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Comparison of Keratometric Values and Corneal Eccentricity

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A B S T R A C T

The aim of this work is to compare the findings of keratometric values and their differences at various refractive errors. The eccentricity of the cornea in the sense compared to the possible influence of refraction of the eye is topographically observed. Groups of myopia, hyperopia and emmetropia (as a control group) are always represented in total 600 eyes. The studied cohort in total of 300 clients enrolled. Autorefraktokeratometer with Placido disc was used to measure the steepest and the flattest meridian to determine the corneal eccentricity. Group I consisted of 100 myopes, 35 men and 65 women, average age 37.3 years. Objective refraction – sphere: –2.9 D, cylinder: –0.88 D. Keratometry in this group is in the steepest meridian 7.62 mm and the flattest meridian is 7.76 mm. The eccentricity was 0.37. Group II consisting of 100 hyperopic subjects, 40 men and 60 women, average age 61.6 years. Objective refraction – sphere: +2.71 D, cylinder: –1.0 D. Keratometric measurement looks as follows: the steepest meridian is 7.67 mm, the flattest meridian then is 7.81 mm. The value of the eccentricity is 0.37. The third group III consists of 100 emetropic subjects, then clients without refractive errors who achieve without corrective aids Vmin = 1.0. This group is composed of 42 men and 58 women, mean age 41.4 years. Objective refraction – sphere: +0.32 D, cylinder: –0.28 D. The steepest meridian is 7.72 mm the flattest meridian then 7.83 mm. The eccentricity is represented by the observed values of 0.36. Keratometry as well as topography are fundamental methods of corneal anterior surface measurement. Their proportions are essential for the proper parameters selection especially in case of contact lenses as one of the possible means intended to correct refractive errors.

***Key words**: corneal eccentricity, keratometry, corneal topography, refractive error, anterior surface*

Introduction

Soft contact lenses are increasingly searched and selected for correction of refractive errors. First of all the new materials, higher dioptric ranges and expanding deals allow to offer these medical aid for all types of correction of refractive errors. It is necessary for proper application to evaluate the condition of anterior segment and to perform the basic optometric measurement of the cornea among which is surely the keratometry or corneal topography. Keratometry is a method of measurements of the corneal surface, corneal topography is characteristic feature of the corneal surface. Anterior surface of the cornea measuring methods have a deep and rich history. As the first method was used classical keratometry.

Corneal topography starts to be one of the most important measuring methods of valuation of anterior eye shape and corneal curvature for contact lens fitting. Topography as measuring method has also own historic development. The requirement of accurate measuring is being performed not only by developing techniques but mainly by getting more metric values on cornea is necessary. This is concerned especially the anterior surface in the case of special contact lens application with extension of other parameters. The first benefit is no invasive assessing. Choosing the ray of light of acceptable wave lenght the dazzling is kept from patient comfort. Tear film thickness is by the way on its standard level and measurement result is more valid. Corneal topographer producers offer nowadays a board range of varieties in constructions, principles and their combinations.

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In the last years the producers and suppliers of soft contact lenses started to produce and supply to the market these corrective devices with only one possible radius of curvature, so-called »Unifit«. The question arises whether clients needs will be met and will conform to the corneal physiology wearers.

To choose the basic parameters of hydrogel respectively silikonhydrogel contact lenses in particular the value of the radii of curvature of the cornea in the flattest and the steepest meridian is essential information. These values are based on selection of trial or permanent contact lens.

In today's hurried time is start to leave some major and standard measurement procedures followed by selection of the appropriate corrective aids. In the case of optics, optometry and ophthalmology is based on the laws of spectacle, geometric and physical optics. For the mathematical description of the anterior segment is possible to use different schematic models of the eye.

The front surface of the cornea is generally characterized as a second-degree curve from which can be expressed as: $p = b^2/a^2$; $\varepsilon = v1–p$; $SF = \varepsilon^2 = 1 – p$; $Q = –\varepsilon^2$. The axial section of the corneal surface forms the curve, which can be approximated as an ellipse.

