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Interocular differences of the Pentacam measurements in normal subjects

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Purpose: The aim of this study was to determine the interocular differences of the Pentacam corneal measurements in a normal population.

Methods: A retrospective analysis was performed on 550 eyes of 275 consecutive subjects evaluated for refractive surgery at the Rassoul Akram Hospital, Iran University of Medical Sciences. A Pentacam Scheimpflug camera was used for corneal measurements. Statistical analysis was performed to determine the normal levels of the difference between the two eyes.

Results: One hundred and four men and 171 women with a mean age of 29.1 ± 7.73 years were evaluated. The mean (range) interocular difference was 2.17 (zero to 21) μm for maximum anterior elevation (AEmax), 3.62 (zero to 31) μm for maximum posterior elevation (PEmax), 8.42 (zero to 30) μm for minimum corneal thickness (CTmin), 0.06 (zero to 0.4) mm^3 for three millimetre corneal volume (CV3), 0.19 (zero to 1.2) mm^3 for five millimetre corneal volume (CV5), 0.44 (zero to 2.9) mm^3 for seven millimetre corneal volume (CV7), 0.24 (zero to 2.5) dioptres for the mean keratometry (Km) and 0.39 (zero to 2.5) D for measurements of the corneal dioptric power in the steepest meridian (Kmax).

Conclusions: Individuals with differences greater than 17.4 μm in AEmax, 29.1 μm in PEmax, 29.6 μm in CTmin, 2 D in Km, 2.27 D in Kmax, 0.32 in CV3, 1.05 in CV5, and 2.6 in CV7 between eyes represent less than 0.5 per cent of the population. An interocular difference outside the normal range should alert the clinician to examine for other parameters that are more predictive of post-refractive surgical ectasia.

Key words: interocular asymmetry, keratometry, keratorefractive surgery, pachymetry, Pentacam Scheimpflug camera

Keratoconus is a non-inflammatory disorder, characterised by corneal thinning and anterior protrusion. Diagnosis of keratoconus in eyes with clinical and topographic signs is not difficult. Advances in topography instruments have lead to a variety of quantitative indices that have been found to be highly sensitive and specific in aiding with the diagnosis of keratoconus.[1–5] Detection of forme fruste or subclinical keratoconus is challenging.[1,2] This may result from the absence of clinical signs, subtle changes in the topographic features or undefined threshold criteria.[6] Because keratorefractive procedures may have unsatisfactory results and lead to post-operative complications in subclinical keratoconus, detection of this disease is particularly important in candidates for refractive surgery.[7,8]

Eyes with keratoconus have a greater degree of interocular asymmetry than normal eyes.[9,10] Interocular asymmetry may become more important when other screening tests are normal and warrants more extensive evaluation.[11,12] By determining normal variance for the

	Right eye	Left eye
Maximum anterior elevation (μm)	7.6 ± 3.6	7.9 ± 3.9
Maximum posterior elevation (μm)	15.3 ± 5.7	14.9 ± 5.7
Minimum corneal thickness (μm)	536.4 ± 51.0	535.1 ± 51.2
3 mm corneal volume (mm^3)	3.9 ± 0.2	3.9 ± 0.3
5 mm corneal volume (mm^3)	11.4 ± 0.6	11.4 ± 0.7
7 mm corneal volume (mm^3)	24.5 ± 1.6	24.6 ± 1.7
Mean keratometry (D)	43.6 ± 2.8	43.6 ± 2.9
Steepest keratometry (D)	44.6 ± 1.4	44.7 ± 1.4

μm: micrometres, mm: millimetres, D: dioptres

Table 1. Mean (± SD) of Pentacam measurements for each eye

interocular difference, we can identify patients who fall outside this range. Although the corneal parameters may be normal in both eyes, significant differences between the two eyes may reflect an underlying disease. In this study, we evaluated interocular asymmetry of the corneal parameters in a normal population.

