CASE REPORT

Comparison of Central Corneal Thickness and Keratometric Measurements using the Scheimpflug HR Imaging System, Laser Interferometry, Automatic Keratometry and Ultrasound Pachymetry

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SUMMARY

Comparison of Central Corneal Thickness and Keratometric Measurements using the Scheimpflug HR Imaging System, Laser Interferometry, Automatic Keratometry and Ultrasound Pachymetry

Introduction: The aim of our study was to compare keratometry and central corneal thickness measurements obtained with three different ophthalmic devices and to decide if they can be used interchangeably in clinical practice.
Methods: 43 healthy persons were included in the study (29 women and 14 men, average age 25 ± 3.5 years). Central corneal thickness (CCT) was measured with the Scheimpflug HR imaging system (Pentacam), Allegro BioGraph and with ultrasound pachymetry (RXP OcuScan). Keratometry in two main meridians of the cornea (K1, K2) was measured with Pentacam, Allegro BioGraph and automated keratometry.
Results: The mean difference in K1-readings was 0.01 ± 0.31 D for BioGraph vs. automated keratometry, 0.06 ± 0.23 D for BioGraph vs. Pentacam and 0.05 ± 0.34 D for automated keratometry and Pentacam. The mean difference in K2-readings was 0.29 ± 0.45 D for BioGraph vs. automated keratometry, 0.11 ± 0.28 D for BioGraph vs. Pentacam and 0.19 ± 0.44 D for automated keratometry and Pentacam. The interdevice differences were in all cases statistically significant ($p < 0.05$). The mean difference in CCT was 4.57 ± 7.84 μm for BioGraph vs. ultrasound, 4.33 ± 7.55 μm for BioGraph vs. Pentacam and 8.90 ± 7.49 μm for ultrasound vs. Pentacam. The interdevice differences in CCT were also statistically significant ($p < 0.05$).
Conclusion: Our results suggest that the measurements of keratometry and CCT may differ significantly between the tested machines and therefore should not be used interchangeably in clinical practice.

Key words: keratometry, pachymetry, CCT, Pentacam, BioGraph

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INTRODUCTION

Measurement of the curvature of the cornea (keratometry) and its thickness (pachymetry) is a very common examination in ophthalmology. Keratometry is routinely determined in patients before cataract surgery, before a refractive procedure on the lens and on the cornea or in patients with keratoconus. Pachymetry is also a component of examination before laser refractive surgery on the cornea and in recent years has become an essential component in the diagnosis of glaucoma.
Advances in the surgical equipment of ophthalmological workplaces enable an examination of both parameters using various instruments, which however mostly use various physical principles of measurement. In the case of keratometry it is possible for example to use corneal topography, a rotating Schemipflug HR imaging system, automatic keratometry, laser interferometry or optical coherence tomography. Wavefront analysis enables completely precise mapping of corneal aberrations. In the case of pachymetry there is a fundamental differentiation between contact methods (ultrasound pachymetry) and noncontact methods (optical pachymetry).
In a range of patients it is necessary to perform an examination of the curvature and thickness of the cornea repeatedly. In particular in patients before a surgical procedure on the lens or cornea we should attempt to eliminate any error of measurement. The aim of our study was to compare the results of pachymetry and keratometry of the cornea on three different ophthalmological instruments with this function and to determine whether these instruments are mutually interchangeable in practice.

METHOD

43 healthy persons with a normal ocular finding were included in the study (29 women and 14 men, average age 25 ± 3.5 years). Keratometry and pa-

