Corneal Eccentricity

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In the past, the human eye was said to be spherical, the cornea circular, and corneal astigmitism unexplained. However, new technology and careful measurements show that the eyeball is oblate and the cornea elliptical. The object of this paper is to introduce my study which evaluated 30 normal corneas using computer assisted videokeratography. My purpose is to compare data performed in the past that will support my clinical data regarding corneal eccentricity. Using color coded topographic maps for each cornea, my goal is to find an average corneal eccentricity (e) and correlate that figure to each patients corneal toricity.

Theory supporting Corneal Eccentricity

The neonatal eyeball has a radius of approximately 8.25 mm, whereas the adult radius is nearer 7.4 mm. Studies have proven that action of the recti muscles apply heterotropic surface forces transmitted to the cornea via the sclera. The corneal fibrallar organization is not random but polarized, as though the cornea were subject to lines of force, in line with the muscular directions of action. Authors agree the cornea grows little after birth and its radius of curvature increases only by an equivalent of less then 4D. Therefore the cornea grows and develops in sequence with the rest of the eye but resists the effects of ocular growth after birth more and more effectively.

Dr. Weale's postulate is that corneal ellipticity and physiological astigmitism (with-the-rule) are accounted for by the oblate form of the fetal eye, which is supported by the observation that the young cornea yeilds less to stress then does the sclera. However others agree that forces stretch the eyeball differently in the two directions perpendicular to the optic axis and in so far as they are transmitted to the corneal limbus. Therefore, the pull on the vertical meridian is smaller than the horizontal giving rise to corneal ellipticity. In summary, a consideration of the tensile forces during development on the surface of our ocular globe helps our understanding of the development of corneal shape and curvature.

The analysis and description of corneal topography is receiving more interest as corneal surgical procedures become more refined. Methods of measuring and describing corneal topography include keratometry, keratoscopy, photokeratography, computer assisted videokeratography, inferometry, and raster stereography.

Computer assisted videokeratography combines concentric keratoscopy with analysis by computer programs to produce a high-resolution representation of corneal topography. The computer calculates the dioptic power and radius of curvature at hundreds of points on the anterior corneal surface based on a single video image of keratoscopic rings reflected from the corneal surface. A graphic presentation of this information can be generated in the form of a color coded topographic map. One such system, EyeSis Modeling System, is accurate to within 0.25 diopters for measuring calibrated steel test balls, and is precise to within 0.50 diopters in 76 percent of measurements on human corneas for rings 2 through 13.

Classic descriptions of normal corneal topography have arbitrarily partitioned the cornea into four surface zones: central (optical), paracentral, peripheral, and limbal. However, these zones are really only conceptual anatomic divisions that have not been well defined topographically. Based on keratometric and keratoscopic data, we know that the cornea has an aspheric, radially assymmetric anterior surface, and that the size, shape, and position of central spherical zone, as well as the rate and amount of peripheral flattening are highly variable. Computer assisted videokeratography now make it possible to describe the entire corneal surface in one measurement and to evaluate corneal eccentricity quantitatively and qualitatively as I did in this study. The increased resolution, compared with multiple measurements with a keratometer or the use of emperical formulas, allows a more detailed analysis of corneal eccentricity.

Subjects and Methods

I analyzed prospectively 30 normal corneas of 18 subjects. Subjects included patients to the Ferris State University Eye Clinic, college students, employees at the Ferres State Eye Clinic, and patients with normal corneas. Two subjects were excluded from analysis because of poor quality keratographs, probably due to narrow palpebral fissures.

Criteria for entry into the study included (1) no history of ocular surgery, (2) no external evidence of trauma or corneal disease, (3) and no history of contact lens wear. Recruitment was completely random, because I attempted to examine patients from all age groups with a wide range of refractive errors.

Technique of Videokeratography

The EyeSis Modeling System consisted of a keratoscope that projected 32 rings onto the anterior corneal surface, a scanning helium neon laser slit beam for alignment, a real-time digital video monitoring system, and a computer that digitized and processed keratographs using proprietary alogorithms and computer programs.

