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Professional paper

Corneal Shape and Eccentricity in Population

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A B S T R A C T

The human cornea is an important tissue involved in the mediation of visual perception. It is important to measure its shape especially in the case of correction of refractive errors. Suitable correction such as contact lenses is chosen based on the measured values of the refractive error. An inappropriately fitted contact lens can significantly affect the physiology of the cornea and the eye. Corneal eccentricity can be modeled on the sections of a conoid by which is possible to describe corneal surface. This article follows the keratometry values in a sample of a population as one of the factors affecting contact lenses fitting.

***Key words**: cornea, keratometry, corneal topography, eccentricity, anterior eye, population*

Introduction

Corneal topography is beginning to be one of the most important methods for measuring the anterior shape of the eye and corneal curvature for contact lens fitting. The need for accurate measurement is determined not only by developing investigative techniques, but primarily due to the need to get more metric data on the cornea. This is a concern especially for the anterior surface of the eye in the case of special contact lens application with extension of other parameters[1,3]. The aspheric anterior corneal surface can be described by a conic sections which are defined by their radius of curvature and by a parameter measuring corneal eccentricity (asphericity). Conic sections, obtained by cutting a cone by a plane, include oblate and prolate ellipses, hyperbolas and parabolas. Another two useful parameters are the apical radius of the ellipse and its eccentricity. These are defined as terms by a second order equation where the apical radius is r_0 and the eccentricity is ε. The apical radius is that of the circle tangent to the apex of the conic section and å describes the variation of this curve with distance from the corneal apex. There are different schematic models of the eye that describe the anterior segment mathematically. Aspheric surface such as the anterior cornea shows how the aspheric shape is different from the reference surface of ball (sphere) if it moves from center to the periphery. The radius of curvature of the peripheral part of the lens must be an ellipsoid lower than the spherical surface. For the description it is sufficient to know the apical radius r_0 and the coefficient of asphericity (*Q*). We have $Q = p - 1$, $Q = -SF$, $Q = -\varepsilon^2$, where *p* and *SF* are shape factors and ε is eccentricity. For a spherical surface is $Q = 0$ for any aspheric surface Q will not be zero[1,2,8]. The term asphericity is referred to as a Q. The anterior surface of the cornea can be described as: $p = b^2/a^2$; $\varepsilon = \sqrt{1-p}$; $SF = \varepsilon^2 = 1 - p$; $Q = -\varepsilon^2$ (where *a* is horizontal and *b* is vertical semi-axis). It can therefore express the relationship of hyperbole where $Q<-1$; for parabole along the Z axis is $Q = -1$. In the case of oblate ellipses with the axis Z it is in the interval $-1<Q<0$, for a prolate ellipse axis between X and Y it is $Q>0$. The average of asphericity in the population has a value of –0.26. There are a great individual variatoins in the population. Little connection between the asphericity and refractive error (ametropia) is reported, except for a tendency to flattening in myopia. Most algorithms assume these properties of ellipsoids. Asphericity is translated into variations in radius of curvature from apex to periphery, increasing for a flat periphery and decreasing for a steep one[1,3,9,13].

Methodology and Methods

Nowadays corneal topographer producers offer a wide range of varieties in constructions, principles and their

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combinations. Corneal measurement uses Placido-disc topographers and tomographers, creating three-dimensional corneal models from cross-sectional images. A parameter that characterizes the course and shape of the cornea is eccentricity. Determining values of the corneal curvature radius in two perpendicular sections, the steepest and the flattest was performed on autorefraktokeratometer with Placido disc (KR 8100P, Topcon, Japan). At the same time objective refraction was measured and monitored with a topographical map by calculating mean values of corneal eccentricity. For evaluation the program Software Corneal Analyzer, Version 3.0 was used. The method of measurement and display of keratometric values with topography is in the form of color maps (mostly sagittal), coincident with the optical axis of the eye. Tangential maps show the radius of curvature of the cornea where the more pronounced changes are located (eg. keratoconus, post-operative states). This map shows the real distance from the apex of the cornea[2,6,8].

The measurement was also carried out screening for keratoconus and any assessment of its compatibility with the results of corneal topography performed. The results are processed from seven-millimeter zone of the anterior surface of cornea away from its center. From the study it was possible to exclude unsuitable entities. Also excluded were respondents who had undergone laser refractive surgery, had any manifestation of an inflammatory nature or other symptoms that might distort the final measurements. The reproducibility of measurements was ensured[4,5,7]. The study adhered to the tenets of the Declaration of Helsinki. Informed consent was obtained before data collection from the adults or guardians as long as subjects fell under the defined study criteria.

