Curvature Analyses of the Corneal Front and Back Surface

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ABSTRACT

In 25 eyes, age range 60–80 years, in purpose of preoperative treatment prior to cataract surgery, measurements of the radius of curvature as well as main meridians of the anterior and posterior corneal surfaces were performed. Average value of the curvature of the anterior corneal surface (R1) was R1=7.84 mm, while posterior radius (R2) was 6.4mm. Main meridian of the anterior corneal surface was in 70% in plus value (+), while postrerior main meridian was always in minus value. It is very important to highlight that main corneal meridians R1 and R2 always cross outside the 90° angle. That is why the combination of the calculation based on the two main meridians superposition (overrefraction) as a form of crossed cylinders has to be calculated (Astigmatismus directus seu obliquus decusatus) using special formula. One of that kind of formulas is Thompson's. Authors want to emphasise the importance of the optical calculation of the posterior corneal surface in the refractive surgery.

Key words*: corneal curvature anterior and posterior, astigmatism anterior and posterior surface of the cornea*

Introduction

Optical analysis of the corneal surface can be seen from different aspects of the geometrical optics. With its anterior surface cornea gives great contribution to the optical strenght of the eye. That is because its anterior surface with the air makes optical system with big refractive index difference »n«, which is shown in the following formula:

$$D = n - 1/R$$

In all other cases optical surface of the optical system fo the eye, except cornea, refractive indices are relative, comparing one optical object with the other (Fig. 1.). In corneal anterior surface its anterior refractive index is n=1.376 compared to the absolute refractive index of the light through the vacuum (arbitrary value taken value of 1). Corneal optical system is defined with the optical power of the anterior surface (with the + value), as well as back surface (– value). In optical way of thinking we have to include the central corneal thickness, but also the depth of the anterior chamber with its refractive index. That values is shown in Gullstrand's formula (d/n):

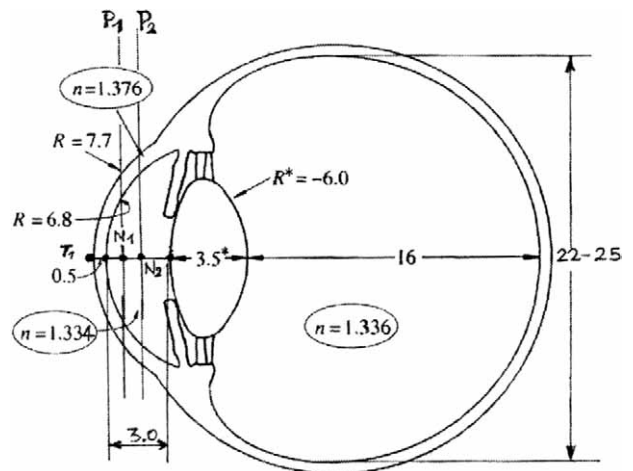Gullstrand's formula: $D = D_1 + D_2 - d/n (D_1 \times D_2)$

Fig. 1. Shows the basic optical values in geometrical optic. The positions of cardinal plains P1 and P2 are shown, with corresponding cardinal points (N1 and N2).

That is why the changes in the radius of the anterior corneal surface reflects on the total corneal refractive

power more than radius of the posterior surface, in which case the value of the relative refractive index is calculated as followed:

$$n = n_1 - n_2 = 1.376 - 1.344 = 0.032$$

while the refractive index of the anterior corneal surface is still 1.376.

The same stands for the greater reflection in the change of the optical meridian values of the astigmatism on the anterior corneal surface compared to the posterior changes.

First person who measured radius of the anterior corneal surface curvature was Christopher Scheiner (1619), after him Servington Savery (1753), than Ser Edvard Home (1796) and von Helmholtz (1856), and at last, nowadays accepted technique established buy Javal and Schiotz (1881). Measurment of the posterior corneal surface was much more harder. Not before Gullstrand (1911) who managed to measure radius of the posterior corneal surface (R2), who got value of the 6.7 mm, which is 300 years after the measurement of the radius of the anterior surface[1].

Nowadays, the methods of measurement are much more sophisticated such as: laser measurement of all optical elements of the eye (with 2nd or 3rd decimal precision) which is quite enough for the eye optics (some other optical systems need much more precise values to the 5th decimal values).

Values of the radius of the anterior corneal surface are quite different according to the different authors. Table with authors and values that they provide is shown in the Fig. 2. The difference is 0.2 mm, or 0.61 Diopters. Having in mind that the corneal radius tend to change during the life, than it is important to define corneal radius according to the age[2–4].

