ARTICLE

Distribution of corneal spherical aberration in a comprehensive ophthalmology practice and whether keratometry can predict aberration values

George H.H. Beiko, BM, BCh, FRCS(C), Wolfgang Haigis, MS, PhD, Andreas Steinmueller, MS

PURPOSE: To determine the spherical aberration of the cornea in the general population and whether keratometry readings are predictive of corneal spherical aberration values.

SETTING: Private comprehensive ophthalmology practice.

METHODS: Corneal spherical aberration and keratometry readings were measured in 696 normal eyes of patients presenting for ocular examination to a comprehensive ophthalmologist. The Easygraph (Oculus) was used to measure the corneal topography and keratometry readings in patients with healthy corneas. The analysis was performed using software in the Easygraph to determine the Zernike coefficients for each cornea. The keratometry and spherical aberration (Zernike coefficient $Z^4{}_0$) were then statistically analyzed.

RESULTS: The corneal spherical aberration, analyzed by the Kolmogorov-Smirnov test for normality, fit a normal Gaussian distribution. The spherical aberration value was $(+0.274 \pm 0.089) \times 10^{-3}$, measured at an optical zone of 6.0 mm. A very weak correlation was found between corneal spherical aberration and central keratometry readings of the cornea: Corneal spherical aberration = $\{0.017 \times (\text{mean keratometry}) - 0.457\} \times 10^{-3}$.

CONCLUSIONS: The corneal spherical aberration distribution was a normal Gaussian curve. However, the mean value was significantly different when the sex of the patient was considered. Corneal keratometry readings could not be reliably used to predict corneal spherical aberration.

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Previously, the goal of cataract surgery was to restore a patient's Snellen visual acuity to its greatest potential. Much emphasis was placed on minimizing sphere and cylinder and obtaining emmetropic results. Recently, the goal of cataract surgery became the rejuvenation of vision, restoring youthful contrast sensitivity through the manipulation of ocular spherical aberration.

Wavefront analysis of the ocular optical system has increased our knowledge of aberrations other than sphere and cylinder in a system that has a significant impact on visual function. Using Zernike transformations, the aberrations of the ocular system can be characterized. The Zernike coefficient for spherical aberration has been linked to contrast visual acuity; as this value increases, contrast sensitivity decreases.[1–4]

The total higher-order aberrations (HOAs) in the phakic eye are composed of aberrations arising from the anterior corneal surface, posterior corneal surface, crystalline lens, and retina; however, in the aphakic eye, 98.2% of aberration arises from the anterior corneal surface[5] (R. Bellucci, MD, Eurotimes, June 2002).

Zernike coefficients of the HOAs can be derived from corneal topographic data.[1,5–8] With current small-incision cataract surgery, it has been reported that the

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Table 1. Descriptive statistical data for mean corneal radius R, K-value, asphericity Q, and Zernike coefficient Z^4_0 (spherical aberration) for the right eye (OD) and left eye (OS) and the mean value in the OD and OS per patient [(OD + OS)/2].

Parameter	OD (n = 301)	OS (n = 301)	(OD + OS)/2 (n = 301)
Mean orneal radius R (mm)			
Mean ± SD	7.71 ± 0.28	7.70 ± 0.28	7.71 ± 0.28
Median	7.71	7.71	7.71
Range	6.88 to 8.44	7.05 to 8.48	7.11 to 8.45
Mean K-value (D)			
Mean ± SD	43.83 ± 1.62	3.88 ± 1.61	43.85 ± 1.58
Median	43.79	43.81	43.78
Range	40.01 to 49.09	39.85 to 47.87	39.99 to 47.50
Asphericity Q			
Mean ± SD	−0.215 ± 0.131	−0.221 ± 0.122	−0.218 ± 0.116
Median	−0.216	−0.219	−0.217
Range	−0.605 to 0.178	−0.797 to -0.004	−0.683 to 0.056
Spherical aberration Z^4_0 (10^{-3})			
Mean ± SD	0.273 ± 0.095	0.275 ± 0.097	0.274 ± 0.089
Median	0.274	0.273	0.274
Range	0.022 to 0.626	0.017 to 0.639	0.041 to 0.632

postoperative corneal topography does not differ significantly from preoperative corneal topography[9] (R. Bellucci, MD, Eurotimes, June 2002).

Thus, it is possible to measure the corneal spherical aberrations in cataract patients using corneal topography preoperatively and then use these data to manipulate the outcomes of cataract surgery by implanting aspherical intraocular lenses (IOLs) with the goal of achieving an optimum spherical aberration for the eye and maximum contrast sensitivity.

The corneal spherical aberration has been reported to be approximately +0.27 μm[10,11] (G. Beiko, "Measurement of the Wavefront Aberrations Using the Oculus Easygraph Topographic System," presented at the ASCRS Symposium on Cataract, IOL and Refractive Surgery, San Diego, California, USA, May 2004). By implanting an aspherical IOL with a spherical aberration of −0.27 μm, it has been reported that image quality and contrast sensitivity can be improved over those in patients who receive an IOL that does not correct for spherical aberration.[12,13] In simulated night-driving tests, patients with the aspherical IOL were able to identify a pedestrian 45 feet or 0.5 seconds sooner at 55 mph than patients with a spherical IOL (Tecnis package insert, Pfizer Inc., April 2004). Thus, not only does correction of spherical aberration improve vision, it also increases patient safety.