Statistical evaluations and analysis were performed by Statistica 10 (StatSoft®). There was no statistical difference existing in the ε value between the right and left eyes. Average ε values of cornea were expressed as mean ± standard deviation. Differences in eccentricity values among groups of age, sex and refractive errors were analyzed by one-way analysis of variance (ANOVA). Normal distribution of variables was assessed by the Kolmogorov-Smirnov normality test. The other relationships were analyzed using Pearson correlation. A p value <0.05 was considered statistically significant[12,13].

Results

The studied sample of population consists of 1408 subjects, 830 female and 578 male eyes.

Average age 45.38 ± 19.8 (min. 3 years, max. 95 years, median 44 years). The detected value is objective refraction – sphere power: –0.66 ± 3.16 D (min. 20.5 D, max. +19.0 D, median 0 D), cylinder power: –0.97 ± 0.92 D (min –0.25 D, max. –7.25 D, median –0.75 D), axis 97.75° ± 51.28° (min. 0°, max. 180°, median 94°).

Subjective refraction measured in this is as follow: sphere power: –0.5 ± 2.81 D (min. –18.0 D, max. +17.0 D, median 0 D), cylinder power: –0.5 ± 0.79 (min. –0.25 D, max. –5.75 D, median 0 D), axis 98.93° ± 53.48° (min. 0°, max. 180°, median 90°).

In the total 712 myopes, 414 hyperopes and 282 emmetropes were represented.

Following are the keratometry measurements obtained in this group: radius of curvature of the anterior surface of the cornea in the steepest meridian is 7.65 ± 0.27 mm (min. 6.67 mm, max. 8.71 mm, median 7.65 mm), axis 89.72° ± 38.34° (min. 0°, max. 180°, median 90°) and the flattest meridian is 7.79 ± 0.27 mm (min. 6.94 mm, max. 8.90 mm, median 7.79 mm), axis 179.71° ± 38.36° (min 0°, max. 180°, median 180°).

The range of the astigmatic diference between the flattest and the steepest meridian is 0.14 ± 0.10 mm (min. 0 mm, max. 0.99 mm, median 0.11 mm). Average of corneal anterior surface astigmatism power is then –0.76 ± 0.62 D (min. 0 D, max. –5.99 D, median –0.60 D). Corneal power was calculated as 43.77 ± 1.54 D (min. 38.34 D, max. 51.76 D, median 43.72 D). Corneal diameter measured white-to-white is 12.01 ± 0.35 mm (min. 10.69 mm, max. 13.27 mm, median 12.00 mm).

629 subjects had with-the-rule corneal astigmatism, only 142 subjects had against-the-rule astigmatism and 601 subjects had oblique astigmatism. 36 subjects had no corneal astigmatism.

The eccentricity was deteceted at 10°, 20° and then mean value of corneal eccnetricity was calculated. Corneal eccntricity at 10° was 0.30 ± 0.17 (min. 0.0, max. 0.93, median 0.29), eccentricity measured at 20° was 0.36 ± 0.14 (min.0.01, max. 0.97, median 0.38), see figure 1. The values of mean eccntricity in this sample of population was 0.41 ± 0.11 (min. 0.0, max. 0.86, median 0.41). These results correspond to the findings mentioned in literature, also in Figures 1 and 2.

From these measurements it is obvious that corneal course is in elliptical shape.

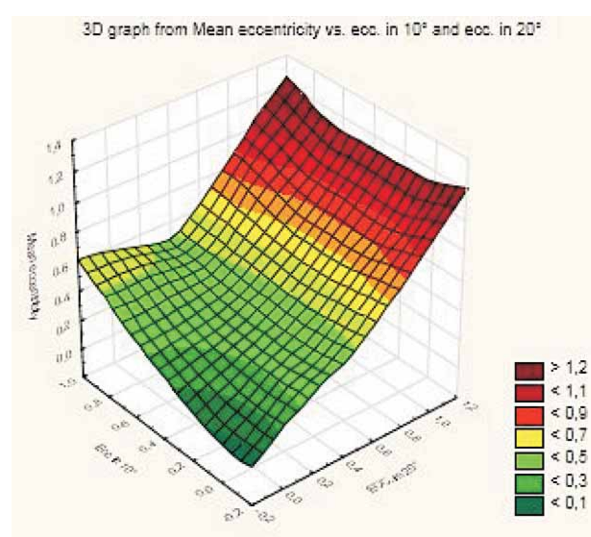

Fig. 1. 3D graph presenting eccentricity at 10°, 20° and mean eccentricity.