MATERIAL AND METHODS

From January 2008 to January 2009, 275 subjects who were referred for corneal refractive surgery were evaluated. Subjects with a history of corneal injury or illness, previous ocular surgery, clinically apparent ectasia, contact lens wear during the past three weeks or pregnancy were excluded. Also excluded were the patients with any topographical abnormality suggesting keratoconus.[1,2,4] The study was performed in accordance with the Declaration of Helsinki guidelines for human research and the approval of the Intuitional Review Board of the Eye Research Center was obtained.

The Pentacam system with the 50-image mode and software version 1.12 was used. The automatic mode of the instrument was employed, in which the image capture starts when correct alignment with the corneal apex and focus is achieved. Only those scans that registered as 'OK' according to the 'examination quality specifications' were included. This ensured that the scans were not affected by poor fixation, misalignment or missing segments.

Both eyes of each patient were measured on the same day within five minutes of each other. The maximum anterior elevation in four-millimetre central circle (AEmax) and maximum posterior elevation in four-millimetre central circle (PEmax) were extracted from anterior and posterior elevation maps. For this purpose the cursor was moved through the screen to find the maximum number for the central four-millimetre circle. Minimum corneal thickness (CTmin), three, five and seven millimetre corneal volumes (CV3, CV5, CV7), mean keratometry (Km) and corneal dioptric power in the steepest meridian for the three-millimetre central zone (Kmax) measurements automatically provided by the software were recorded from the default tables. From the anterior and posterior elevation map options, automatic diameters were selected for the float best-fit spheres.

The Kolmogorov-Smirnov test was used to assess the normality of the distribution of our patient population. For each of the measurements, the difference between right and left eyes in each subject was calculated. The Bland and Altman[13] method was used to plot the mean versus the difference for each of the elevation, mean keratometric and thinnest point parameters.

RESULTS

The mean age of the participants was 29.1 ± 7.73 years (range 18 to 56 years). One hundred and four participants (37.8 per cent) were men. The mean and standard deviation of the spherical equivalent refraction was -3.2 ± 3.03 D in the right eye and -3.2 ± 2.83 D in the left eye ($p = 0.9$). The Kolmogorov-Smirnov test calculated $p > 0.1$ for AEmax, PEmax, CTmin, CV3, CV5, CV7, Km and Kmax distributions, which is consistent with normal data. The average and distribution of Pentacam measurements are shown in Table 1. Figure 1 (A–D) shows scatterplots of the right eye versus the left eye for maximum anterior and posterior elevations, mean keratometric reading and the thinnest corneal pachymetry. Figure 2 (A–D) shows even distributions for the Bland-Altman plots of the average maximum anterior elevation, average maximum posterior elevation, average thinnest corneal thickness and average mean keratometry. Table 2 shows the interocular difference for Pentacam measurements. Individuals with a difference greater than 17.4 micrometres (μm) in AEmax, 29.1 μm in PEmax, 29.6 μm in CTmin, 2.00 D in Km, 2.27 D in Kmax, 0.32 in CV3, 1.05 in CV5 and 2.6 in CV7 between eyes represent less than 0.5 per cent of the population.

DISCUSSION

Improved imaging technology has made it possible to identify better patients who may be at increased risk for complications from refractive surgery. Forme fruste keratoconus has been identified as a risk factor for post-keratorefractive ectasia.[7,8] Despite various diagnostic criteria, detection of some patients with subclinical keratoconus may be difficult.[6]

Previous reports[10,14] have shown that despite normal anterior corneal measurements, posterior elevation abnormalities may be found in the fellow eyes of patients with unilateral keratoconus, so in patients suspected of subclinical keratoconus, special attention should be paid to the posterior elevation measurements. Our