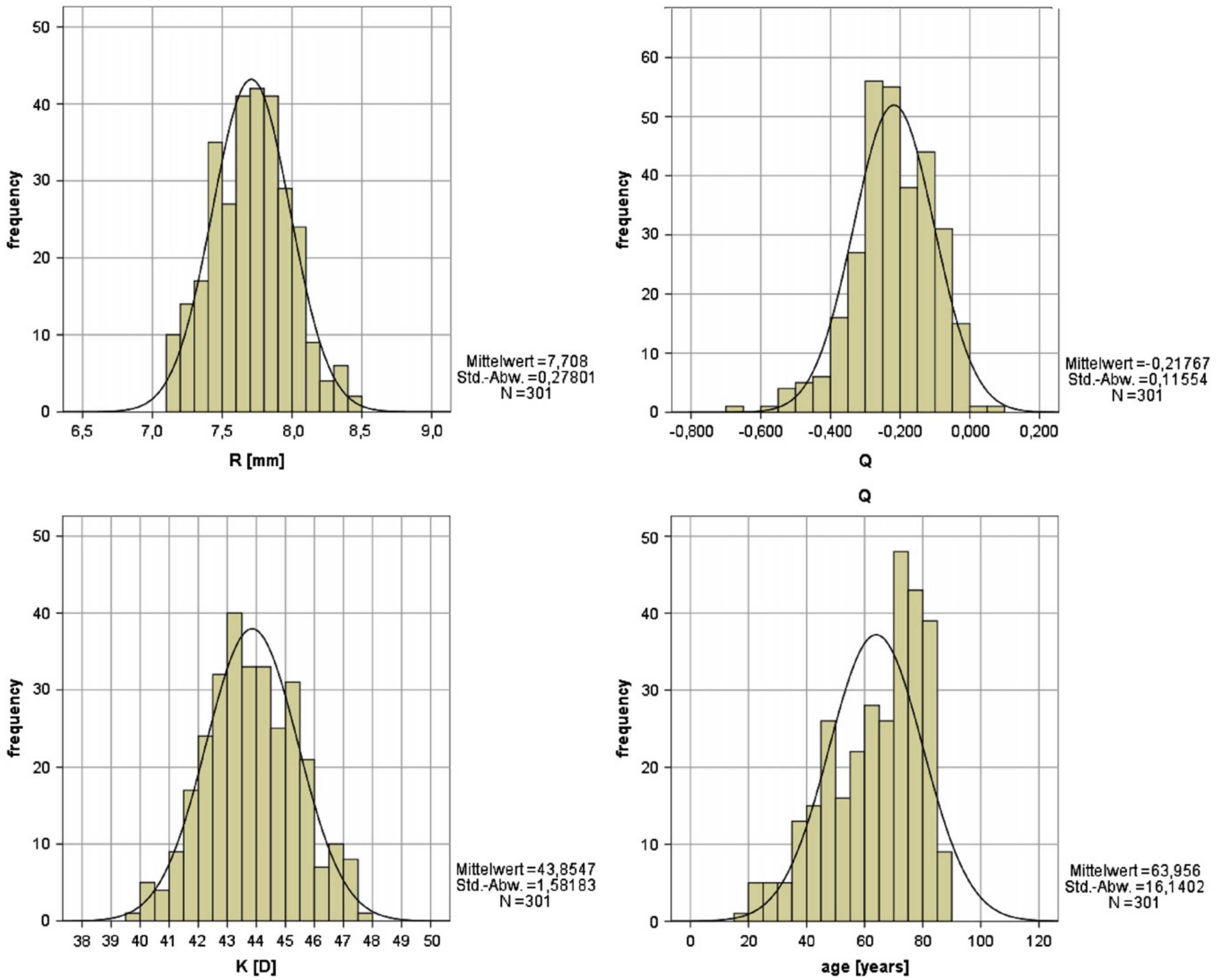
At present, 3 IOLs have been approved by the U.S. Food and Drug Administration for correction of spherical aberration: SofPort LI61AO (Bausch & Lomb), AcrySof IQ (Alcon Laboratories, Inc.), and Tecnis Z9000 (Advanced Medical Optics, Inc.). The 3 IOLs have different strategies for correcting spherical aberration. The SofPort IOL has a spherical aberration of zero[14] and produces no change in the spherical aberration of the eye. The AcrySof IQ IOL has a negative spherical aberration of −0.20 μm (data on file, Alcon Laboratories, Inc.). The Tecnis Z9000 IOL also has a negative spherical aberration, but of −0.27 μm.[11] Each manufacturer has proposed that implantation of 1 of these IOL strategies will result in superior vision for all patients. For this premise to be true, it presupposes that the corneal spherical aberration in all patients lies in a tight distribution about the mean and that the value targeted by each strategy is optimum.

To be able to adequately investigate the manufacturers' proposals, it is essential to know the distribution in the population of the corneal spherical aberration. A small standard deviation relative to the value of the mean would support the premise and a large value would not as this would necessarily

Table 2. The *P* values from the Kolmogorov-Smirnov test.

Parameter	*P* Value: OD (n = 301)	*P* Value: OS (n = 301)	*P* Value: (OD + OS)/2 (n = 301)
Mean K-value	.963	.434	.765
Mean corneal radius R	.934	.305	.747
Asphericity Q	.493	.292	.665
Spherical aberration Z^4_0	.982*	.985*	.944*
Age		.001	

OD = right eye; OS = left eye; (OD + OS)/2 = mean value in the right eye and left eye
*Best agreement for Z^4_0



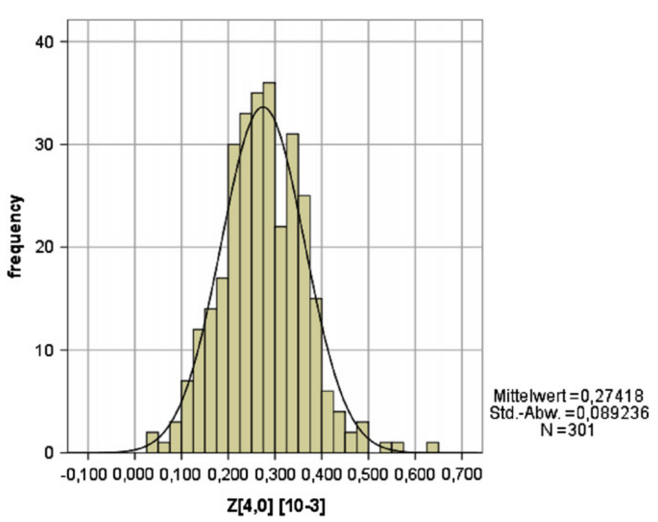


Figure 1. Distributions of mean corneal radius, mean K-value, asphericity Q, Zernike coefficient Z^4_0, and patient age averaged over the right eye and left eye of 301 patients (solid curve = normal [Gaussian] distribution).

support the need for a range of IOLs correcting for different values of spherical aberration.