Parameter that characterizes the course and shape of the cornea is eccentricity. Aspheric surface generally 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 (eg. aspheric lenses) must be smaller than at the spherical surface. For the description it is sufficient to know the apical radius r0 (radius of curvature at the corneal apex) 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 be not zero.

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 is in the interval $–1 < Q < 0$, for a prolate ellipse axis between X and Y is $Q > 0$. The average of asphericity in the population has a value of –0.26[1]. The negative sign is characterized by flattening the cornea toward the periphery; a positive sign reflects a steeper transition in the periphery[2,9].

Eccentricity (ε) is a dimensionless constant which determines the flattening of the cornea toward the periphery. If the cornea is flatter than 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). The average of eccentricity according to literary sources usually takes the values from 0.2 to 0.5. If the e value is lower the cornea is considered to be steeper, a higher value of ε then determines the corneal surface flatter[2,4].

Analogously we can specify the relationships and define the shape of the anterior corneal surface as follows: for hyperbole is $\varepsilon > 1$, $\varepsilon = 1$ a parabole, oblate ellipse $0 < \varepsilon < 1$, $\varepsilon = 0$ sphere and a prolate ellipse $\varepsilon < 0$[3,4].

The Czech literature describes the shape as a constant K, where the $K = 0$ is a parabole, $K < 0$ indicates hyperbole, $0 < K < 1$ is oblate ellipse, $K = 1$ it is a sphere, and $K > 1$ is for the prolate ellipse[5].

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.

Methods

This randomized study is still ongoing and including first 300 clients divided into groups with refractive errors presenting myopia, hyperopia and emmetropia.

Determining of values of the corneal curvature radius in two perpendicular sections, the steepest and the flattest, were performed on autorefraktokeratometer with Placido disc (KR 8100P, Topcon, Japan). At the same time the 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 the 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 in the front area of the site and are more pronounced changes in the localization of the cornea (eg. keratoconus, post-operative states). This map shows the real distance from the apex of the cornea[5,10]. During the measurement it was also carried out screening for keratoconus and possible assessment of its compatibility with the results of corneal topography performed. For higher validity of the results were as unsuitable clients subsequently excluded from groups with corneal astigmatism greater than –1.0 D.

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 the respondents who had undergone laser refractive surgery, or had any manifestation of an inflammatory character or other symptoms that might distort the final measurements were excluded. The reproducibility of measurements was ensured[6].

Results

Monitored cohort was divided according to refractive error to the group I representing myopia, group II representing hyperopia and group III includes emmetropic eyes (as a control group). Due to the validity of the results were subsequently eliminated from the groups as unsuitable respondents with corneal astigmatism greater than –1.0 D. In group I were originally one hundred clients evaluated after 61 myopic subjects, 23 men and 38 women (N=122), average age 35.4±17.8 (min. 10 years,