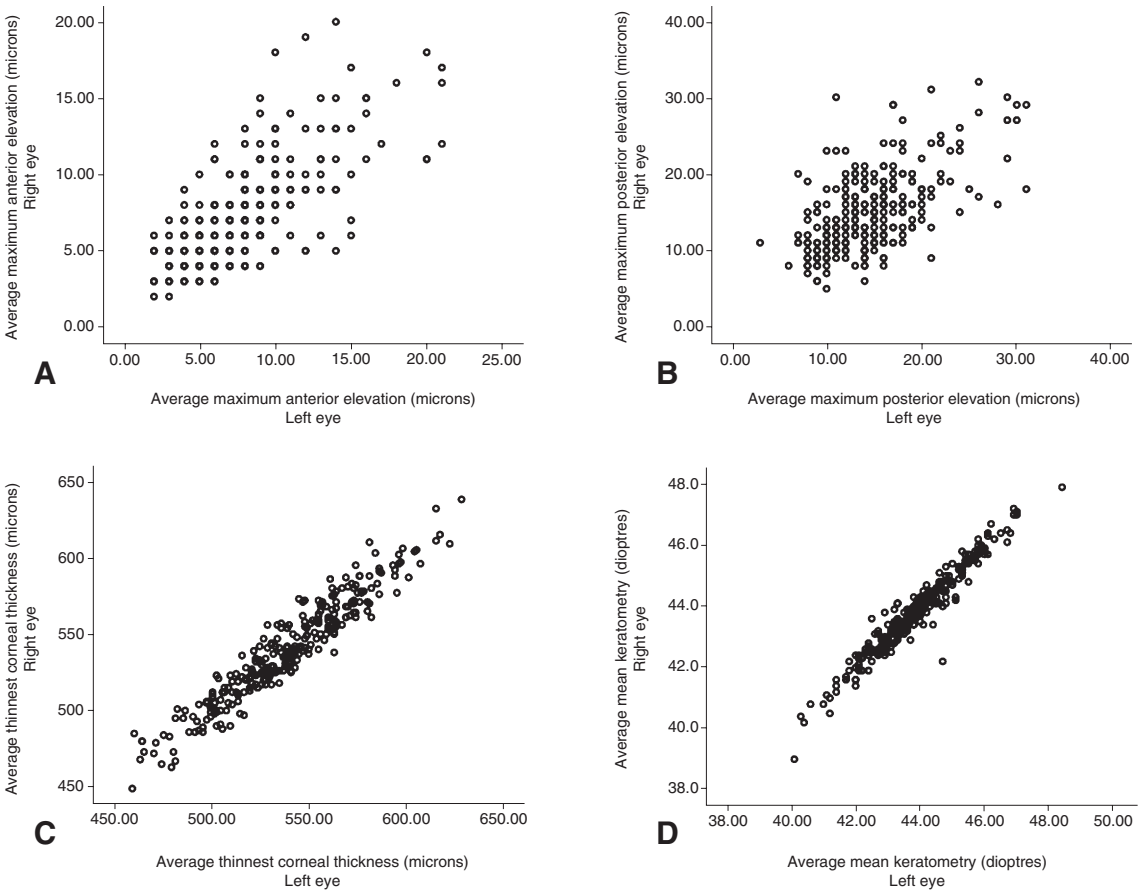

Figure 1. (A) Interocular comparison of the average maximum anterior elevation with a correlation coefficient of 0.5 and $p < 0.001$. (B) Average maximum posterior elevation with a correlation coefficient of 0.4 and $p < 0.001$. (C) Average thinnest corneal thickness with a correlation coefficient of 0.90 and $p < 0.0001$. (D) Average mean keratometry with a correlation coefficient of 0.93 and $p < 0.001$.