The change of the radius of the anterior corneal surface is shown in Fig. 3. It is clear that the anterior corneal surface curvature changes from 8.3 mm (in the early childhood) to the value of the 7.3 mm in the age 60–70
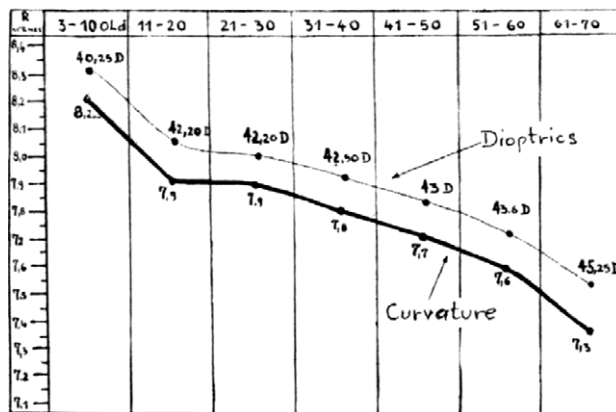

Fig. 3. The curve of the variation of the values of the anterior corneal surface radius with age (2). In the early childhood age cornea is hyperopic, to the age of eighteen it increasingly becomes myopic, and after that it continues to be myopic but more slowly.

years. Parallel to the mentioned above the curve of the dioptric corneal power is shown.

The eye becomes myopic for even 5 Diopters (2). We can tell that for every change of 0.1 mm of the radius of the anterior corneal surface, corresponding dipter change is 0.66 dptr.

As for the changes of the posterior surface curvatures (R2) with age, tendency is that this value becomes higher so it compensates myopic process of the anterior surface. Some researches[5] shows that posterior surface (R2) compensates for the 53% of the myopic anterior surface. Special issues is astigmatism of the both surfaces and their interaction. Some authors papers[4] tell that there is the tendency of the increase of the astigmatism of the posterior surface along with the increase of the anterior surface astigmatism, in which way the total astigmatism is compensated up to 50%. The tendency is that the posterior vertical meridian changes into the horizontal one.

1864.	Donders	7,858 mm
1866.	Helmholtz	7,829
1892.	Sulzer	7,723
1895.	Steiger	7,843
1898.	Tscherning	7,98
1909.	Gullstrand	7,7
1911.	Zeeman	7,78
1911.	Wessely	7,8
1913.	Schiötz	7,865
1934/5.	Tron	7,77
1951.	Cogan	7,7—8

Fig. 2. Shows the values of the anterior corneal surface curvature according to the different authors, without the age of the persons examined.
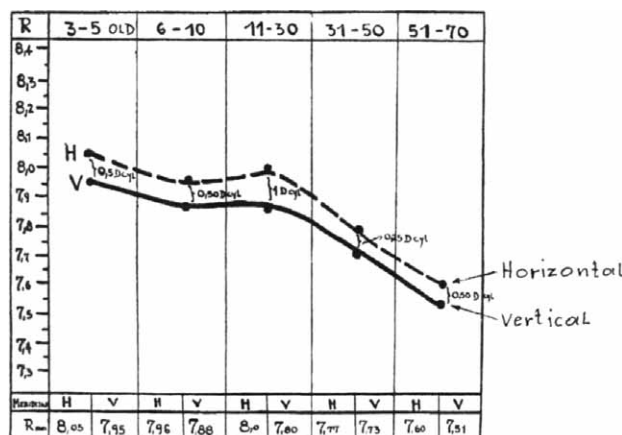

Fig. 4. Thus is the graph of the changes of the curvature in the astigmatism of the anterior corneal surface. The changes of the vertical and horizontal meridians are equal. We can tell that the tendency of the meridian radius change through time corresponds to the change of the radius of the entire sphere surface. Meridians also become myopic with the age.
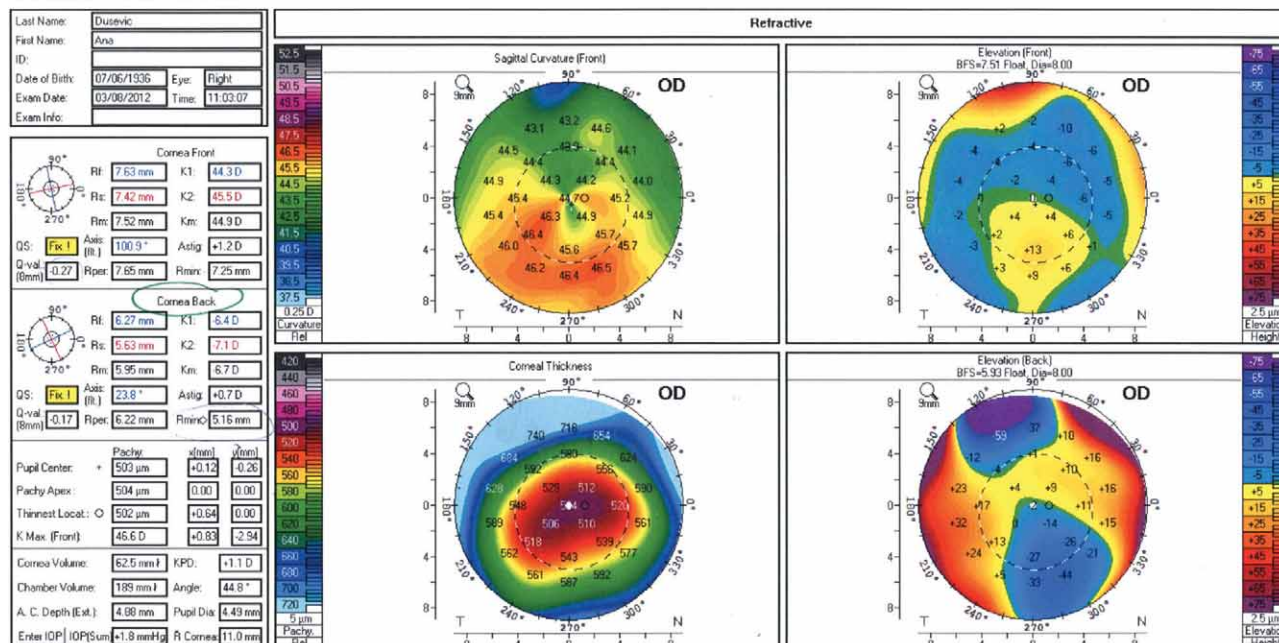
Fig. 5. Oculus-Pentacam, machine that measures all optical relevant values, for the success in calculating optical values in refractive surgery.