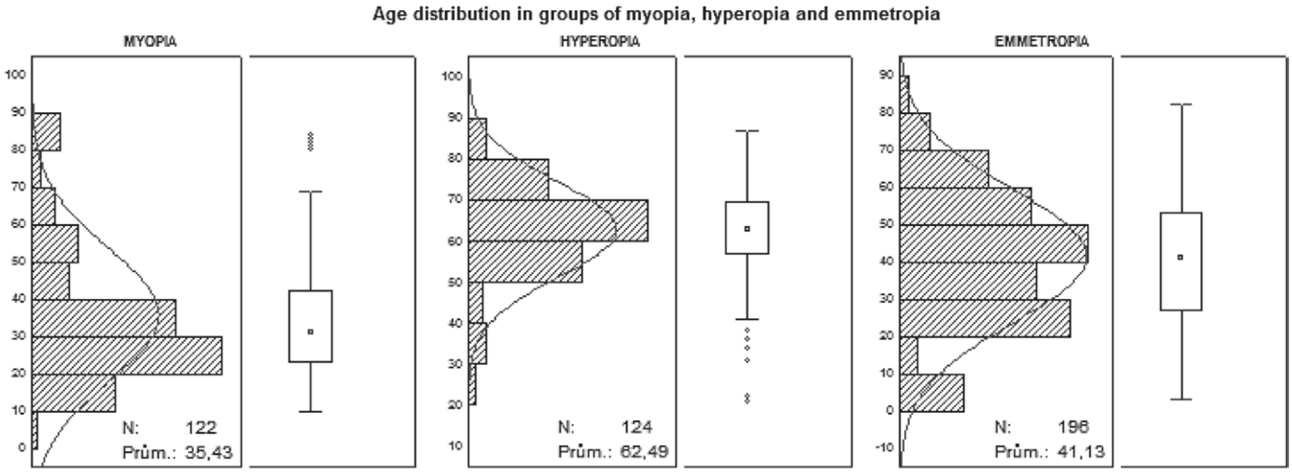

Fig. 1. Age distribution in each group.

max. 84 years), see Figure 1. The detected value is objective refraction – sphere power: –3.21±2.5 D (min. –0.25 D, max. –10.75 D), cylinder power: –0.58±0.25 D (min. –0.25 D, max.–1.0 D).

Keratometry measured in this group is following: radius of curvature of the anterior surface of the cornea in the steepest meridian is 7.60±0.28 mm (min. 6.96 mm, max. 8.44 mm) and the flattest meridian is 7.72±0.29 mm (min. 7.08 mm, max. 8.69 mm), see Figure 3. The eccentricity was 0.37±0.12 (min. 0.10, max 0.79), also in Figure 4.

Group II consists of 62 hyperopic subjects (N=124), 26 men and 36 women, average age 62.4±11.6 years (min. 21 years, max. 87 years) as shown in Figure 1, after the exclusion of clients with higher astigmatism. Objective refraction in this group – sphere power: +2.59±1.35 D (min. +0.25 D, max. +9.0 D), cylinder power: –0.56±0.25 D (min. –0.25 D, max. –1.0 D).

The radius of curvature of the anterior surface of the cornea in two main sections according keratometrical measurement is as follows: the steepest meridian is 7.67 ±0.29 mm (min. 7.03 mm, max. 8.52 mm), the flattest meridian then 7.78±0.29 mm (min. 7.10 mm, max. 8.58 mm), see Figure 3. The value of the eccentricity for this group with hyperopia is 0.36±0.14 (min. 0.00, max. 0.73), also in the Figure 4.

The third group III is represented by 98 emmetropic subjects (n=196) then clients without refractive error which without spectacle correction or contact lenses achieve visual acuity at least 5/5 (1.0) or better. This group is composed of 42 men and 56 women, mean age 41±17.8 years (min. 3 years, max. 82 years), shown in Figure 1. Measured values of objective refraction – sphere power: +0.33±0.45 D (min. –0.75 D, max. +1.5 D), cylinder power: –0.47±0.19 D (min. –0.25 D, max. –1.0 D).

Keratometry values measured at the anterior surface of the cornea in two main meridians are: the steepest meridian corresponds to the radius of curvature of 7.72±0.26 mm (min. 6.91 mm, max. 8.32 mm), the flattest me-

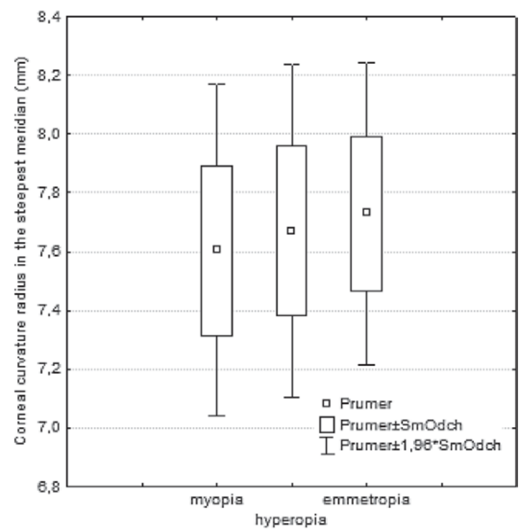

Fig. 2. Distribution of radii of corneal curvature at the steepest meridian for each refractive error.

