Corneal elevation indices and pachymetry values of Saudi myopes using scheimpflug imaging

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Original Article

Corneal elevation indices and pachymetry values of Saudi myopes using scheimpflug imaging

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ABSTRACT

الأهداف: معرفة قيم سماكة وارتفاع القرنية لذوي أصحاب قصر النظر في المملكة ، ودراسة الاختلاف بين هذه القيم في مجموعات فرعية من هذه الفئة المستهدفة.

المنهجية: تم تحليل الخرائط الطبوغرافية للبنتاكام للعين اليمنى للمرضى الذين زاروا مركز الحكماء لطب و جراحة العيون في مدينة الرياض بالمملكة العربية السعودية في الفترة ما بين يناير 2009 وديسمبر 2015 بأثر رجعي. تم تقسيم المرضى إلى ثلاث فئات بناء على درجات قصر النظر : بسيط (-0.25 إلى- 2.75ديوبتر) ، متوسط (-3.00 إلى–5.75ديوبتر) ، وشديد (أكثر من أو يساوي - 6.00 ديوبتر). تم تقسيم المرضى الذين يعانون من لا بؤرية إلى مجموعتين: لا بؤرية حسرية (أكثر من أو يساوي – 1.00 ديوبتر) وقصر نظر بسيط (أقل من – 1.00ديوبتر).

النتائج: تتكون عينتنا من 1,276 مريضا، 838 (65.7%) يعانون من قصر النظر البسيط و 438 (34.3%) يعانون من لا بؤرية حسرية. قيم التصوير الطبغوغرافي للمجموعة التي تعاني من قصر النظر كالتالي: ارتفاع القرنية الأمامي في القمة 2.60±1.48 ، الإرتفاع في المنطقة الأقل سمكا 2.56±1.68، الإرتفاع الخلفي للقرنية في القمة 3.67±3.58، الإرتفاع في المنطقة الأقل سمكا4.92±3.81، سمك القرنية المركزي 550.09±34.29، سمك القرنية في القمة 550.73±34.64، أقل سمك للقرنية 546.30±34.61. كانت جميع قياسات البنتاكام بإستثناء الإرتفاع الخلفي للقرنية في القمة والمنطقة الأقل سمكاً ذات دلالة إحصائية عبر مجموعات قصر النظر البسيط واللابؤرية الحسرية ($p<0.05$). أظهرت مقارنة قصرالنظر البسيط إلى المتوسط إختلافا كبيرا في ارتفاع القرنية الأمامي عند القمة ($p=0.037$)، في حين أن مقارنة قصر النظر البسيط والشديد كشفت أن ارتفاع القرنية الخلفي في القمة و المنطقة الأقل سمكا بالإضافة إلى سمك القرنية المركزي و في القمة وفي المنطقة الأقل سمكاً تختلف اختلافا هاما من الناحية الإحصائية ($p<0.05$).

الخاتمة: مؤشرات ارتفاع وسمك القرنية للأفراد الذين يعانون من قصر النظر في السعودية قابلة للمقارنة مع قواعد البيانات الدولية فقط في بعض المؤشرات و القيم.

Objectives: To report the corneal elevation and thickness values for Saudi myopes and to evaluate the differences between these parameters in subgroups of this target population.

Methods: Pentacam corneal topographic maps of the right eyes of patients visiting Al-Hokama Eye Clinic, Riyadh, Saudi Arabia, a tertiary eye center between January 2009 and December 2015 were retrospectively analyzed in this cross-sectional study. The patients were grouped into 3 categories based on their spherical readings: mild (-0.25 to -2.75D), moderate (-3.00 to -5.75D), and severe (≥-6.00D). Furthermore, patients with cylindrical readings of ≥-1.00 diopter were categorized as having myopic astigmatism, whereas those with less than -1.00 cylindrical diopter were categorized as having simple myopia.