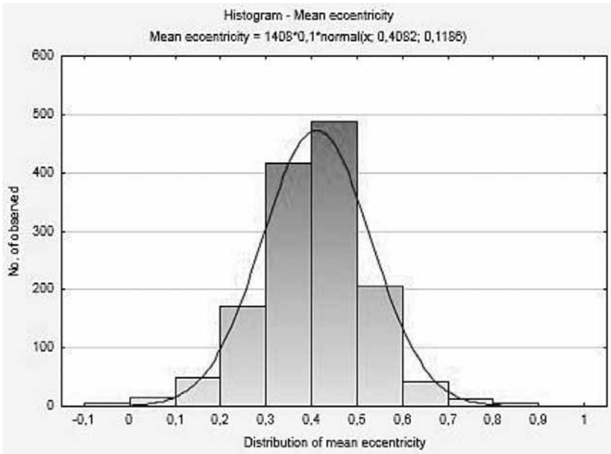

Fig. 2. Distribution of corneal mean eccentricity in sample of population.

Discussion

Advancements in technologies are allowing clinicians to better evaluate the cornea. Corneal measurement continues to advance beyond traditional keratometery. Placido-disc topographers, although limited to evaluation of the anterior corneal surface, now include a powerful greater data point acquisition and more sophisticated data analysis. In addition, divers techniques have been adopted for the estimation of corneal asphericity and different criteria have been used to determine the values that have been presented. For example, the mean of one or two meridians only or a global surface averaged asphericity index. In common population, human cornea gradually flattens form its apex to periphery and assumes an ellipsoidal shape. The term eccentricity mathematiclay describes corneal shape. This value designates the amount by which the cornea differs from a perfect sphere. Average values of human corneas are in range between 0.4–0.6. Eccentricity (ε) is a dimensionless constant which determines the flattening of the cornea toward the periphery. If the cornea is flatter then there is greater eccentricity on the edge. The average value of eccentricity is defined as the square root of the difference of the average values of the radius of curvature of the sagittal (r_s) and the mean central radius (r_0). If the ε value is lower, the cornea is considered to be steeper, a higher value of ε then determines flatter corneal surface[9,10]. This tissue is fully presented by the value of asphericity (Q) and apical radius of curvature. Spherical corneas have the same radius over the whole anterior surface. Prolate means that radius in the periphery is larger than radius of curvature in the center. Analogously oblate shape means that the radius in the periphery is smaller than radius in the center. Average of Q values in population are than –0.26 to –0.42. A simple spherical shape of an anterior surface where is only one radius over the whole area, generates a size of focused points instead of only one. The peripheral rays of light are diffracted more than central rays. This is typical for spherical aberrations. With the change of spherical surface to an aspheric one means that the radius of curvature is getting larger towards the periphery so spherical aberrations are reduced[11–13].

Conclusion

The approximation of the corneal surface by a conic section allows understanding of corneal asphericity and offers a quantitative description. This allows a more precise description of the corneal surface and of the genesis of certain optical aberrations of the eye. Information about the anterior corneal curvature is important in clinical and optometric practice of contact lens fitting and management, ocular aberration analysis, corneal refractive surgery and detection and follow-up of pathological conditions on cornea tissue. Detailed knowledge of the topography of the »normal« corneas are also determining in the analysis of aberrations of the eye for the calculation of IOL implantation and corneal refractive surgery.

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OPTIČKA KONFIGURACIJA I EKSCENTRICITET ROŽNICE U POPULACIJI

S A Ž E T A K

Rožnica predstavlja važan optički medij u stvaranju slike i vidne percepcije. Ističe se važnost mjerenja optičkih karakteristika rožnice u određivanju refrakcije oka,osobito u kontaktologiji. Naglašava se važnosto fiziologije rožnice u kontaktologiji. Naglašava se važnost ekscentriciteta kurvature rožnice, bazirane na keratometriji.