ANALYSIS OF THE ANTEROPOSTERIOR CORNEAL OPTICAL POWER RATIO USING OCT

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SUMMARY

Aims: The aim of the study was to analyse the values of the anteroposterior corneal optical power ratio (*AP* ratio), to compare the resulting values with those theoretical models of the eye, and to define the effect of using an individual ratio value on the approximation of the total corneal power.
Material and Methods: A total of 406 eyes were included. Each patient underwent an OCT (RTVue XR) examination, according to which the *AP* ratio of the cornea was determined, as well as the biometric parameters of the eye (Lenstar LS900). The correlation between the biometric parameters of the eye and the individual *AP* ratio values were evaluated using Pearson's correlation coefficient. In the analysis, the *AP* ratio results were compared with selected schematic models of the eye. Using Gaussian equations, a theoretical calculation of the total corneal optical power (K_G) was performed, by fitting the *AP* ratio value and comparing it with the actually measured total corneal power (*TCP*).
Results: The mean value of the individually determined *AP* ratio was 1.17 ±0.02. The most frequently represented interval (33.74 %) was 1.17 to 1.18 *AP* ratio values, with the vast majority of eyes (79.56 %) in the range of 1.15 to 1.20. Individual values of total corneal optical power were statistically significantly different ($p < 0.05$) from the theoretical values of *TCP* (except in the Liu-Brennan eye model, where $p = 0.06$). The lowest mean difference of values was found for the Navarro schematic model. The dependence of the measured *AP* ratio values and biometric parameters reached a moderate negative correlation ($r = -0.50$ for $p < 0.05$) with the parameter corneal posterior surface curvature (R_p), as well as a weak negative correlation with limbal diameter *WtW* ($r = -0.26$ for $p < 0.05$) and a weak positive correlation with central corneal thickness *CCT* ($r = 0.17$ for $p < 0.05$).
Conclusion: The assumption of a constant value of the *AP* ratio according to the selected schematic models of the eye is statistically significantly different from the actual measured values and was defined to have only a negative weak correlation with the size of the limbus diameter. Using the resulting average value of the determined *AP* ratio (1.17 ±0.02), a lower difference between real and calculated total corneal optical power was achieved.
Keywords: corneal *AP* ratio, posterior corneal radius, total corneal power, optical coherence tomography

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INTRODUCTION

Opto-electronic keratometry is the most commonly used tool for determining the central part of the optical power of the cornea. The principle is to use the reflection of the anterior surface of the cornea to define its radius and optical power. However, the total optical power of the cornea is influenced by its posterior surface, which can be determined using corneal topography or anterior-segment optical coherence tomography (OCT) [1]. The still prevalent use of ocular keratometers or biometers merely approximates the total corneal power, i.e. including the influence of the posterior surface radius, according to the conventionally accepted constant ratio of the anterior to posterior corneal radii in the central corneal area (or AP ratio). Modern calculation formulas for cataract surgery use regression formulas or the Gaussian principle to account for total corneal thickness (excluding topography), where, among other variables, the AP ratio is a constant value of AP = ±1.13 according to the Gullstrand eye model [2,3,4]. Alternative eye models, such as Le Grand [5], Navarro [6], and Liu-Brennan [7], use different values for the ratio [3].

The aim of the study was a retrospective analysis of 406 eyes with physiological findings, which underwent biometric examination with simultaneous topography using anterior-segment OCT to define individual AP ratio values,

mean difference with constants for selected schematic models of the eye, including the determination of the difference between approximated total power and real measured total corneal optical power. Furthermore, the correlation between the biometric parameters of the eye and the individual AP ratio value will be evaluated.