It is also important to know whether there is a relatively cost-effective means of measuring corneal spherical aberration. At present, the most widely used devices—wavefront aberrometers and corneal topography units (eg, Orbscan or Humphrey Atlas)—are expensive and may prevent access to this

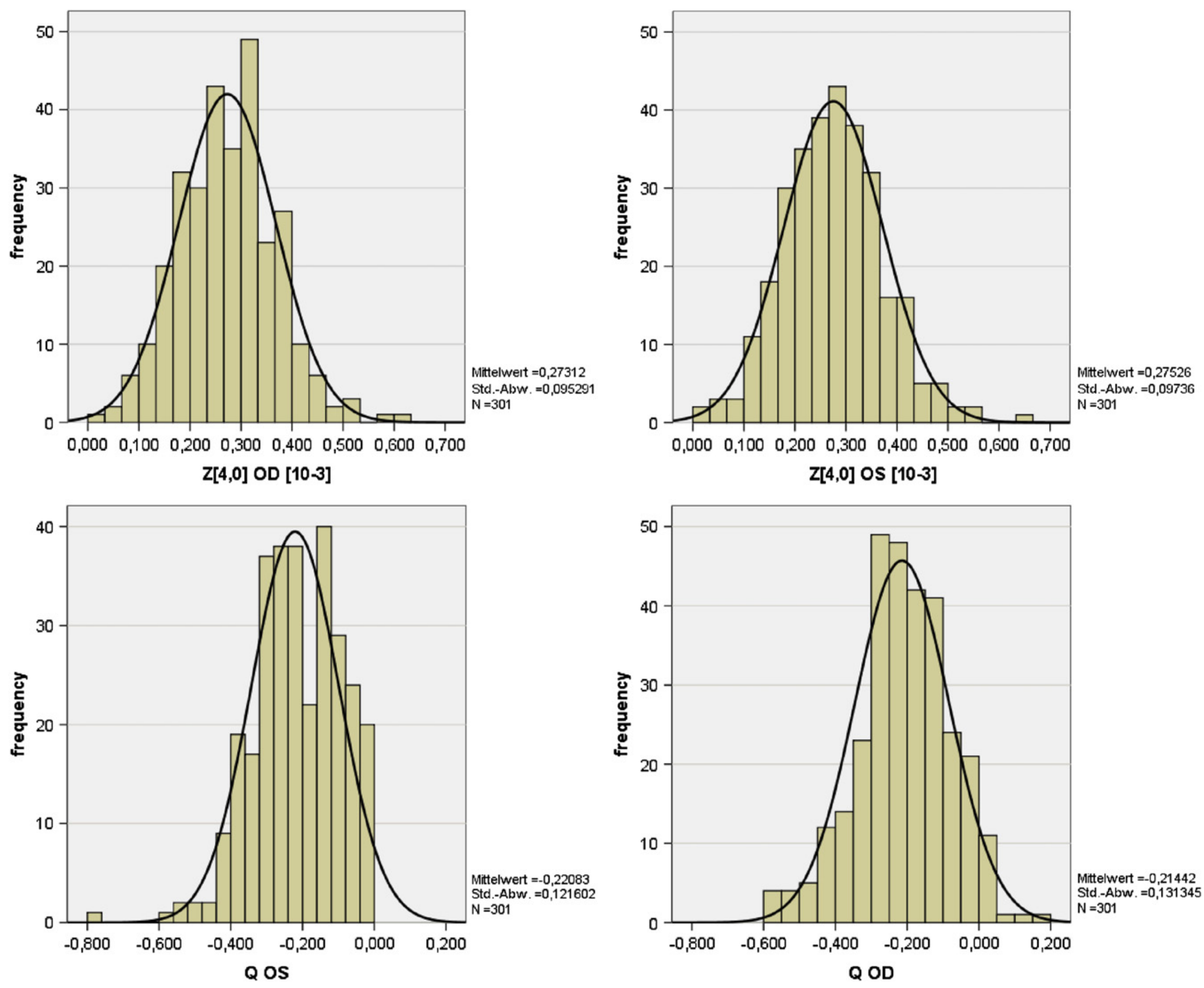


Figure 2. Distributions of Zernike coefficient Z^4_0 and asphericity Q separately for right eyes (OD) and left eyes (OS) (n = 301) (solid curve = normal distribution).

measurement to most comprehensive ophthalmologists. It has been suggested that keratometry may be predictive of corneal spherical aberration and may preclude the need to measure it directly.

The purpose of this study was to determine the distribution of the corneal spherical aberration in the general population. A secondary goal was to determine whether keratometry can be used to predict the corneal spherical aberration.

PATIENTS AND METHODS

Patients presenting for ocular examination to a comprehensive ophthalmologist were considered for measurement. All patients with normal corneas were included; those with previous corneal disease, inflammation or infection, corneal dystrophy or ectasia, previous corneal surgery, and corneal scarring were excluded. Patients wearing contact lenses were asked to discontinue their use for 1 month before examination. The study eyes were measured using a corneal topography unit, the Oculus Easygraph (Oculus Optikgeraete GmbH). This device has been validated against other topographers (G. Beiko, "Measurement of the Wavefront Aberrations Using the Oculus Easygraph Topographic System," presented at the ASCRS Symposium on Cataract, IOL and Refractive Surgery, San Diego, California, USA, May 2004). The central 6.0 mm of the cornea was measured using a reference shape of an ellipse with an eccentricity $\varepsilon = 1/n = 1/1.3315 = 0.751$. The data were then analyzed using software for calculating Zernike coefficients, which is included in the device.

From the eccentricity e measured by the Easygraph, the asphericity Q was calculated according to $Q = -e^2 \times \mathrm{sgn}(e)$.[15] The term sgn(e) must be added to make allowance for the specific way the eccentricity e is reported in the instrument.