Results: Our sample was comprised of 1,276 patients; 838 (65.7%) had simple myopia and 438 (34.3%) had myopic astigmatism. The values for the whole myopic group were as follows: anterior corneal elevation (AE) at the apex= 2.60±1.48 (standard deviation), thinnest AE= 2.56±1.68, posterior elevation (PE) at the apex= 3.67±3.58, thinnest PE= 4.92±3.81, central pachymetry= 550.09±34.29, apical pachymetry=550.73±34.64, and thinnest pachymetry= 546.30±34.61. All of the measurements, except the apical PE and thinnest PE, were statistically significant across the simple and myopic astigmatism groups ($p<0.05$). Comparing the mild to moderate myopia groups revealed a significant difference in the apical AE ($p=0.037$). Moreover, the comparison between the mild and severe myopia groups revealed that the apical PE and the thinnest PE, as well as the central, apical, and thinnest pachymetry values were statistically significantly different ($p<0.05$).

Conclusion: The corneal elevation indices and thicknesses specific to the Saudi myopes were found to be comparable to the international databases in terms of the elevation and thickness in some of the parameters.

Keywords: myopia, myopic astigmatism, refractive error, corneal topography, pachymetry

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Myopia is a condition that affects a wide range of individuals in the global community, and it has been increasing in prevalence, particularly in developing countries.[1,2] The prevalence of myopia has been reported as 25% among the United States population, up to 59% in school-age children in Australia, and as high as 80% among high school students in Beijing, China.[1,3,4] However, there is a lack of data regarding the prevalence of refractive errors, such as myopia, among the Saudi population. The milder form of myopia is primarily regarded as a benign condition that requires those afflicted to wear corrective spectacles, and it has inconsequential effects on the wellbeing of the eyes and patient's quality of life. However, high myopia, which is identified as a refractive error of -6.00 diopters or more, holds more bearing in the anatomical morphology of the eye and the overall ocular morbidity. It is commonly associated with thinning and lattice degeneration of the retina, focal sub-retinal neovascularization, higher incidences of retinal detachment, dense nuclear cataracts, and glaucoma.[1] Because myopia is a condition that has been increasing in frequency in civilized societies, those afflicted commonly opt to acquire corrective surgery.[1]

Preoperative corneal tomography (namely, Pentacam) provides certain clinical information, such as the corneal thickness and elevation, and it is an essential study to ensure the suitability of interventional procedures and to establish a baseline for postoperative monitoring.[5-8] Obtaining corneal thickness measurements is universally regarded as the main stay preoperative study determining the suitability of refractive surgery.[6,9,10] Therefore, it is highly recommended to establish population-specific normative values for these indices whenever possible.[10,11] Reports in the literature have previously explored the relationships between the refractive status and the anterior segment parameters, particularly the corneal thickness, with varying results. Ucakhan et al,[5] studied the corneal topography measurements of 215 patients with various refractive errors using the Pentacam Scheimpflug system (OculusOptikgeräte GmbH, Wetzlar, Germany), and the results showed that the highly myopic eyes had significantly lower mean corneal thicknesses in addition to higher anterior chamber depths and anterior chamber volumes. Moreover, Chang et al,[12] further substantiated the association between myopia and thinner corneas in their study, despite the fact that the results did not reach statistical significance. However, Pedersen et al,[13] found that the central corneal thickness was not systematically altered in myopia. This was further corroborated in another prospective study conducted by Al-Mezaine et al,[14] who compared the central corneal thicknesses of 982 myopic eyes and 158 emmetropic eyes. They found no difference between the emmetropic and myopic eyes, and the authors concluded that the cornea was not involved in myopic progression.[14] Due to the ongoing debate involving the relationship between the myopic refractive status and the corneal topography and the contrasting results, undertaking a study to report the normal anterior segment values of a population in the Kingdom of Saudi Arabia (KSA) has become important.

Various technologies are being used today to evaluate the corneal topography. One popular imaging modality is the oculus pentacam.[15] This instrument utilizes non-invasive Scheimpflug imaging technology to acquire the anterior segment measurements that are pertinent to clinicians.