MATERIALS AND METHODS

The analysed population, formed of 64.87% females and 35.13% males, consisted of 406 eyes. The mean age of the cohort was 45 ±7, ranging from 15 to 80 years. All patients met the following inclusion criteria: ametropia ±4.5 D, ocular findings without pathologies and relative contraindications affecting the anatomical conditions of the eye. Biometric parameters of the eye (axial length – AL; anterior chamber depth – ACD; pachymetry – CCT; limbus diameter – WtW) and keratometry (K) according to the anterior surface were determined, using an optical biometer (Lenstar LS900, Haag-Streit, Switzerland). The radius of the anterior (R_a) and posterior (R_p) corneal surface and its total optical power (TCP) in the 3 mm diameter measurement area (Figure 1) were evaluated, using the anterior segment module on the Avanti OCT (OptoVue, USA). For statistical evaluation (Pearson's correlation coefficient r, two-sample T-test for statistical significance p), the functions of STATISTICA 10 (StatSoft) and MS Excel (Office 365) were used.

According to the OCT measurements, the individual AP ratio (defined by the ratio R_a/R_p) of each eye was determined, its correlation with the biometric data (Pearson correlation coefficient), as well as the difference and statistical significance of the difference from the theoretical values according to selected schematic models of the eye (Gullstrand, Le Grand, Navarro, Liu-Brennan). Thereafter, the comparison of the total optical power parameter according to OCT (NetPower) and the theoretical calculated value (K_G) was realised by means of the individually determined AP ratio, using the Gaussian relations presented below [3,8]:

$$P_p = \frac{(n_c - n_{aq})}{(1/AP) \cdot R_a} \quad (1)$$

$$K_G = P_a - P_p + CCT \cdot P_a \cdot \frac{P_p}{n_c} \quad (2)$$

where P_p [D] is the calculated optical power of the posterior corneal surface, R_a [mm] is the radius of the anterior surface of the cornea, P_a [D] is the optical power of the anterior surface of the cornea, n_c [-] is the refractive index of the cornea, n_{aq} [-] is the refractive index of aqueous humour, CCT [mm] is central pachymetry, K_G [D] is total corneal power and AP [-] is the value of the anteroposterior ratio of corneal power.

RESULTS

After determining the individual AP ratios, the frequencies were evaluated from minimum (1.08) to maximum (1.27) values and divided into intervals of 0.04. The most frequently represented interval (33.74%) was 1.17–1.18 AP ratio values, while the vast majority of eyes (79.56%) were in the range of 1.15–1.20 (Figure 1).

The mean value of the individually determined AP ratios was equal to 1.17 ±0.02, and the lowest difference in the absolute value of the individual and theoretical AP ratio was found for the schematic model of the eye according to Navarro. All considered theoretical model values differed from individual AP ratios at the 5% level of statistical significance. Furthermore, the evaluation of the difference between the theoretical calculation of the total corneal optical power (K_G) using Gaussian relations (assuming constant AP ratios and parameters, corresponding to the schematic models according to the literature [9]) and the real measured values (TCP), was performed. Except for the Liu-Brennan eye model ($p = 0.06$), the theoretical values of total corneal optical power were statistically significantly different ($p < 0.05$) from TCP. The median absolute difference between TCP and K_G was higher for the schematic eye models according to Gullstrand (0.21