With respect to the Zernike coefficient Z^4_0 measured by the Easygraph, the Zernike decomposition applied in the instrument relates to the deviation between the measured corneal surface (elevation) and a reference body (here, ellipsoid

Table 3. Dependence of Q and Z^4_0 on mean corneal radius R, mean K, and age for the right eye (OD) and left eye (OS) separately and the mean value in the right eye and left eye per patient [(OD + OS)/2].

Dependence and Condition	Linear Regression	*r*	*P* Value
Q = f(R)			
(OD + OS)/2	Q = −0.035 R + 0.051	0.084	.147
OD	Q = −0.010 R − 0.138	0.021	.712
OS	Q = −0.044 R + 0.121	0.103	.074
Z^4_0 = f(R)			
(OD + OS)/2	$Z^4_0 = (-0.093\ R + 0.994) \times 10^{-3}$	0.291	<.001
OD	$Z^4_0 = (-0.080\ R - 0.997) \times 10^{-3}$	0.238	<.001
OS	$Z^4_0 = (-0.095\ R + 1.009) \times 10^{-3}$	0.277	<.001
Q = f(K)			
(OD + OS)/2	Q = 0.006 K − 0.479	0.082	.157
OD	Q = 0.002 K − 0.281	0.019	.746
OS	Q = 0.008 K − 0.561	0.103	.075
Z^4_0 = f(K)			
(OD + OS)/2	$Z^4_0 = (0.017\ K - 0.457) \times 10^{-3}$	0.295	<.001
OD	$Z^4_0 = (0.014\ K - 0.349) \times 10^{-3}$	0.241	<.001
OS	$Z^4_0 = (0.017\ K - 0.474) \times 10^{-3}$	0.283	<.001
Q = f(age)			
(OD + OS)/2	Q = 0.001 age − 0.308	0.197	.001
OD	Q = 0.001 age − 0.307	0.178	.002
OS	Q = 0.001 age − 0.309	0.184	.001
Z^4_0 = f(age)			
(OD + OS)/2	$Z^4_0 = (0.001\ age + 0.224) \times 10^{-3}$	0.141	.015
OD	$Z^4_0 = (0.001\ age + 0.229) \times 10^{-3}$	0.118	.041
OS	$Z^4_0 = (0.001\ age + 0.220) \times 10^{-3}$	0.142	.013

P value = *P* value of slope of regression line; *r* = Pearson correlation coefficient

with ε = 1/n = 1/1.3315 = 0.751). This must not be confused with the Zernike decomposition of the wavefront error. Comparing the dimensionless Z^4_0 values given by the Easygraph with the corresponding wavefront errors in microns, which can be calculated for example with the VOL-CT software (version 6.89, Sarver & Associates Inc.), a conversion factor of 1011 was obtained (unpublished data).

In each eye (right and left), the mean corneal radius R was derived from the horizontal (R_h) and vertical (R_v) radii according to $R = 0.5\ (R_h + R_v)$. The mean K-value was calculated as $K = 0.5\ (K_h + K_v)$ with $K_h = 0.3375/R_h$ and $K_v = 0.3375/R_v$.

Furthermore, the asphericity Q, the spherical aberration in terms of the Zernike coefficient Z^4_0, the mean corneal radius R, and the mean K-value were also calculated for each patient by averaging over the right eye and the left eye. This is an accepted statistical procedure[16,17] to avoid inflated significance levels resulting from the paired-organ problem that would arise if left eyes and right eye results were treated as independent quantities.

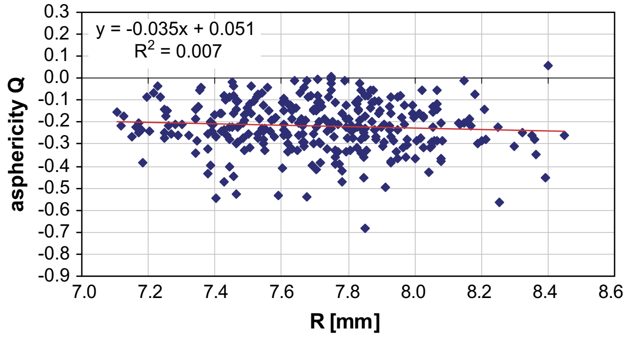


Figure 3. Asphericity Q versus mean corneal radius averaged over the right eye and left eye of 301 patients.

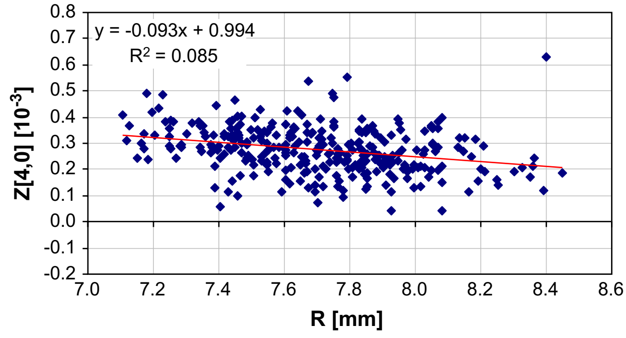


Figure 4. Zernike coefficient Z^4_0 versus mean corneal radius averaged over the right eye and left eye of 301 patients.

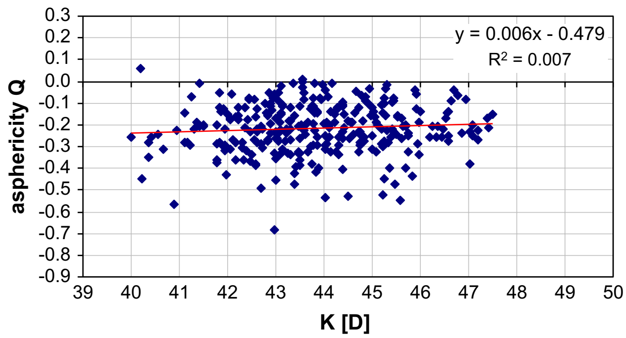


Figure 5. Asphericity Q versus mean K-value averaged over the right eye and left eye of 301 patients.

