Corneal Power Is Correlated with Anterior Chamber Diameter

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Purpose. Although corneal power and axial length are known to be inversely correlated, the biological determinants of corneal power are unknown. To elucidate this correlation further, study authors investigated the relationships among corneal power, corneal diameter, anterior chamber diameter, and axial length in a sample of human adults.

Methods. The eyes of 61 subjects seen consecutively in an eye clinic were studied with a high-resolution optimal coherence tomography (OCT) pachymetry device and ophthalmic optical biometer. The relationships between corneal power, white-to-white (WTW) corneal diameter, anterior chamber diameter, and axial length were assessed with Pearson correlations.

Results. The mean age of the 61 subjects was 48.7 ± 19.4 years. Corneal power was negatively correlated with axial length ($r = -0.303$, $P < 0.01$); WTW corneal diameter ($r = -0.399$, $P < 0.001$); and most interestingly, anterior chamber diameter ($r = -0.646$, $P < 0.001$). There was also a positive correlation between anterior chamber diameter and axial length ($r = 0.489$, $P < 0.001$).

Conclusions. Greater anterior chamber diameters were associated with flatter corneas and, conversely, smaller anterior chamber diameters with steeper corneas. The growth patterns of the anterior segment may be determinants of corneal power. (*Invest Ophthalmol Vis Sci.* 2012;53:3788–3791) DOI: 10.1167/iovs.11-8949

Myopia (near- or shortsightedness) is the most common refractive error, and its causes and possible treatments have been the subject of much investigation in recent years. Until the 19th century, it was commonly accepted that differences in refractive error were due to differences in axial length. According to this view, myopic eyes were simply longer than normal, and hyperopic eyes shorter or undeveloped. The cornea and the lens were thought not to be responsible for differences in refractive error, and the power of the lens was assumed to be constant. The history of these ideas was admirably reviewed in the early 1970s by Duke Elder,[1] in an interesting chapter called "The nature of refractive errors."

The work of Tron,[2] however, demonstrated that the values of corneal power, lens power, and axial eye length were normally distributed. It followed from this that the high prevalence of emmetropia—i.e., the occurrence of more emmetropic eyes than would be expected by chance—requires a harmonious or coordinated interaction between the ocular components of refraction. This idea was supported by the work of Stenstrom,[3] Sorsby,[4] and van Alphen,[5] which revealed a wide range of combinations of the optical elements in emmetropic eyes: from longer eyes having a flatter cornea and a less powerful lens, to shorter eyes having a more steeply curved cornea and a more powerful lens. Interesting negative correlations were found between axial length and both corneal power and lens power. Sorsby[6,7] even showed prospectively that, during the period of growth in schoolchildren, the lens lost power while axial growth continued. This led him to propose that there was some kind of mechanism for conjoint retinal control of axial length and lens growth.[4]

Research in the last 30 years has brought new evidence to bear upon the nature and cause of refractive errors.[8] Studies of refractive development in animal models, including fish, birds, and mammals, have shown that the retina itself is largely responsible for regulating axial growth, by discriminating key image parameters and sending a cascade of "stop" or "grow" messages via the pigment epithelium and choroid to the sclera, thereby altering its size and shape.[8] Parallel studies in human subjects showed that corneal power declines after birth but soon stabilizes, reaching adult values during the first year of life.[9–12] The distribution of refractive errors changes from broader (platykurtic) at birth to tighter (leptokurtic) at 1–2 years of age.[13–14] As visual cues can be used for matching axial length to optical power of the refractive elements of the eye, it is reasonable to expect that the high correlation between corneal power and axial length is refined at these ages.

The earliest known study of corneal curvature was published in 1619 by Father Christoph Scheiner,[15] who compared the reflections of windows panes on marbles of known sizes with those reflections from the cornea to determine corneal curvature. By the end of the 19th century, Javal had introduced his keratometer; and many years later, when axial length was accurately measured or calculated, corneal power and axial length were found to be highly correlated with each other. Now, however, although the matching of axial length to corneal curvature has been well established, the biological determinants of corneal power still seem not to have been explored. The present study was developed, therefore, to investigate the relationships between corneal power, white-to-white (WTW) corneal diameter, anterior chamber diameter, and axial length in a sample of normal human adults.

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Submitted for publication October 29, 2011; revised April 17, 2012; accepted May 9, 2012.