Now, there is an open question how much is important in the ophthalmological practice to measure the value of the posterior corneal surface curvature, and especially when thinking about astigmatism. Some authors[3,4] emphasize that it is necessary in refractive surgery of the cornea and lens ton include the astigmatism and curvature of the posterior corneal surface in the calculation.

Subjects and Methods

In 25 persons, age range from 60 to 80 years, preoperative measurements of the anterior and posterior corneal surfaces were performed. Measurements were performed on the Oculus – Pentacam machine, which gives possibility to measure posterior and anterior astigmatism as well.

Results

All measurements and results refer to the age range from 60 to 80 years.

1. Radius of the anterior corneal surface curvature: average R=7.84 mm
2. Radius of the posterior corneal surface curvature: average R=6.42 mm
3. Astigmatism of the anterior surface was oblique in two cases
4. Astigmatism of the posterior surface was direct in all cases

5. Main meridian of the anterior suface had + value in 70% of cases
6. Main meridian of the aposterior suface had + value in 100% of cases
7. Combination of the meridians of the both corneal surfaces make obliquely crossed cylinder in 100% of cases
8. Calculation of the above mentioned meridian values (overrefraction) must be performed in the special way of the calculation with meridian power included.

Discussion and Conclusion

Special attention will be given to the astigmatism of the anterior and posterior corneal surface. Our results show that the astigmatism of the posterior corneal surface is always less, and that the maximum value of the main meridian was 0.70 in diopters value. Other important thing to emphasize is that the combination or the over-refraction of the anterior and posterior corneal astigmatism always manifest in the crossed position, which make regularly or obliquely crossed astigmatism. In other words when the two main meridians angles are not perpendicular (main meridians of the anterior and posterior corneal surfaces) than the sphero-cylindrical calculation have to be performed with the special formula. One of those is the Thompson's formula for the obliquely crossed cylinders.

Our research shows that it is necessary to measure the curvature of the posterior corneal surface, and to include the obtained additional data in the existing calculations in the refractive surgery. Today, that problem is solved in those ophthalmological clinics where the corneal calculations are performed by the mentioned machine, as Oculus – Pentacam is.

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ANALIZA ZAKRIVLJENOSTI PREDNJE I STRAŽNJE PLOHE ROŽNICE

SAŽETAK

Kod 25, očiju, u starosti od 60–80 godina, u svrhu preoperativne pripreme za operaciju katarakte, izvršena su mjerenja radiusa zakrivljenosti i glavnih meridijana prednje i stražnje plohe rožnice. Dobiveno je da prosječna vrijednost radiusa prednje plohe (R1) rožnice iznosi R1=7,84 mm dok je stražnji radius R2=6,4 mm. Glavni meridijan prednje plohe u 70% slučajeva je plus +, dok je stražnji glavni meridijan –. Posebno je važno istaknuti da se glavni meridijani rožnice R1 I R2 križaju u 100% slučajeva izvan kuta 90°, pa se stoga kombinacija izračuna superponiranja dvaju meridijana (overrefraction) kao forma ukriženog cilindra: Astigmatismus directus seu obliquus decusatus, mora kalkulirati po posebnoj formuli, a jedna od takovih je Thompson formula. Autori ističu važnost optičkog izračuna stražnje plohe rožnice u refraktivnoj kirurgiji.