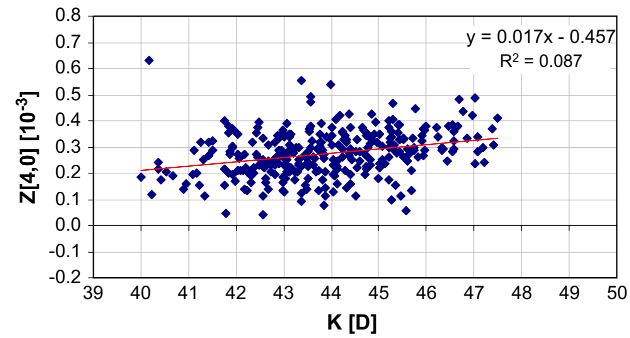


Figure 6. Zernike coefficient Z^4_0 versus mean K-value averaged over the right eye and left eye of 301 patients.

The distributions of the asphericity Q, spherical aberration Z^4_0, mean corneal radius R, and mean K-value and the computed statistical means, standard deviations, medians, and ranges were determined.

The dependence of the asphericity Q and the spherical aberration Z^4_0 on the mean corneal radius R and on the mean K as well as on age was derived by linear regression analysis. Furthermore, the correlations of Q, Z^4_0, R, and K between the right eye and the left eye were determined. Finally, results for Q, Z^4_0, R, and K with respect to sex were analyzed together.

To check for normal distribution, the Kolmogorov-Smirnov test was applied. The quality of linear regression analysis was judged from the Pearson correlation coefficient (*r*). The Student *t* test was used to compare means of unpaired samples after normal distribution of variables had been established. Absolute agreement between left eyes and right eye was checked with the intraclass correlation coefficient (ICC) based on a 2-factor mixed model with absolute agreement definition of concordance. To test for differences between the results in men and women, an analysis of variance (ANOVA) with repeated measures and mixed factorial design was performed.[18] For statistical evaluation, SPSS 13.0 and 14.0 (SPSS, Inc.) and Excel 2000 (Microsoft Corp.) software packages were used.

RESULTS

Six hundred ninety-six eyes (354 right, 342 left) of 395 patients (150 men, 245 women) were included in the study. The mean patient age was 65.6 years ± 15.9 (SD) (range 19.3 to 94.1 years). In 301 patients (111 men, 190 women; mean age 64.0 ± 16.1 years), both eyes were examined and in 94 cases (39 men, 55 women; mean age 70.7 ± 14.2 years), only 1 eye was examined.

In all 301 patients, averaged over the right eye and the left eye, the following results were obtained: mean corneal radius, 7.71 ± 0.28 mm; mean K-value, 43.85 ± 1.58 D; mean asphericity Q −0.218 ± 0.116; mean $Z^4_0 = (+0.274 \pm 0.089) \times 10^{-3}$, measured at an optical zone of 6.0 mm. Table 1 shows further statistical data and separate results for right eyes and left eyes.

The mean corneal radius, mean K, asphericity Q, and Z^4_0 all showed Gaussian (normal) distributions, as shown from the *P* values of the Kolmogorov-Smirnov test in Table 2 and from Figures 1 and 2. Patient age was not normally distributed. For the spherical aberration Z^4_0, the best agreement with a Gaussian distribution was obtained, as seen in Figure 1 for the eye averages and in Figure 2 for the separate results in left eyes and right eyes.

Table 3 shows the results of the regression analysis for Q and Z^4_0 and their dependence on mean corneal

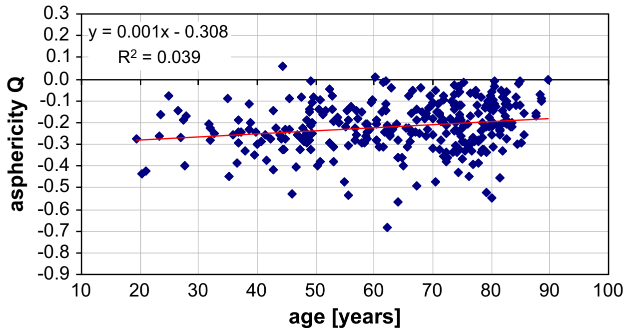


Figure 7. Asphericity Q versus age averaged over the right eye and left eye of 301 patients.

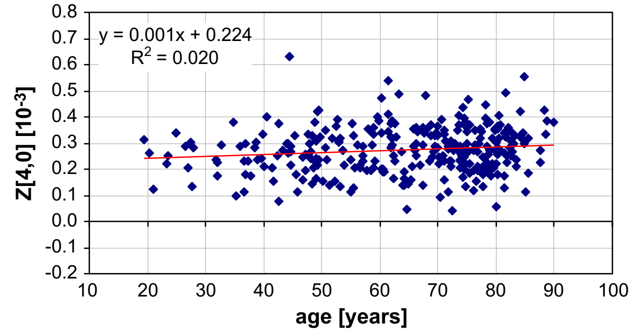


Figure 8. Zernike coefficient Z^4_0 versus age averaged over the right eye and left eye of 301 patients.

Table 4. Dependence of values R, K, Q and Z^4_0 between right eye (OD) and left eye (OS).