Keratographs were taken as follows: (1) The subject placed his or her eye as close as possible to the examination cone, keeping both eyes widely open, and avoiding blinking while pictures were being taken. (2) I repeatedly reminded the subject to fixate on the pinpoint light at the end of the examination cone. (3) Proper alignment was achieved when images of the two laser slit beams overlapped at the fixation point on a properly focused video screen image of the cornea. (4) A keratograph was taken of each eye and was reviewed to ensure good quality before being stored in the computer memory. Poor quality keratographs were deleted and repeated. (5) After processing, the keratographs were displayed graphically as color coded maps. A Picture was taken of the color-coded map for each eye using the normalized scale. In this scale, 11 available colors were used in each keratograph depending on the range of dioptric powers across the cornea. In most cases, this resulted in .2 to .3D steps between adjacent colors. Therefore, areas with the same color represent areas with equal dioptric powers +/- 0.10D.

Results

All corneas examined were steeper centrally (4 mm) and flattened progressively toward the limbus. Note that the corneal apex location was variable for all eyes. In 16 of 30 eyes, the flattening began closer to fixation on the temperal side. In 6 eyes, the rate of flattening began closer to fixation on the nasal side. In 8 eyes, the degree and rate of flattening appeared to be symmetrically distributed.

Corneal eccentricity varied from individual to individual. Only 60 % of the subjects had similar eccentricity patterns of their fellow eye. The other 40 % were significantly variable between their two eyes. In this study, a .60 was the average e value that ranged from .20 to 1.00 for all the subjects.

As the chart illustrates, this study prevails a wide range of corneal eccentricity with corneal toricity. In this study, 13 out of 30 eyes have with-the-rule astigmitism. Only 11 eyes had spherical corneas (<.35D) whereas 6 eyes had oblique corneal toricity. The average e values for each group were .63, .58, .48 respectively. Note that no subjects presented with against-the-rule astigmitism.

Comments

The major purpose of this study was to develop a specific pattern of corneal eccentricity and correspond that pattern to other variables such as corneal toricity. Also to compare my data using computer assisted videokeratography to other data retrieved from other methods. Dingeldern and Klyce were the first documented cases of recording corneal eccentricity. Their findings revealed that corneal flattening began closer to fixation on the nasal side in 70 % of their patients whereas in no eyes did the cornea flatten more rapidly temperally than nasally. In contrast, greater than 50 % of my subjects corneal flattening began closer to fixation on the temperal side where only 20 % began flattening on the nasal side. Therefore, no correlation could be made between the rate of corneal flattening.

As mentioned earlier, I calculated an average e value for each different condition regarding corneal toricity. My studies indicate that people with WTR astigmitism have the highest average e value followed by oblique and spherical. Note that no cases of ATR astigmitism were documented in this study. Overall, an average e value of .60 was recorded for all participating subjects. Consequently this figure is closely related to the average of .55 found in recent contact lens literature. Therefore some correlation could be obtained from the overall average e value.

In previous studies, Clark showed that there was a high degree of mirror image symmetry often found between the right and left eyes of many individuals. However this did not hold true in this study due to the fact that only 60 % of the subjects had similar eccentricity patterns whereas 40 % were significantly variable between their two eyes. This mirror image symmetry is not uncommon elsewhere in the body (fingerprints,hand,feet,etc.) and therefore is quiet contraindicative to the data collected.

Due to the variability in corneal eccentricity patterns among individuals, developing a clinically meaningful classification system is a challenge. However the goal of this study was to collect data and relate it to other studies for further references. Unfortunately, the data did not correspond as expected. However, little research has been reported on this topic and with advancing technology, any data reported is a starting point. The eventual goal of such work is to build this experience into a set standard with the rest of the parameters of the human eye.

Variable		Mean	Range
Age		26.3	16-48
Gender			
	Male	18	
	Female	12	
Corneal Toricity			
	WTR	.99 D	.63 - 1.15
	Oblique	.92 D	.65 - 1.62
	Spherical	0.25 D	.05 - .35
	ATR	None	
Eccentricity		.57 D	.20 - 1.00
	WTR	.63 D	.45 - .95
	Oblique	.57 D	.20 - .95
	Spherical	.48 D	.25 - 1.00
	ATR	None	