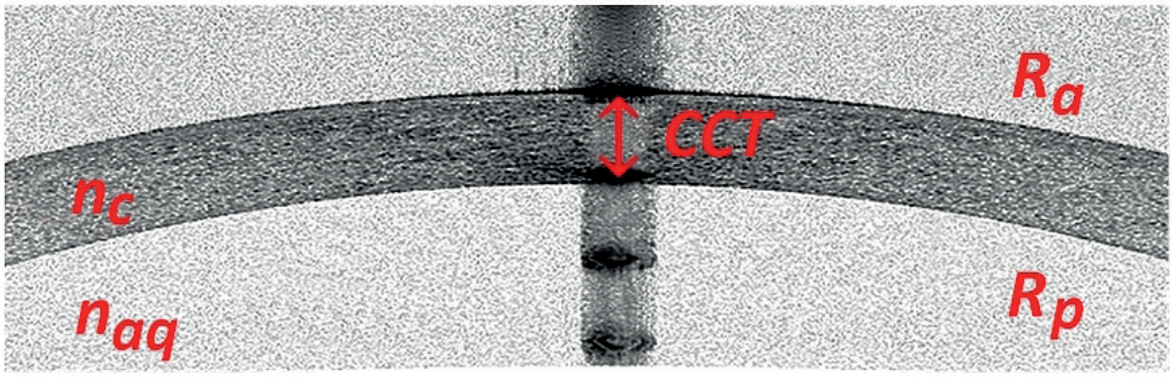


Figure 1. Sample image of a tomographic cross-section of the central part of the cornea with a diameter of 3 mm. R_a – radius of the anterior corneal surface, R_p – radius of the posterior corneal surface, n_c – refractive index of cornea, n_{aq} – refractive index of aqueous humour, CCT – central pachymetry

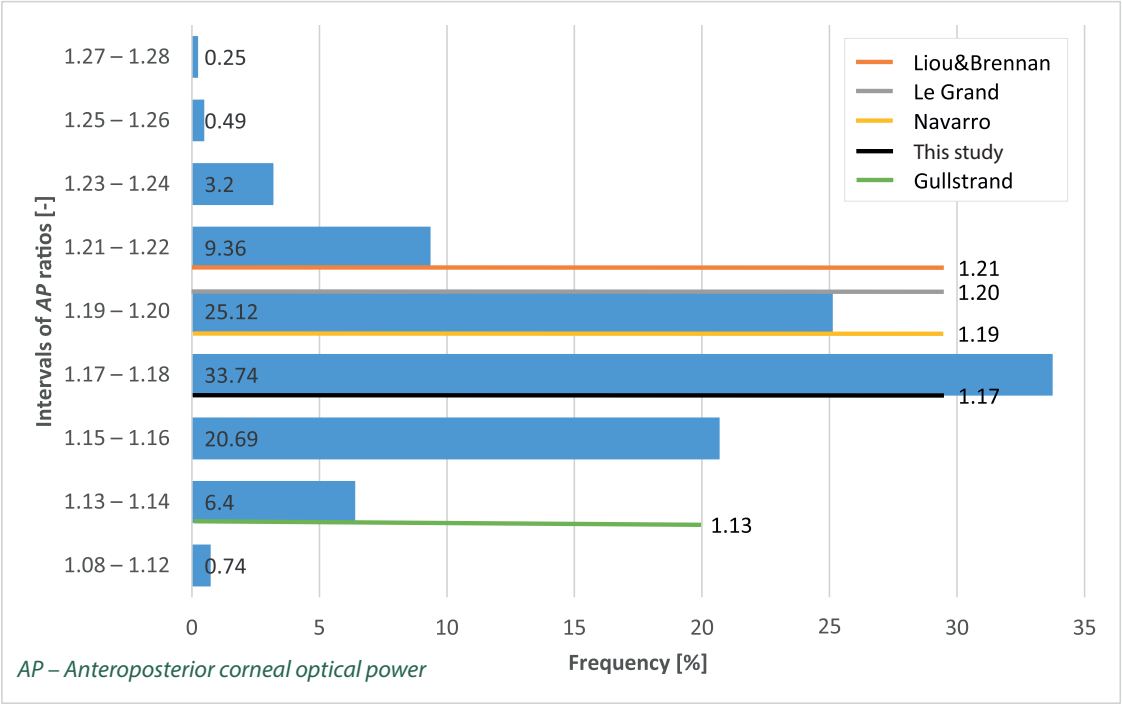
D), Le Grand (0.30 D), Navarro (0.23 D), and Liu-Brennan (0.20 D) than when using the mean AP ratio of this study (0.08 D), for which the difference did not exceed 0.45 D. (Table 1)

The median and mean values of all observed biometric parameters (see Table 2) of the data confirm the physiological ranges of the values of the analysed population. The dependence of the measured AP ratio and the biometric parameters reached statistical significance ($p < 0.05$) for a moderate negative correlation ($r = -0.50$) with the parameter R_p, a weak negative correlation with WtW ($r = -0.26$) and a weak positive dependence on CCT ($r = 0.17$). No association with AP ratio was found for the parameters K, AL and ACD. Table 2.