Disclosure: **R. Iribarren**, None; **F. Fuentes Bonthoux**, None; **T. Pfortner**, None; **P. Chiaradia**, None; **W.K. Stell**, None

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Materials and Methods

Subjects were enrolled in this study, without selection for ocular or visual characteristics, as consecutive outpatients coming for an eye examination at the Special Studies Section of Pförtner Laboratory. The investigative procedures were explained and all subjects gave informed consent for the eye examination. The tenets of the Declaration of Helsinki were followed. The institution's review board decided that approval was not required for this study. For statistical reasons, only the right eye of each subject was measured. The usual distance correction was measured in a lensometer in the case of subjects who used lenses.

Biometrics of the anterior chamber and the cornea were obtained by noninvasive, clinical imaging methods. Horizontal anterior chamber diameter was determined by OCT anterior segment imaging (Visante OCT; Carl Zeiss, Oberkochen, Germany), using calipers in the imaging software to measure the distance from angle to angle (Fig. 1). Keratometry, WTW corneal diameter, and axial length measurements were performed with an ophthalmic optical biometer (IOLMaster 500; Carl Zeiss).

Corneal power, WTW corneal diameter, anterior chamber diameter, and axial length were normally distributed (Kolmogorov-Smirnov test). Therefore, they were correlated in pairs with Pearson correlation analysis, and correlation coefficients (r) were calculated. All P values were considered statistically significant for $P < 0.05$. Variables that were significantly correlated with corneal power ($P < 0.05$) were studied with multiple stepwise regression analysis, to establish which ones remained significant in the model. Commercially available software was used for the analysis (SPSS; SPSS Inc., Chicago, IL). Values presented are means ± standard deviations.

Results

There were 61 subjects, with a mean age of 48.7 ± 19.4 years; 41 of them (67.2%) were women. The mean spherical equivalent refractive error was +0.11 ± 2.92 diopters (D), ranging from −11.50 to +4.75 D; the refractive errors of 28 subjects (45.9%) were in the emmetropic range, from −0.50 to +1 D.

The mean corneal astigmatism was −1.07 ± 0.66 D, with 13 subjects (21.3%) having astigmatism greater than −1.5 D (maximum: −2.91 D). The means and standard deviations were: corneal power = 43.76 ± 1.21 D; axial length = 23.59 ± 1.35 mm; WTW corneal diameter = 11.97 ± 0.38 mm; and anterior chamber diameter = 11.94 ± 0.51 mm. No sex-specific differences were found in corneal diameter or anterior chamber diameter.

According to the Pearson correlations between the ocular parameters (Table 1), corneal power was negatively correlated with axial length, WTW corneal diameter, and anterior chamber diameter, while axial length was positively correlated with WTW corneal diameter and anterior chamber diameter. The correlations of corneal power and axial length with anterior chamber diameter were more robust than those with WTW corneal diameter. A scatter plot of the correlation between WTW corneal and anterior chamber diameters (Fig. 2) shows that, although these two parameters were well correlated, the data values were highly dispersed.

Finally, a stepwise multiple linear regression analysis was performed, comparing corneal power as the dependent variable with each of the three significantly correlated independent variables. Anterior chamber diameter was the only significant variable left in the model, with an $r = -0.646$ ($P < 0.001$; $r^2 = 0.417$; Fig. 3).

Discussion

The air-cornea interface is the principal refractive surface of the optical system of the eye. As the eye grows in diameter, by simple geometry, the radius of curvature of the sclera increases (i.e., steepness of the scleral curvature decreases). Since the cornea is a prolate aspheric section of steeper curvature (i.e., smaller radius of curvature) than the rest of the eye, its curvature may depend—at least in part—on the diameter of its origin at the sclera. This diameter can be measured externally, from white-to-white (because the sclera is white and the cornea clear), or internally, from angle to angle (diameter of

