well as from both corneal surfaces ($r = 0.3969$, $R^2 = 0.1575$, $P < .0001$).

However, we could not confirm Holladay's hypothesis that the R^2 coefficients would have been much higher if the Z(4,0) values had been used instead of the Q-values. As shown in Table 1, once we regressed the refraction prediction error over the spherical aberration, the R^2 coefficients were similar or even lower than those reported in our original study. Adding data from the posterior corneal surface did not affect the statistical results.

These findings likely depend on the small pupil typical of cataract patients, such as those in our sample, in which the mean photopic pupil diameter was 2.5 ± 0.7 mm (range 1.47 to 4.56 mm). Such a small pupil makes the 6.0 mm diameter Z(4,0) coefficient an unrealistic parameter, especially under mesopic and photopic conditions.

For this reason we also measured the Z(4,0) coefficient with the same diameter of the patient's pupil measured by the Scheimpflug–Placido topographer. For the anterior corneal surface it dropped to 0.20 ± 0.02 and was no longer correlated with the Q-value (although the correlation with the prediction error was maintained with all formulas but Haigis').

On the other hand, the low R^2 coefficients found with both the Q-value and the Z(4,0) coefficient mean that the contribution of corneal asphericity and spherical aberration to the refraction prediction error is only moderate, although clinically and statistically significant. We all know that the most important factor

Table 1. Correlation coefficients between the refraction prediction error for each formula and spherical aberration measured as Z(4,0) Zernike coefficient with a diameter of 6.0 mm.

	Anterior Corneal Measurements		Anterior + Posterior Corneal Measurements	
Formula	R^2	*P* Value	R^2	*P* Value
Haigis	0.01968	NS	0.01359	NS
Hoffer Q	0.08758	.0014	0.08333	.0018
Holladay 1	0.05433	.0126	0.05326	.0131
SRK/T	0.03748	.0390	0.03871	.0351

NS = not significant

affecting the refractive outcome remains the prediction of the effective lens position.[1]

Regarding our statement about prolate corneas, this was the most likely explanation we found to justify the trend toward myopic outcomes in eyes with prolate corneas (ie, with more negative Q-values). We agree with Holladay when he states that for all prolate corneas with Q-values between −0.53 and 0.00, the power is lowest at the apex due to Snell's law. However, this is probably true only with a 6.0 mm pupil diameter, which was not present in any patient in our series. The effect of corneal aberration with such small pupils is low. On the contrary, a steepest apical corneal radius might increase the paraxial dioptric power of the cornea.

Finally, we agree that aspheric IOLs should now be preferred to the spherical models, although the advantages are moderate and limited to a better contrast sensitivity with larger pupil diameters. Our data were retrospectively collected, and the Acrysof SA60AT IOL was chosen because it was the IOL with the largest sample in our database. Since 2012, we have been using the aspheric model, and it will be interesting to assess whether the same results can be found with this IOL.—*Giacomo Savini, MD, Kenneth J. Hoffer, MD, Piero Barboni, MD*

Financial disclosure: *Dr. Hoffer receives licensing fees for the commercial use of the registered trademark Hoffer from all biometry manufacturers using the Hoffer Q formula to ensure it is programmed correctly and receives book royalties from Slack, Inc. for the textbook* IOL Power.

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