Linear Regression			Reliablity	
Dependence	*r*	*P* Value	ICC	*P* Value
$R_{OS} = 0.9140\ R_{OD} + 0.6540$	0.919	<.001	0.917	<.001
$K_{OS} = 0.9155\ K_{OD} + 3.7567$	0.918	<.001	0.918	<.001
$Q_{OS} = 0.6224\ Q_{OD} - 0.0872$	0.673	<.001	0.670	<.001
$Z^4_{0(OS)} = 0.7323\ Z^4_{0(OD)} + 0.0752$	0.717	<.001	0.717	<.001

ICC = intraclass correlation coefficient

radius R, mean K, and age, which are represented as graphs in Figures 3 to 8. Separate results for the right eye, left eye, and the mean of the right eye and left eye [(right eye + left eye)/2] are given. In all eyes, the best, yet small, correlation (correlation coefficient $r = 0.241$ to 0.295) was between Z^4_0 and K (Figure 6) with slopes, that although small (0.014 to 0.017 $\times$ 10^{-3}/D), were significantly different from zero. Practically the same results applied to the correlation between Z^4_0 and R (Figure 4); that is, small correlation ($r = 0.238$ to 0.291) and small slope (-0.080 to -0.095×10^{-3}/mm) yet significantly different from zero. Third best ($r = 0.197$) was the dependence of Q on age (Figure 7), with a small yet significant slope of 0.001/year. Next was the dependence of Z^4_0 on age (Figure 8), with a slope of 0.001×10^{-3}/year. The correlation, however, was small ($r = 0.118$ to 0.142). Even smaller ($r = 0.021$ to 0.103) was the correlation between Q and R (Figure 3), for which there was no significant dependence ($P = .074$ to .712). Likewise, there was a poor correlation between Q and K, for which there was no significant dependence ($P = .075$ to .746) (Figure 5).

Table 4 and Figures 9 to 12 show the results of the comparisons between the respective values of R, K, Q, and Z^4_0 in right eyes and left eyes. In all cases, there was a strong correlation between the right eye and left eye values that was strongest for the mean radius ($r = 0.919$) (Figure 9) and mean K ($r = 0.918$) (Figure 10), followed by Z^4_0 ($r = 0.717$) (Figure 11) and, last, asphericity Q ($r = 0.670$) (Figure 12). The test for absolute agreement between left eye and right eye results yielded a high ICC of 0.670 to 0.918 (Table 4), indicating good agreement.

Finally, the data were analyzed for differences between male eyes and female eyes. For this purpose, 2 approaches were used. First, an ANOVA with repeated measures and mixed factorial design was performed for the 301 eye pairs including tests for intersubject and intrasubject effects. The results are summarized in Table 5 and shown in Figure 13. Second, the Student *t* test for unpaired samples was applied to compare the means of all right eyes (354 total; 133 men, 221 women) after normal distribution of variables was established with the Kolmogorov-Smirnov test. The results of this analysis are compiled in Table 6.

For the 301 eye pairs, the following means were obtained in men: corneal radius, 7.78 $\pm$ 0.28 mm; K-value, 43.46 $\pm$ 1.53 D; asphericity, -0.236 ± 0.122; Z^4_0, $(0.258 \pm 0.079) \times 10^{-3}$. The respective means in women were 7.67 $\pm$ 0.27 mm; 44.09 $\pm$ 1.57 D;

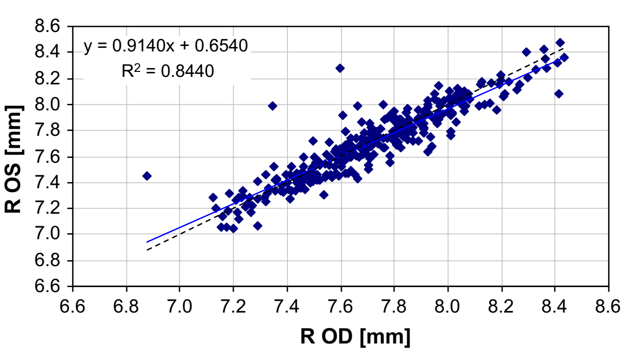


Figure 9. Correlation between mean corneal radii in left eyes and right eyes (n = 301).

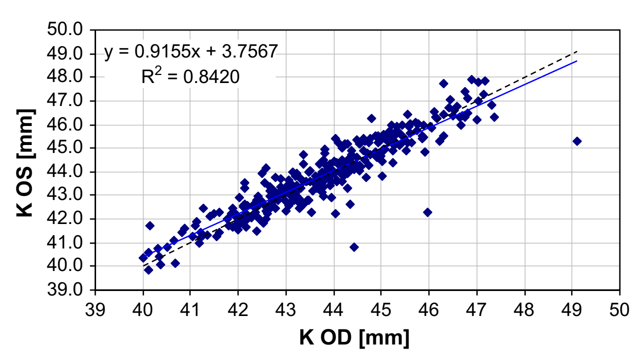


Figure 10. Correlation between mean K-values in left eyes and right eyes (n = 301).

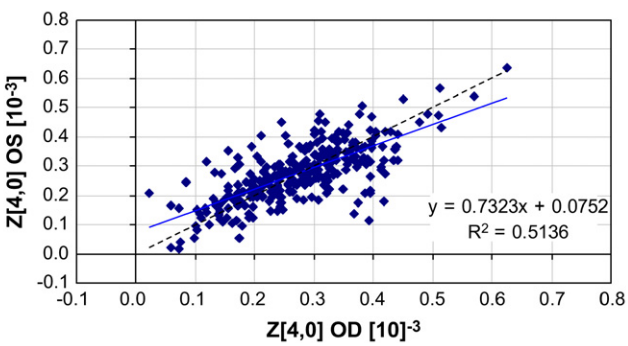


Figure 11. Correlation between Zernike coefficient $Z^4{}_0$ in left eyes and right eyes (n = 301).

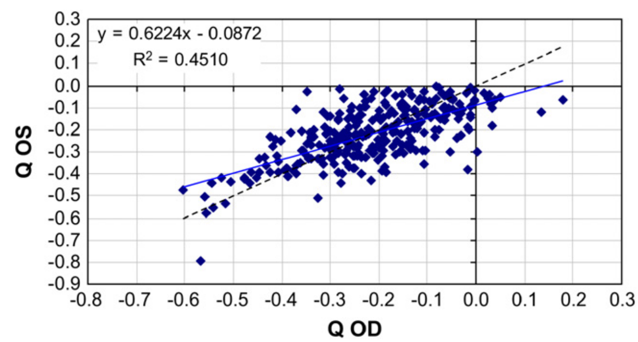


Figure 12. Correlation between asphericities in left eyes and right eyes (n = 301).