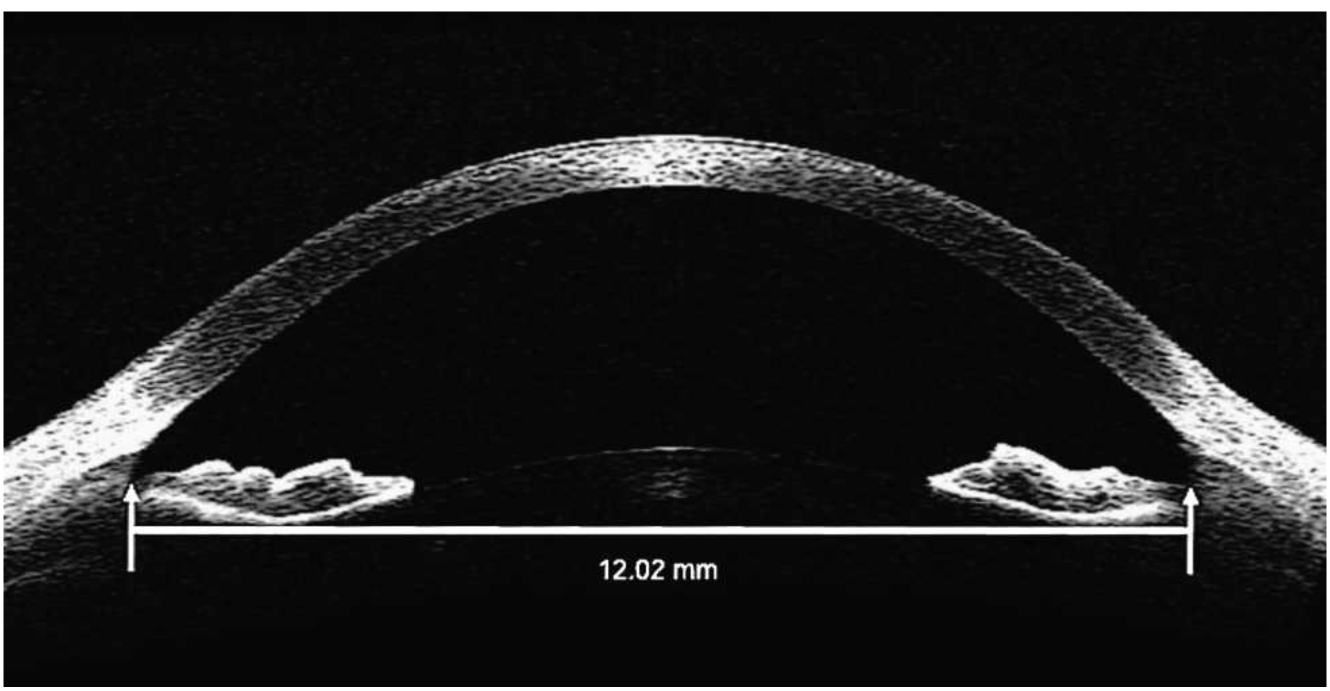

Figure 1. Visante OCT image showing the caliper measurement of the anterior chamber diameter from angle to angle (*arrows*).

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Table 1. Pearson Correlations between the Ocular Parameters (r value)

	Axial Length	WTW	Anterior Chamber Diameter
Corneal power	–0.303*	–0.399†	–0.646†
Axial length	–	0.252*	0.489†
WTW	–	–	0.593†

* $P < 0.05$.
† $P < 0.001$.

the anterior chamber in this study). These measures are expected to be similar and closely correlated, but not identical (Fig. 2).

Previous studies have employed measurements of axial length, corneal power, and WTW corneal diameter, and the correlations between those measurements have been determined.[16–18] The mean WTW corneal diameter of 11.97 mm (IOLMaster, present study) is in accordance with the 11.71 mm measured with a multidimensional diagnostic system (Orbscan II; Bausch & Lomb, St. Louis, MO) by Rüfer.[16] Hoffmann[17] reported a similar significant correlation of –0.471 between WTW corneal diameter and corneal curvature, and Touzeau[18] observed a significant correlation of +0.60 between WTW corneal diameter and anterior radius of curvature of the cornea. As reported here, study authors have confirmed these previously reported correlations between corneal power and WTW corneal diameter. Furthermore, an even more significant negative correlation was found between corneal power and the anterior chamber diameter, which has not been reported previously. Since the r-square (r^2) value for this correlation is 0.417, about 40% of the variability in corneal power can be explained by variations in anterior chamber diameter. Among other factors that may explain corneal curvature, corneal internal structure is likely to contribute to its aspheric shape, but this factor was not assessed in the present study.

The WTW diameter of the cornea increases during postnatal life, reaching adult values during the first year of life.[10,12] Corneal power becomes lower after birth and it too stabilizes during the first year of life, with no subsequent change.[9–12] As the internal and external diameters of the cornea are negatively correlated with corneal power, one can conclude that the growth of the sclera around the limbus, which determines WTW corneal diameter, is at least partly responsible for determining corneal power. This growth of sclera surrounding the limbus may be modulated by signals from the retina, as is growth of the rest of the sclera. Full-thickness retina is not present in adult eyes along the 7 mm of sclera that surrounds the limbus (limiting distance of the *ora serrata*); however, the limbus is closer to the retina in babies (about 2–3 mm). This suggests that, during the first year of life, growth at the corneal limbus (i.e., the increase in WTW corneal diameter) could be regulated by activity in the adjacent retina, and that retinal control of scleral growth at the limbus may decline as the eye grows and the retinal margin becomes more and more separated from it. This would explain the fact that corneal power is determined in the first year of life and does not change much thereafter.