results show that individuals with a greater than 25.8 µm interocular difference in PEmax measurements represent less than 0.5 per cent of the population. This cut-off value is much higher than the reported mean difference of intersession variability of Pentacam measurements (0.51 µm).[15] Using Orbscan, Lema, Suárez and Díez-Feijoo[10] reported the characteristics of patients with unilateral keratoconus. They showed a statistically significant increase in the mean distance between the posterior face and the best-fitting sphere of the involved eyes compared to the fellow eyes. In a different article, Lema and colleagues[16] reported that in unilateral keratoconus, the mean of the maximum posterior elevation of the non-keratoconic eyes was similar to that of the normal controls. A similar result was reported for keratometric measurements. They found a significant interocular difference in corneal curvature in patients with unilateral keratoconus (51.45 ± 6.65 D in the affected eyes and 43.58 ± 1.71 D in the contralateral eyes). The maximum simulated keratometry for the non-involved eyes (median 44.52 D) was reported to be the same as the measurements of the normal subjects (median 44.07 D).[16] We found a maximum of 2.5 D interocular difference in both mean keratometric and maximum keratometric readings. This value is much higher than the intersessional difference for the Pentacam measurements. Chen and Lam,[17] reported the coefficient of repeatability (COR) of ± 0.21 D for intersessional measurements of the Pentacam simulated keratometry. Similar to our results, Myrowitz, Kouzis and O'Brien[12] found a maximum interocular difference of 2.05 D in SimK measurements of 121 normal candidates for refractive surgery evaluated by Orbscan. Thus, it may be concluded that a marked interocular difference in posterior elevation and keratometric measurements outside the normal range should prompt the clinician to search for other parameters suggesting subclinical keratoconus.

Progressive thinning of the cornea is a well-known feature of the pathophysiology of keratoconus.[18] Lema, Suárez and