−0.207 ± 0.110; (0.284 ± 0.094) × 10^{-3}. All mean values were significantly different between men and woman, as seen in the *P* values for intersubject effects (Table 5). The respective *P* values for intrasubject effects showed that differences between right eyes and left eyes did not play a role.

The analysis of all right eyes produced essentially the same results (Table 6). All variables were normally distributed by the Kolmogorov-Smirnov test (see *P* values, Table 6). The means of the mean corneal radius, mean K-value, asphericity Q, and Zernike coefficient $Z^4{}_0$ were all significantly different between men and women. For men, the mean values were 7.78 ± 0.28 mm, 43.46 ± 1.53 D, −0.236 ± 0.122, and (0.258 ± 0.079) × 10^{-3}, respectively. The corresponding values for women were 7.67 ± 0.27 mm, 44.09 ± 1.57 D, −0.207 ± 0.110, and (0.284 ± 0.094) × 10^{-3}.

DISCUSSION

In this study, the mean corneal spherical aberration value, measured at an optical zone of 6.0 mm, was +0.273 to 0.275 × 10^{-3}, with a large standard deviation of ±0.089 to 0.097 × 10^{-3}, depending on the respective statistical population (right eye, left eye, or averaged over right and left eyes). The $Z^4{}_0$ values were obtained with reference to a Cartesian ovoid with an eccentricity $\varepsilon = 1/n = 0.751$; that is, n = 1.3315. In the literature, it is often not clear how the reference body used for the derivation of $Z^4{}_0$ is defined. Another reasonable value for n would be n = 1.376, resulting in $\varepsilon = 1/n = 0.727$. If we had used this value, our $Z^4{}_0$ results would have been smaller by approximately 10%; that is, approximately 0.247 × 10^{-3}. Using our previously mentioned conversion factor (1011) between elevation and wavefront-based $Z^4{}_0$ results, we may set our $Z^4{}_0$ results in units of 10^{-3} equal to the

Table 5. Descriptive statistical data for 301 patients for mean corneal radius R, mean K-value, asphericity Q, and Zernike coefficient $Z^4{}_0$ (spherical aberration) averaged over the right eye and left eye separated into men (n = 111) and women (n = 190). All respective mean values were all significantly different between the 2 sexes (intersubject effects) but not between left eyes and right eyes (intrasubject effects).

				P Value	
Parameter	Mean ± SD	Median	Range	Intrasubject Effects	Intersubject Effects
Mean corneal radius R (mm)				.901	<.001
Men	7.78 ± 0.28	7.78	7.25 to 8.39		
Women	7.67 ± 0.27	7.68	7.11 to 8.45		
Mean K-value (D)				.925	<.001
Men	43.46 ± 1.53	43.38	40.22 to 46.57		
Women	44.09 ± 1.57	43.94	39.99 to 47.50		
Asphericity Q				.823	<.001
Men	−0.236 ± 0.122	−0.221	−0.683 to 0.008		
Women	−0.207 ± 0.110	−0.215	−0.546 to 0.056		
Spherical aberreration $Z^4{}_0$ (10^{-3})				.054	<.001
Men	0.258 ± 0.079	0.265	0.041 to 0.473		
Women	0.284 ± 0.094	0.285	0.045 to 0.632		