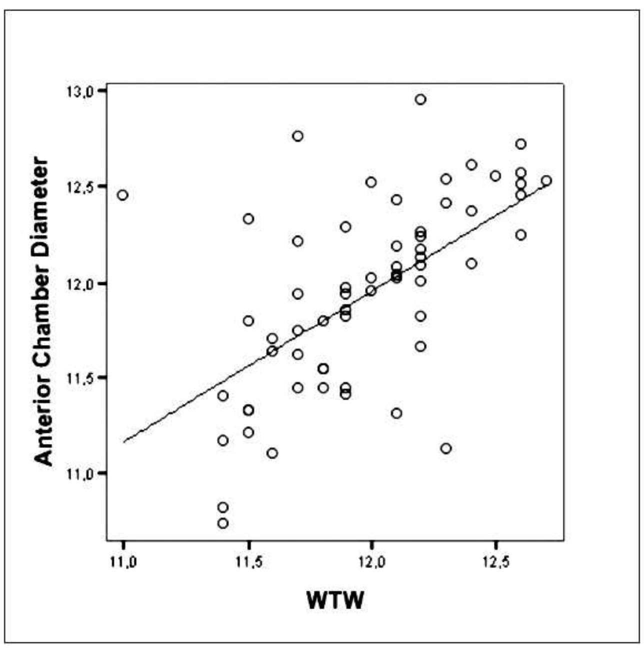

Figure 2. Significant positive correlation between anterior chamber diameter and WTW corneal diameter: $r = 0.593$ ($P < 0.001$, $r^2 = 0.352$).

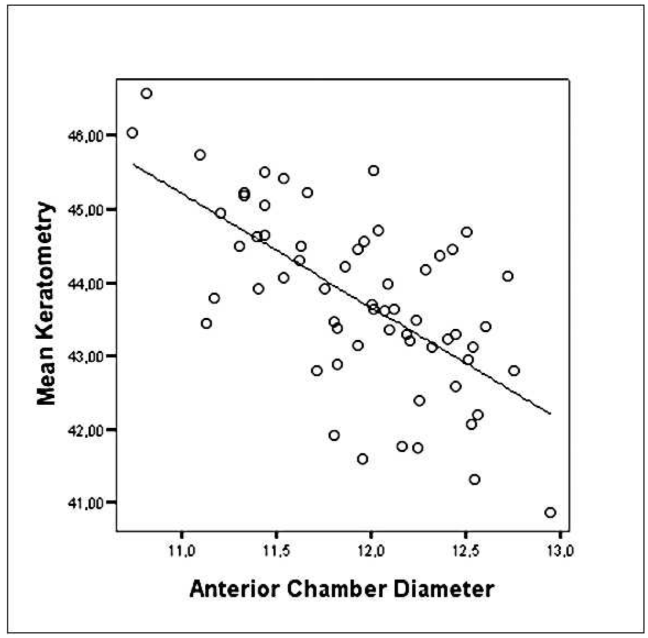

Figure 3. Significant negative correlation between corneal power and anterior chamber diameter: $r = –0.646$ ($P < 0.001$, $r^2 = 0.417$).

The cessation of growth in the anterior segment after age 2 years was shown originally by Larsen, in his monumental biometric study of the eye in children and adults.[19] Furthermore, the eyes of premature infants, which are exposed to visual experience many weeks before normal term, have shallower anterior chambers and more steeply curved corneas at 40 weeks of gestational age than do full-term infants.[20] While these findings might be due to other abnormalities of ocular growth in premature infants, similar to those that have been described in retinopathy of prematurity,[21] they could also be explained by visual control of anterior segment growth.

The proposed control of corneal power by the retina would be expected to apply in humans only during the first year of life, because of the rapid separation of limbus and peripheral retina discussed above. While such a mechanism has not been identified in the eyes of mammals, a system by which the peripheral retina regulates equatorial expansion of the globe—independently of axial elongation—has been identified in chicks.[22] Since this system also is visually controlled, it suggests that retinal activity may indeed regulate not only

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axial elongation, but also corneal diameter and curvature, during early postnatal life.

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