In KSA, there is an insufficient data on corneal topographic and anterior segment spatial values for the Saudi population. Therefore, it seems pertinent to benchmark and establish the normative values of these parameters for Saudi myopes. In this study, we aimed to report the corneal elevation, corneal thickness, corneal curvature, and anterior segment parameter values in different degrees and subtypes of myopia using the Scheimpflug imaging modality within the Saudi population. In doing so, we hoped to establish a reliable reference range unique to both the Pentacam machine and the Saudi population in order to clarify the relationship between the anterior segment spatial values and myopia, as well as to elaborate on the possible differences found in the different subtypes and degrees of this refractive condition. This will aid practitioners in distinguishing normal from abnormal topographic findings pertaining to this population and in screening for refractive surgery.

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Methods. This study was a retrospective non-comparative cross-sectional review of the Pentacam Scheimpflug corneal topographic maps of 1,276 myopic Saudi patients visiting the Al-Hokamah Eye Clinic, Riyadh, KSA. The data gathered came from the Pentacam 4maps' refractive corneal topography display pertaining to patients from different cities and provinces across the Kingdom between January 2009 and December 2015. The elevation data used to calculate the reference surface (best fit sphere, [BFS]) was gathered from a fixed 8.0-mm in diameter zone that was centered on the corneal apex, with no data extrapolation, where the corneal elevation was then measured from the BFS.

The inclusion criteria were set as following: all of the participants should be Saudi citizens over 18 years of age at the time of the examination. The data from patients with previous histories of refractive surgery, trauma, corneal scarring, corneal dystrophy, or corneal transplants were excluded from the study. This study was ethically approved by the Institutional Review Board of Al-Hokamah Eye Clinic and adheres to the tenets of the Declaration of Helsinki.

Categories based on refractive errors. The manifest refractive errors for all of the subjects were recorded, and the patients were sub-divided and grouped into one of 3 categories according to their spherical (SPH) readings: mild (SPH= -0.25 to -2.75 D), moderate (SPH= -3.00 to -5.75 D), and severe (SPH≥ -6.00 D) Furthermore, all of the patients with cylindrical readings of -1.00 D more were categorized as having myopic astigmatism, and those with a cylindrical reading of less than -1.00 D were categorized as having simple myopia.

Details of the Pentacam device. This device records anterior segment spatial values with the use of 2 cameras. The first is situated in the center to detect the pupil size and orientation and to control fixation, and the second rotates 360 degrees to obtain up to 50 images of the anterior segment from the cornea to the lens in approximately 2 seconds. This technique provides up to 25,000 true elevation points for the front and back surfaces of the cornea, which, in turn, allows for an extrapolation of the pachymetry, corneal topography, anterior and posterior corneal curvature, and astigmatism.[5,16] The data provided by the Pentacam is considered to be clinically relevant, accurate, and highly reproducible, and it aids clinicians not only in screening candidates for refractive surgery, but it also provides for a wide array of other clinical applications, such as the intraocular lens calculation and glaucoma screening. Moreover, it works to evaluate the extent and progression of ectatic corneal conditions, such as keratoconus, over the long term.[5,15-17]

Outcome measures. The main outcome measures were the anterior corneal elevation (AE) and posterior corneal elevation (PE) indices within 5-mm and 8-mm radius zones, as well as the apex and thinnest point, central corneal thickness, corneal thickness at the apex and thinnest point, front and back corneal curvatures, anterior chamber volume (ACV), and anterior chamber depth (ACD). All of these underwent descriptive analyses. All of the variables were summarized and reported across the study cohorts using descriptive statistics.

Although the data of both eyes were collected (1,252 OD and 1,252 OS), only the right eye of each individual was included in the final analysis. This is primarily due to the high rate of symmetry found in fellow eyes in terms of corneal elevation and pachymetry readings.[18]

Statistical analysis. The data were collected using a specifically designed data collection sheet. The data were then managed and cleaned for the analysis. A descriptive analysis was conducted in which the categorical variables were presented in the form of frequencies and percentages. The continuous variables were summarized and reported as means and standard deviations (SDs), and they were compared statistically using the Mann-Whitney U-test. The test of normality (Shapiro) showed that the population data was not normally distributed and it was represented in the form of medians and 25-75% quartiles. The *p*-value was calculated for the medians using the Mann-Whitney U-test. A probability of less than 5% ($p<0.05$) was considered to be statistically significant. The mild, moderate, and severe myopia groups underwent further multiple comparison analyses using the Kruskal-Wallis H test to elaborate on the specific statistical differences found among all 3 of the groups. The statistical analyses was performed by the Statistical Package for Social Sciences for Windows, version 22.0 (IBM Corp, Armonk, NY, USA).