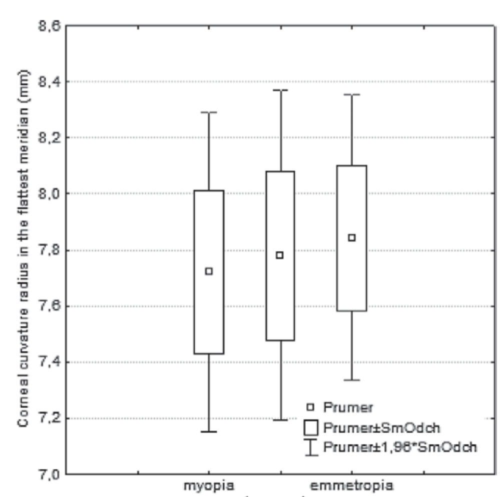

Fig. 3. Distribution of radii of corneal curvature at the flattest meridian for each refractive error.

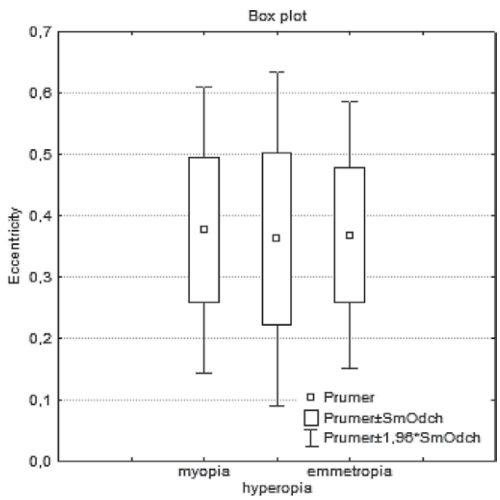

Fig. 4. Layout of eccentricity values of myopia, hyperopia and emmetropia (as a control group).

ridian reaches values of 7.84±0.26 mm (min. 7.10 mm, max. 8.53 mm) see Figure 3. The eccentricity is represented by the observed values of 0.36±0.11 (min. 0.00, max. 0.57), also shown in the Figure 4.

Figure 5 then shows correlation of the steepest and the flattest meridian of radii of curvature (r=0.976).

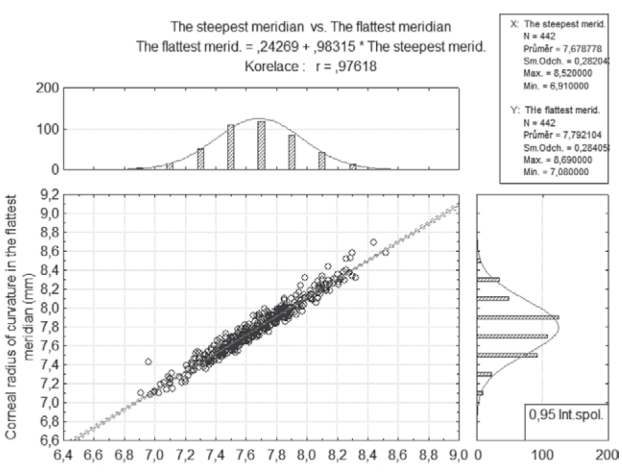

Fig. 5. Correlation of the steepest and the flattest meridian of radii of curvature (r=0.976).

Table 1 shows that the radius of curvature of the cornea of myopic eye is the samllest. These corneas are steeper; its value is growing towards emmetropia. Generally, we can say that the radii of curvature of refractive errors of hyperopia and emmetropia are higher and the shape of the cornea is flatter.

The eccentricity values found in individual representatives of refractive errors are evident that the cornea observed in the study have an ellipsoidal shape ($0 < \varepsilon < 1$).

Correlation between the radius of curvature and mean value of eccentricity are not statistically significant.

The radii of curvature of the cornea of all subjects who were included in this study show a mean value of 7.73±0.29 mm (min. 6.91mm, max. 8.69 mm, median 7.74 mm), in the case of eccentricity were results of diameter measurements as follows: 0.36±0.12 (min. 0.00, max. 0.79, median 0.39), Figure 6, (Spearman correlation, $p<0.05$).