DISCUSSION

The aim of the study was to create an analysis of individual values of the anteroposterior ratio of the optical power of the cornea, using OCT images and subsequent comparison with the values of selected schematic models of the eye. The individual values of the measured AP ratio differed from all theoretical models at the 5 % level of statistical significance. The Navarro model was judged to be the best fit, due to the lowest median absolute difference between the individual and constant values.

The mean value of the individual AP ratios of our study (1.17 ±0.02) was compared with the results of alternative studies, which are summarised in Table 3. The difference in values should theoretically depend on the methodology of the instrumentation used, i.e. on the principle itself, on the inconsistent size of the diameter of the measurement area, and, of course, on the centration of the scan and the quality of the images. In addition, the different number and ethnicity of the eyes studied also have an important impact [10]. In a study using the principle of



Graph 1. Percentage frequency distribution of AP ratio values measured using OCT with AP ratio values plotted according to different eye models and the mean value determined in this study

Table 1. Summary of the input parameters of the calculation and determination of the median absolute difference between the individual and constant value of the AP ratio

schematic model of the eye	constant AP ratio [-]	refractive index of cornea [-]	median of absolute difference	
			measured and theoretical AP ratio [-]	measured (TCP) and theoretical (KG) corneal power [D]
Gullstrand	1.13	1.376	0.04	0.21
Le Grand	1.20	1.377	0.03	0.30
Navarro	1.19	1.377	0.02	0.23
Liou-Brennan	1.21	1.376	0.04	0.20
this study	1.17	1.375	0.02	0.08

AP – Anteroposterior corneal optical power

Table 2. Median, mean parameters and correlation coefficients r for AP ratio and biometric parameters of the eye

	K	R_a	R_p	*AL*	*CCT*	*ACD*	*WtW*
	[D]	[mm]	[mm]	[mm]	[μm]	[mm]	[mm]
median	43.5	7.73	6.58	23.62	554	3.33	12.2
mean ±sd	43.5 ±1.5	7.7 ±0.3	6.6 ±0.3	23.8 ±1.1	553 ±35	3.4 ±0.4	12.2 ±0.5
r for AP ratio	*r = 0.05 p > 0.05*	*r = 0.02 p > 0.05*	*r = -0.50 p < 0.05*	*r = -0.04 p > 0.05*	*r = 0.17 p < 0.05*	*r = -0.06 p > 0.05*	*r = -0.26 p < 0.05*

AP – Anteroposterior corneal optical power, K – keratometry, R_a – radius of the anterior corneal surface, R_p – radius of the posterior corneal surface, CCT – central pachymetry, AL – axial length of eye, ACD – anterior chamber depth, WtW – diameter of limbus.

combining slit-scan technology and Placido disc reflection in a 10 mm diameter area, a total of 2 429 eyes were analysed with a mean AP = 1.22 ±0.03 [2]. Studies, using Scheimpflug camera-based instrumentation evaluating Pentacam results in the 4-mm central zone, reached virtually identical values in 221 and 7 893 eyes, respectively [8,11]. According to the results of the study with the Sirius device, combining the principle of the Scheimpflug camera and the Placido disk, the AP ratio = 1.19 ±0.02 for 117 eyes, regardless of the size of the measured area (3 mm, 5 mm and 7 mm diameter zones were compared) [12], an alternative study using the 3-mm zone resulted in an AP ratio = 1.20 ±0.03 for 114 eyes [13]. Diagnostics of 114 eyes with the Topcon SL-45 instrument (with Scheimpflug camera for measurements in the central zone of 7.5 mm) resulted in an AP ratio = 1.19 [14]. Using the Casia OCT system, AP ratio = 1.20 ±0.02 was determined in 501 eyes [15]. The only directly methodologically comparative study (using the identical RTVue OCT system) evaluated only 38 eyes with a different result of AP ratio = 1.20 ±0.02 [16].