chymetry were examined in all persons in the study on three different instruments with this function. All examinations were conducted by the same ophthalmologist (P.P.).
Central corneal thickness (CCT) was measured on the instrument Pentacam HR, Allegro BioGraph and using ultrasound pachymetry on the instrument OcuScan RxP. Curvature of the cornea in the two main meridians (K1, K2) was measured on the instrument Pentacam HR, Allegro BioGraph and using automatic keratometry. The individual instruments differ in their physical principle, wavelength of the emitted radiation or parameters of the read area. With the exception of ultrasound pachymetry, all measurements on the tested instruments were conducted without contact.
The Allegro BioGraph instrument works on the principle of laser interferometry. For measurement of pachymetry it uses light with a wavelength of 820 nm, corneal thickness is measured in the axis of fixation of the patient on fixating light. For examination of keratometry light with a wavelength of 950 nm is used, keratometry is calculated on the basis of refraction of 32 points of light arranged in 2 circles, in which the external points of measurement are at a distance of 2.3 mm from each other and the internal points of measurement 1.65 mm.
Pentacam uses the principle of Scheimpflug HR imaging. For measurement of pachymetry and keratometry it uses light with a wavelength of 475 nm and states corneal thickness in all measured points of the cornea. Keratometry is determined around the perimeter of a hypothetical 3 mm ring of the cornea in two main lateral and mutually perpendicular cross-sections.
Ultrasound pachymetry represents a contact method of measuring corneal thickness. A probe is placed on the centre of the cornea. An ultrasound impulse transmitted by a crystal convertor is refracted from the anterior and posterior surface of the cornea. Upon examination it is necessary for the probe to be placed perpendicular on the surface of the cornea.
Curvature of the cornea is measured on an auto-keratometer using 4 rays of infra-red light projected onto the cornea. The instrument reads the light refracted from the cornea and calculates corneal curvature. Keratometry is determined in the central area of the cornea with a standard defined diameter of 3.3 mm.
The statistical evaluation included the results of keratometry and pachymetry of both eyes of all patients in the study group (n = 86). The values of corneal curvature in both main meridians (K1, K2) and their thickness determined by measurement on the different instruments were mutually compared using a paired non-parametric Wilcoxon test.

RESULTS

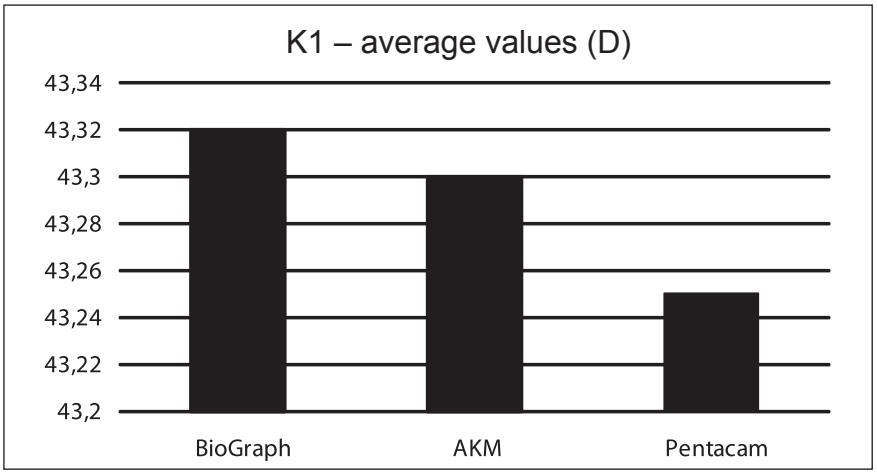
The average values of corneal curvature in the studied group examined on Pentacam, Biograph and automatic keratometry are summarised in tables and graphs 1 and 2. The average values of central corneal thickness in the studied group measured using ultrasound pachymentry , Pentacam and BioGraph are summarised in table and graph 3.
The average difference in the K1 value between the BioGraph and auto-keratometer was 0.01 ± 0.31 D, between BioGraph and Pentacama 0.06 ± 0.23 D and between auto-keratometer and Pentacam 0.05 ± 0.34 D. The average difference in the K2 value between BioGraph and auto-keratometer was 0.29 ± 0.45 D, between BioGraph and Pentacam 0.11 ± 0.28 D and between auto-keratometer and Pentacamem 0.19 ± 0.44 D. The determined differences in keratometry were statistically significant in all cases ($p < 0.01$).
The average difference in CCT between BioGraphem and ultrasound was 4.57 ± 7.84 mmmm, between BioGraph and Pentacam 4.33 ± 7.55 mmmm and between ultrasound and Pentacam 8.90 ± 7.49 mmmm. The differences in corneal thickness were also statistically significant ($p < 0,01$).