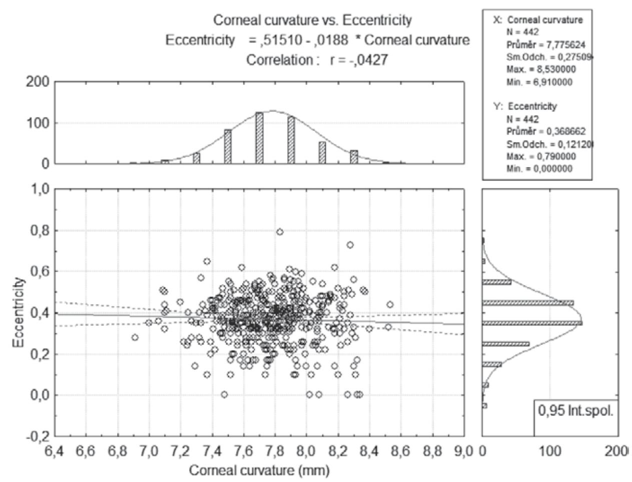

Fig. 6. Linear regression between corneal curvature and eccentricity. The resulting correlation is statistically significant at level of p<0.05 (r=–0.427).

Discussion

The main benefit of aspheric surfaces in general is a precise optical imaging and limitations of spherical and chromatic aberration errors which is primarily important to increase the visual impact performance. This is most obvious especially in technology and construction of corrective appliances, such as spectacle lenses and contact lenses with aspheric surface.

TABLE 1
KERATOMETRY VALUES AND THE ECCENTRICITY MEASURED IN EACH OF REFRACTIVE ERRORS AND A CONTROL GROUP

Groups	The steepest meridian (mm)	The steepest meridian (mm)	Eccentricity
Myopia – (A)	7.60±0.28	7.72±0.29	0.37±0.12
Hyperopia – (B)	7.67±0.29	7.78±0.29	0.36±0.14
Emmetropia – (C, control group)	7.72±0.26	7.84±0.26	0.36±0.11

Aberrometry still has a significant position in the assessment of refractive errors and their correction methods. The current software equipment of new measuring instruments calculates automatically the spherical aberration of the anterior surface of cornea. Higher-order aberrations are errors in the optical imaging that cannot be corrected without the available tools. The aim in clinical practice is achieving the highest possible results in a solution or cataract refractive surgery to reduce or completely eliminate these aberrations and improve visual function. If after surgery the signification of these defects in perception appear as halo effects, haze and glare are then very distracting.

As already mentioned in the introduction, rotationally symmetrical aspherical surface is a certain kind of conic rotation around its axis (outside the circle) and ranks here ellipse, parabole and hyperbole.

These conic sections are changing radius of curvature throughout its course. The radius is the smallest in the axis and on both sides towards the periphery is gradually flattened curve symmetrically in relation to the increasing radius of curvature[7,8].

In case of selecting appropriate parameters of contact lenses are undoubtedly assessing topographic maps of the anterior surface of cornea determination of the flattest and the steepest meridian, respectively values of eccentricity. Its course varies depending on the corneal shape.

Knowledge of production technology, materials, water content, oxygen permeability, refractive index, modulus, wettability, surface quality, the stability of the lens in an environment prone to fouling, biocompatibility and ease of handling for the client are the criteria for recommending suitable corrective contact lenses as a corrective aids[9].

Free availability of these products on the market especially the unregulated internet boom can damage vision of the wearer seriously and permanently. Appellations on the distributing companies are misguided. The main drawback is the possible complications caused by poor or no education of patients especially in the area of disinfection and proper hygiene when handling contact lenses.

Conclusion

In the results there are evident differences in the values of the radii of curvature of the cornea at the anterior surface of each group represented by refractive errors. The group of myopic eyes has the lowest radii of curvature of the cornea and such its shape is steeper. Towards emmetropia with increasing radius of curvature the cornea is flatter. This clearly shows that in case of distribution of contact lenses in one radius of curvature it is not possible to meet the needs of clients with various refractive errors. This could be compromised by corneal physiology. Therefore careful examination of the anterior segment of the eye and to put attention to metric values is necessary.