The clinical impact of individual differences was assessed through median absolute difference measured (TCP) and theoretical corneal power (KG). Numerically higher values of the AP ratio than the mean value of this study (i.e. including the Le Grand, Navarro, and Liu-Brennan models) result in an underestimation of the real corneal optical power, which, for example, results in an overcorrection of the optical system for the hypothetical calculation of intraocular lens (IOL) power. Whereas a numerically lower AP ratio will overestimate the corneal optical power, which may lead to the calculation of a less than adequate IOL power, resulting in undesirable postoperative hypermetropia. However, the median absolute values of the differences between TCP and K_G for all models were low, in the interval of 0.20–0.30 D. The effect of such a difference on the resulting hypothetical IOL (using the average biometric parameters according to Table 2) according to conventional regression formulas would result in a change in IOL magnitude practically adequate to the given difference. However, given that the vast majority of IOLs are produced at 0.5 D intervals, these average differences cannot be considered relevant. Individual consideration of the AP ratio is beneficial for IOL calculation, especially at the extremes, and not only in patients after corneal refractive surgery.

In determining the relationship between AP ratio size and biometric parameters of the eye, a moderate negative correlation was detected, with corneal posterior surface radius R_p ($r = -0.50$ for $p < 0.05$), a weak correlation with CCT ($r = 0.17$ for $p < 0.05$) and corneal diameter WtW ($r = -0.26$ for $p < 0.05$). Similar correlation results were presented by the Hasegaw study, with a correlation coefficient of $r = -0.47$ ($p < 0.0001$) for R_p, $r = 0.22$ ($p < 0.0001$) for the CCT parameter, $r = -0.12$ ($p = 0.0094$) for corneal diameter, and no significant relationship for the other parameters [15]. Given the weak values of the correlation coefficients (except for the logical assumption of a dependence on the posterior surface radius), the consideration of the biometric parameters of the eye against the

Table 3. Comparison of the resulting AP ratio values with alternative studies

main author (year of publication)	corneal measurement methodology	number of eyes	mean AP ratio ±sd
Fam HB. (2007) [2]	Orbscan II	2429	1.22 ±0,03
Dubbelman M. (2006) [14]	SchI (Topcon SL-45)	114	1.19 ± not specified
Montalbán R. (2012) [12]	SchI+Placido (Sirius)	117	1.19 ±0.02
Savini G. (2017) [13]	SchI+Placido (Sirius)	114	1.20 ±0.03
Ho JD. (2008) [8]	SchI (Pentacam)	221	1.22 ±0.03
Tang Ch. (2021) [11]	SchI (Pentacam)	7 893	1.22 ±0.01
Hasegawa A. (2018) [15]	OCT system (Casia)	501	1.19 ±0.02
Tang M. (2010) [16]	OCT system (RTVue)	38	1.20 ±0.02
this study	OCT system (RTVue)	406	1.17 ±0.02

AP – Anteroposterior corneal optical power, SchI – Scheimpflug Imaging

AP ratio cannot be considered beneficial.

CONCLUSION

The determination of the individual corneal AP ratio in a group of 406 eyes showed that the assumption of a constant AP ratio according to the theoretical eye models (Le Grand, Navarro, Liou-Brennan, Gullstrand) was statistically significantly different from the actual measured individual values, even though these were patients without previous refractive surgery. Only a weak negative correlation with the WtW parameter was found for the biometric values and the resulting AP ratio. Using the individual pachymetry parameters and the median study-determined AP ratio = 1.17, the lowest median difference (0.08 D) between the theoretically calculated and measured values of total corneal optical power was achieved.

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