DISCUSSION

Measurement of keratometry and pachymetry of the cornea is important for refractive and cataract surgery, diagnosis and evaluation of progression of keratoconus or for diagnosis

Table 1. Average value of keratometry (K1) examined using different instruments and standard deviation (SD) of measurement

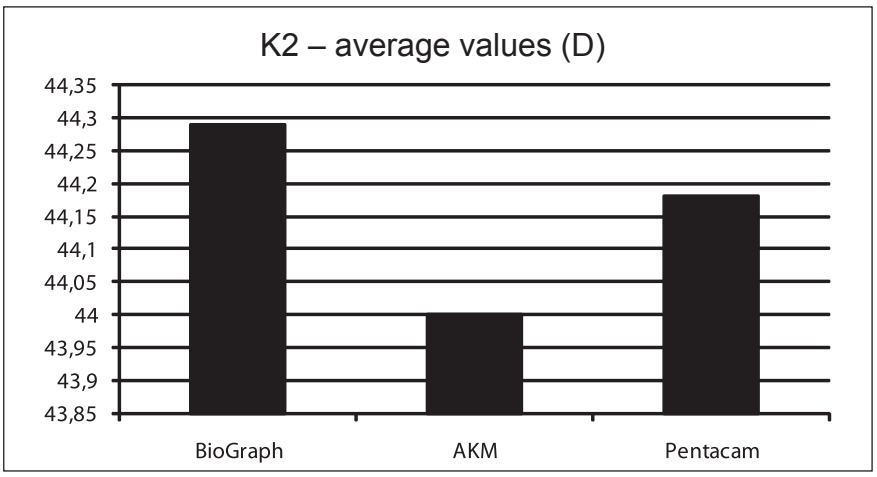
K1	Average (D)	SD
BioGraph	43.32	1.29
AKM	43.30	1.27
Pentacam	43.25	1.27



Graph 1

Table 2. Average value of keratometry (K2) examined using different instruments and standard deviation (SD) of measurement

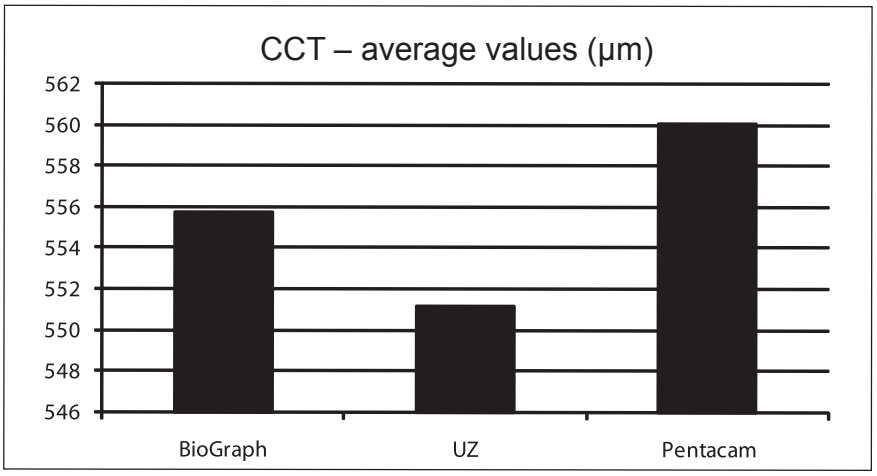
K2	Average (D)	SD
BioGraph	44.29	1.41
AKM	44.00	1.45
Pentacam	44.18	1.35



Graph 2

Table 3. Average value of central corneal thickness examined using different instruments and standard deviation (SD) of measurement

CCT	Aveage (μm)	SD
BioGraph	555.77	34.28
AKM	551.20	35.79
Pentacam	560.09	32.56



Graph 3

of glaucoma. Error in measurement may generally be caused by a human factor or by the instrument itself. Especially in the case of refractive patients it is desirable to limit both of these factors to the maximum possible extent in order to obtain the best possible result of the refractive procedure.

In our study the differences in the values of keratometry and pachymetry using different instruments were statistically significant. These differences may have a number of causes. It may depend for example on whether this concerns a contact or noncontact method, on the character of the radiation used and its wavelength, on how the area in which the measurement is performed is defined, on the location of refractive surface of the emitted radiation and on the principle by which the refraction takes place. It may also be important as to whether the instrument embraces the lacrimal film upon measurement.

The lowest CCT values were repeatedly determined upon contact examination using ultrasound. The authors of other studies obtained the same result. For example, Módis et al. compared CCT measured by two independent observers using Pentacam HR and ultrasound pachymetry in 46 healthy persons. The CCT values from the examination on Pentacam were significantly higher on Pentacam for both examiners (572 ± 33 and 575 ± 31 mmmm) than upon measurement by ultrasound pachymetry (546 ± 27 and 548 ± 28 mmmm) ($P < 0.0001$) [5].