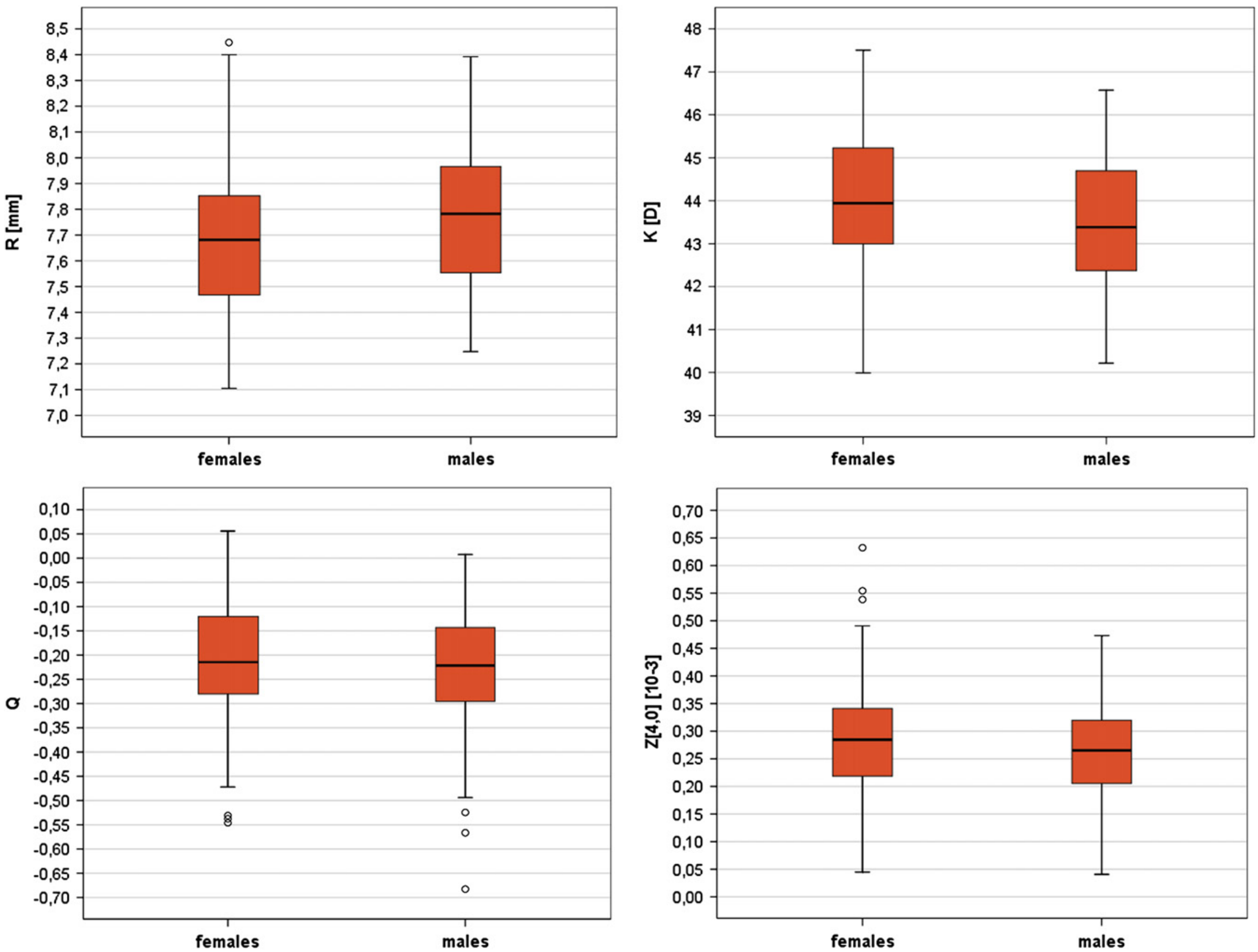


Figure 13. Box plots of mean corneal radius, mean K-value, asphericity Q, and Zernike coefficient $Z^4{}_0$ averaged over the right eye and left eye of 301 patients separated into women and men. All respective means differed significantly ($P \leq .001$).

respective wavefront error in microns; that is, $Z^4{}_0 = 0.247 \times 10^{-3}$ is equivalent to a wavefront error of approximately 0.25 μm. This value is similar to the value previously reported.[10,11]

However, although the mean corneal spherical aberrations values in this study are similar to those in previous studies, the standard deviations were different. Holladay et al.[11] found the standard deviation to be 0.02 μm, and Wang et al.[10] found greater standard deviations, 0.089 μm and 0.086 μm. Such a large standard deviation compared to the mean value shows there is a wide distribution of measurements in the population. Such a wide distribution of corneal spherical aberrations suggests the necessity for measurements of individuals if this measurement is being studied.

A new finding was that the mean of the corneal spherical aberration was significantly different in men and women. The significance of these findings, namely a different mean for each of the sexes and a large standard deviation, is that individuals should be measured to determine their unique value when considering correction of this aberration.

This study confirms what was previously thought; that is, that the distribution of the corneal spherical aberration is Gaussian. This held true in both men and women and irrespective of whether the right or left eye was measured.

The second goal of the study was to determine whether keratometry or corneal radius could be used to estimate the corneal spherical aberration. If they were found to be correlated to any significant degree, the benefits would be realized; that is, another instrument would not be necessary to gauge an individual's corneal spherical aberration. Unfortunately, this study found a poor correlation between the spherical aberration and Q value and the keratometry and corneal radius. An instrument capable of measuring corneal spherical aberration is necessary. In this study,

Table 6. Descriptive statistical data for mean corneal radius R, mean K-value, asphericity Q, and Zernike coefficient $Z^4{}_0$ (spherical aberration) of right eyes (OD) separated into men (n = 133) and women (n = 221). All respective mean values were significantly different (Diff). All variables were normallly distributed (K-S).

				P Value	
Parameter	Mean ± SD	Median	Range	K-S	Diff
Mean corneal radius R (mm)					
Men	7.77 ± 0.27	7.78	7.22 to 8.41	0.631	.001
Women	7.68 ± 0.27	7.69	6.88 to 8.44	0.933	
Mean K-value (D)					
Men	43.47 ± 1.48	43.43	40.13 to 46.75	.828	.001
Women	44.02 ± 1.58	43.92	40.01 to 49.09	.826	
Asphericity Q					
Men	−0.235 ± 0.126	−0.216	−0.568 to 0.133	.415	.017
Women	−0.202 ± 0.126	−0.217	−0.605 to 0.178	.444	
Spherical aberreration $Z^4{}_0$ (10^{-3})					
Men	0.253 ± 0.085	0.259	0.060 to 0.516	.919	.001
Women	0.287 ± 0.095	0.287	0.022 to 0.626	.971	

Diff = difference; K-S = Kolmogorov-Smirnov

the Easygraph, a relatively inexpensive unit, was able to provide this information. This instrument has been validated with other corneal topographers in its ability to measure corneal spherical aberration (G. Beiko, "Measurement of the Wavefront Aberrations Using the Oculus Easygraph Topographic System," presented at the ASCRS Symposium on Cataract, IOL and Refractive Surgery, San Diego, California, USA, May 2004).

Similar to a previous report,[10] this study found good correlation of values between right eyes and left eyes for corneal spherical aberration. There was also good correlation between right eyes and left eyes for keratometry, corneal radius, and asphericity. Although the values were strongly correlated in this study of a population, there can be a significant difference between 2 eyes and if manipulation of the values is being considered, the values should be measured in each eye.

In the introduction to this study, 3 IOLs that manipulate ocular spherical aberration were discussed. Each is proposed as a single solution for all patients. Our findings strongly disagree with this proposition. The large distribution of the corneal spherical aberration in the population, the difference between sexes, and the difference between right eyes and left eyes all support direct measurement of these parameters. Without measurement, the implantation of an IOL with a given spherical aberration aimed at correcting the mean value for a population is akin to placing an IOL with a power of +19.00 diopters in all cataract patients because it is the mean power for the population. Although this would advantageous over having no IOL, no one would argue at this time that the approach is exemplary. In the same way, in most patients, placing an IOL that corrects for spherical aberration is preferable over placing one with a high positive spherical aberration (as would occur if a standard nonspherical aberration-correcting lens were implanted), but the preferred practice should be to individually correct each patient based on direct measurement of his or her corneal spherical aberration. The challenge now is to determine the optimum ocular spherical aberration for the best contrast sensitivity in the postoperative patient.

In conclusion, corneal spherical aberration can be measured using corneal topography. Although in our population, the mean value was reproducible and similar between right eyes and left eyes, in an individual, the value can have a wide distribution of measures and can be significantly different between the 2 eyes. The importance of direct measurement cannot be overemphasized.

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