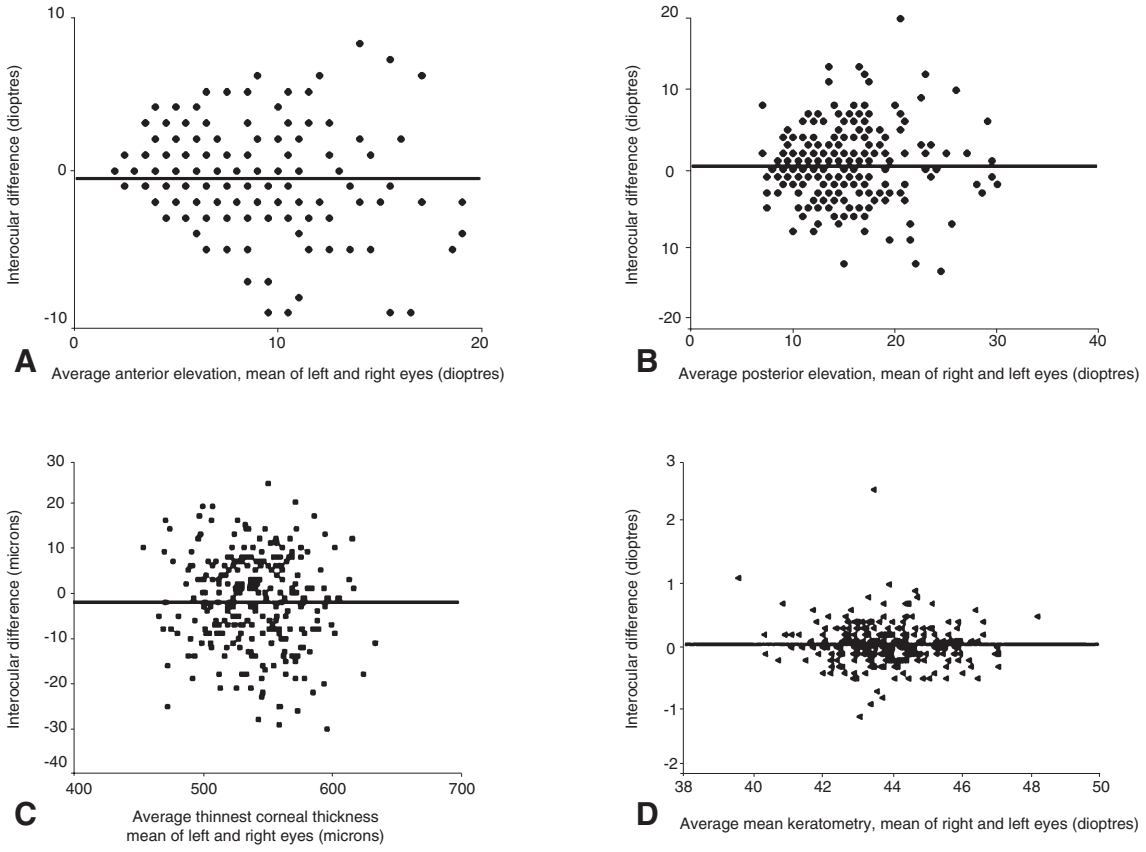

Figure 2. The Bland and Altman plots show: (A) Even distribution for average maximum anterior elevation. (B) average maximum posterior elevation. (C) Average thinnest corneal thickness. (D) Average mean keratometry.

	Mean	Median	Range	25th-95th percentile
Maximum anterior elevation (μm)	2.17	2	0–21	1–6
Maximum posterior elevation (μm)	3.62	3	0–31	1–11
Minimum corneal thickness (μm)	8.42	7	0–30	3–21
3 mm corneal volume (mm^3)	0.06	0.1	0–0.4	0–0.2
5 mm corneal volume (mm^3)	0.19	0.2	0–1.2	0.1–0.5
7 mm corneal volume (mm^3)	0.44	0.4	0–2.9	0.2–1.1
Mean keratometry (D)	0.24	0.2	0–2.5	0.1–0.7
Steepest keratometry (D)	0.39	0.3	0–2.5	0.1–1.2

μm: micrometres, mm: millimetres, D: dioptres.

Table 2. Interocular difference in Pentacam measurements

Díez-Feijoo[10] reported a significant difference in corneal thickness measurements between two eyes in patients with unilateral keratoconus. Lema and colleagues[16] also found a significant difference between the thinnest pachymetric measurements of fellow eyes of patients with unilateral keratoconus and control eyes. We found a maximum interocular difference of 30 μm in thinnest pachymetric measurements. Our findings are in accordance with those of the recent study of intrasubject corneal pachymetric measurement in a refractive surgery population.[11] Using Pentacam, Khachikian, Belin and Ciolino[11] found a difference in average pachymetry of 9.0 μm between fellow eyes at the thinnest region. Based on their results, individuals with a difference

greater than 33.9 µm thinnest pachymetry represent less than 0.5 per cent of the population. They suggested that large amounts of asymmetry may prompt repeat testing to confirm measurements and calculations prior to surgery. Similarly, Myrowitz, Kouzis and O'Brien[12] found a mean difference in the thinnest corneal thickness of eight microns. In their results, only seven patients (5.7 per cent) had a difference over 20 µm and the remaining 114 were 20 µm or less. Our findings show that individuals with a greater than 29.6 µm thinnest pachymetric difference represent less than 0.5 per cent of the population and individuals with a difference greater than 21 µm represent less than five per cent.

Ambrosio and associates[19] reported that the measurements of corneal volume in eyes with mild to moderate keratoconus were significantly lower than those in a group of normal eyes. According to the authors, keratoconic corneas had a mean volume 0.94 mm^3 less than the mean volume in normal eyes. Similar to this report, Emre, Doganay and Yologlu[20] showed that measurements of corneal volume in the control group were statistically significantly different from those in the keratoconic group.

We used a single examination for each eye for comparison. While the Pentacam instrument has been found by a number of studies to provide reliable measures,[15,21,22] some recent studies have also noted that for the most reliable corneal measurements with the Pentacam, the mean of three or four scans should be used.[17] Although a small part of the interocular difference may be attributed to the intercessional variability, a large degree of asymmetry outside the normal range of interocular difference should alert the clinician to repeat the examinations and carefully search for other parameters, which may help in predicting postoperative ectasia. To elucidate better the significance of interocular asymmetry, a large study comparing corneal measurements in keratoconic eyes with normal subjects is required.

FINANCIAL INTEREST

None of the authors has any financial interest in the subject matter of this paper.

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