Lee et al. in their publication compared central corneal thickness upon examination on Tonopachy, Pentacam and ultrasound pachymetry on 104 patients. The differences in CCT between the individual instruments were statistically significant ($p < 0.0001$). The CCT values measuring using ultrasound pachymetry were again repeatedly lower than on other instruments (541.7 ± 30.6 μm). The differences in CCT determined using Tonopachy and Pentacam were smaller (557.3 ± 34.3 and 558.0 ± 33.7 μm) [4], but still statistically significant.

Differences in corneal thickness on Pentacam and ultrasound pachymetry may be caused by the different principle of measurement of both methods. Pentacam measures CCT without contact, whereas in ultrasound pachymetry contact of the ultrasound probe with the cornea of the patient is required. Ultrasound pachymetry determines the time interval between the refractions (echoes) of sound waves from the anterior and posterior surface of the cornea. Nevertheless, the precise point of refraction from the posterior surface of the cornea is not known, and it is therefore possible that it is located between the Descemet's membrane and the anterior chamber. By contrast, Pentacam measures corneal thickness using a monochromatic ray of blue light with a wavelength of 475 nm, which is refracted from the individual interfaces on the basis of the different refraction index of the air, the cornea and the chamber fluid. According to the manufacturer of Pentacam, the lacrimal film has no influence on the measurement of corneal thickness. By contrast, in the case of ultrasound it has been demonstrated that the ultrasound probe can easily overcome a 7 to 40 μm thick lacrimal film, and even compress the corneal epithelium[6].

Although the explanation for the lower values of ultrasound pachymetry seems to be clear, there are also studies which refer to contrary results. For example, Hashemi et al. compared corneal thickness in the centre, at the apex and in its thinnest point on 47 patients using the instruments PARK1, Pentacamu and ultrasound pachymetry. In contrast with the previous studies, the CCT values mea-

sured by ultrasound were significantly higher than the values measured by Pentacam (average difference 5.54 ± 8 µm) [3]. The explanation for this finding is not yet clear.

Most studies therefore engage in a comparison of measurement of CCT using Pentacam and ultrasound pachymetry. Few studies have been conducted on examination of pachymetry using laser interferometry (in our study on the instrument Allegro Biograph), despite the fact that this represents a relatively simple noncontact method of CCT measurement. Beutelspacher et al. retrospectively compared CCT measured using optical reflectometry and ultrasound in 50 patients, and determined a very good correlation of results between both (correlation coefficient r = 0.929) [1]. Further studies on this theme would undoubtedly be of benefit.

Keratometry was always examined without contact in our study. Rather than mechanical factors, the determined differences between the instruments in this case should be attributed rather to differences in the technique of measurement, such as the different wavelength of the used radiation or different size of the defined surface of the cornea from which the keratomety is read. As in our study, a significant difference between keratometry measured on Pentacam and auto-keratometer was found for example by Elbaz et al., who compared keratometry measured by Pentacam, auto-keratometer (AK) and IOL Master in 22 eyes of healthy persons. The differences in keratometry between Pentacam v AK, Pentacam v IOL Masterem and AK v IOL Master were -0.046 D, -0.471 D and -0.424 D. Keratometry on IOL Master differed statistically significantly from the values on Pentacam ($P < 0.01$) and AK ($P < 0.01$) [2]. The authors of the study explain the determined difference by the fact that the posterior curvature of the cornea is directly covered by the algorithm of Pentacam, whereas IOL Master and AK calculate the radius of the posterior surface of the cornea as approximately 82.2% of the radius of the anterior surface of the cornea and the refraction index of the cornea is therefore 1.3375. As another possible cause of the determined difference they state the different diameter of the read area of the cornea by the individual instruments.

The curvature of the cornea from measurements on Pentacam and OPD Scan (Optical Path Difference – combines topography, wavefront analysis, auto-refractometry, keratometry and pupilometry, and enables a precise and reliable analysis of aberrations of the cornea) was compared in a study sample of 117 eyes by Refai et al. In contrast with previous publications, however, they did not determine any significant differences in the corneal curvature [7].

CONCLUSION

The values of keratometry and central corneal thickness measured on a number of different instruments with this function were statistically significantly different in our study. According to our results, the tested instruments are not mutually interchangeable in practice, and repeat examinations of both parameters should be conducted always on the same instrument. The examining ophthalmologist should be aware of the differences in the methodology of the individual techniques, and if possible always use the same instrument on the given patient.

LITERATURE

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