Among the representatives of classical methods belong manual keratometry performed on equipment. In modern times the use of electronic devices in the interpretation of the results processed by computer programs is routine. The most common topographical instrument in our country is Keratograf (Oculus) which connects topography with keratometry as method of measuring of the corneal surface that is reflected by the Placido disc. All data are then evaluated by appropriate software where the analogy resulting image is digitalized and compressed by computer that suggests measured corneal topographic image. The resulting measurement is in the form of a colour chart. Measured values (horizontal and vertical radius of curvature in the centre of the cornea, astigmatism and axis position, eccentricity) are displayed depending on the location, size and orientation angle of astigmatism. Corneal curvature values can be indicated either as a radius in millimetres or equivalent of curvature in dioptres[10,11].

For a visual demonstration of all values taken by us a three-dimensional geometric display of surface of the cornea serve us the best. To improve the spatial perception the image can be presented in motion. The image underlines the very good progress and eventual corneal curvature measurement differences. Of course, there is also possibility to measure the corneal diameter and pupil, another important value of the cornea, ie. corneal thickness.

These systems offer to contact lenses wearer a view of different types of lenses without having to try them. Collected geometric data from the cornea are then theoretically offered by types of contact lenses, that fit best to the measured cornea. Another imagination is the simulation with fluorescent use.

Corneal topography provides quantitative and qualitative analysis of the radius of curvature of the corneal anterior surface throughout the diameter of the cornea. More sofisticated and the best imagination in this direction is the possibility to provide the OCT of anterior segment of the eye by instruments for example presented by Visante (Zeiss), Pentacam (Oculus), Orbscan (Bausch and Lomb), Galilei (Ziemer) or Casia (Tomey).

Developments in technologies restrict not only to the front surface of the cornea but the methods using the latest technical knowledge on the principle of laser or interference patterns allow to view and measure performance of the anterior segment – i.e. the area of the corneal surface including its eccentricity, corneal thickness with arbitrary choice of various points, the radius of the posterior corneal surface, anterior chamber depth, iris-corneal angle, any pathology of the iris. They can show progress and changes of the cristaline lens. For routine in optometric practice is widely used corneal topographer for the needs of detailed descriptions and calculations required. Especially for corneal surgery are more complex devices used[11]. This study shows a correlation between central corneal radius of curvature and the value of eccentricity but it does not show in the monitored groups of ametropias significant evidentiary difference.

Topography is important to carry out the elimination of degenerative diseases and corneal dystrophies. Higher-order aberrations and eccentricity play an important role in the application of special contact lenses also in cataract and refractive surgery.

Refraction of the eye is formed by the ratio between refractive optical system and the axial length of the eye; therefore is dependent on the central radius of curvature, refractive index and the environmental top distance. The study monitors and evaluates the radius of curvature and eccentricity of the population. In the performed survey the refractive errors had not significant impact on the values of radii of curvature. The central radius of curvature and eccentricity of the cornea are clearly correlated together.

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USPOREDBA KERATOMETRIJSKIH VRIJEDNOSTI I EKSCENTRIČNOSTI ROŽNICE

SAŽETAK

Svrha ovoga rada bila je usporediti keratometrijske vrijednosti i njihove razlike kod različitih refrakcijskih grešaka. Rađeno je na ukupno 600 očiju od 300 pacijenata (skupina miopija, hiperopija, i emetropija kao kontrolna skupina). Mjerenja su se provodila pomoću autorefraktokeratometra sa Placido diskom. Skupina I: ukupno 100 osoba s miopijom, od toga 35 muškaraca i 65 žena, prosječne dobi 37,3 godine. Skupina II: ukupno 100 osoba s hiperopijom; 40 muškaraca i 60 žena, prosječne dobi 61,6 godina. Skupina III: ukupno 100 osoba s emetropijom; 42 muškarca i 58 žena, prosječne dobi 41,4 godine. Keratometrija je zajedno s topografijom fundamentalna metoda za mjerenje prednje površine rožnice. Esencijalne su za selekciju parametara posebice u slučajevima nošenja kontaktnih leća za korekciju refrakcijskih grešaka.