Results. Our total sample consist of 1,276 patients (2,504; 1,252 OD and 1,252 OS) consisting of 464 (36.4%) males and 812 (63.6%) females. The patients had a mean (SD) age of 25.4±6.11 years old, with a range of 18-61 years.

For the individual groups, 838 (65.7%) patients had simple myopia; 288 (34.4%) males and 550 (65.6%) females. There were 438 (34.3%) patients in the myopic astigmatism group; 174 (39.7%) males and 262 (59.8%) females.

Table 1 summarizes the data collected from all of the myopic patients included in the current study. The normal distribution curves for each of the PEs at the 5 and 8-mm radius zones, the PE at the apex, and the PE at the thinnest point are displayed in **Figure 1**. These showed that the majority of our myopic population fell within ±2 SDs of the mean.

When comparing both the simple and myopic astigmatism groups in terms of the corneal indices, keratometry, and anterior segment spatial parameters, all of the Pentacam measurements, except the apical and thinnest PEs, showed statistically significant differences, ($p<0.05$) **(Table 2)**.

Table 1 - Descriptive statistics of 1252 patients.

Variables	Median	Mean±SD	Min	Max
Age (year)	24.00	25.39±6.11	18.00	61.00
Sphere (Di)	-2.75	-3.21±1.95	-17.50	-0.25
Cylinder (Di)	-0.50	-0.81±0.81	-5.75	0.00
AE 5mm (μm)	3.00	3.49±1.41	-2.00	9.00
AE 8mm (μm)	5.00	4.97±2.31	1.00	26.00
AE apex (μm)	3.00	2.60±1.48	-6.00	9.00
AE thinnest (μm)	3.00	2.56±1.68	-6.00	9.00
PE 5mm (μm)	6.00	6.34±3.05	-1.00	19.00
PE 8mm (μm)	10.00	10.83±4.00	-2.00	33.00
PE Apex (μm)	3.00	3.67±3.58	-6.00	21.00
PE Thinnest (μm)	5.00	4.92±3.81	-6.00	18.00
Front K1 (Di)	42.70	42.72±1.43	37.50	52.50
Front K2 (Di)	43.80	43.82±1.58	38.80	54.60
Back K1 (Di)	-6.10	-6.07±0.23	-6.90	-5.30
Back K2 (Di)	-6.40	-6.37±0.27	-7.20	-5.40
Central pachymetry (μm)	550.00	550.09±34.29	427.00	677.00
Apical pachymetry (μm)	551.50	550.73±34.64	418.00	680.00
Thinnest pachymetry (μm)	547.00	546.30±34.61	422.00	677.00
ACV (mm^3)	202.00	203.00±31.43	98.00	315.00
ACD (mm)	3.26	3.25±0.26	2.30	4.02

AE: anterior elevation, PE: posterior elevation, ACV: anterior chamber volume, ACD: anterior chamber depth, SD: standard deviation.

Moreover, comparing the mild (<-3.0 D) to the moderately (-3 to -5.75 D) myopic eyes showed that the statistically significant differences detected between the 2 groups were in the apical AE (p=0.037) and the front and back keratometry measurements (p<0.001) where the mildly myopic eyes had slightly lower values compared to the moderately myopic eyes (Table 3). Comparing the elevation, thickness, and anterior chamber spatial values of the moderately (-3 to -5.75 D) to the highly (≥6.0 D) myopic eyes demonstrated that the 2 groups were similar, except for the ACD, which was statistically significantly deeper in the moderately myopic group (p=0.037) (Table 4). Additionally, comparing the mild (<-3.0 D) to the highly myopic (≥6.0 D) eyes revealed that the apical PE (p=0.021) and thinnest PE (p=0.011) measurements, as well as the central, apical, and thinnest pachymetry measurements, and the ACD (p<0.005) were statistically significantly different, whereas the high myopes had overall thicker corneas and lower ACD values (Table 5).

Discussion. Of the many methods used for obtaining corneal topography data, one machine that

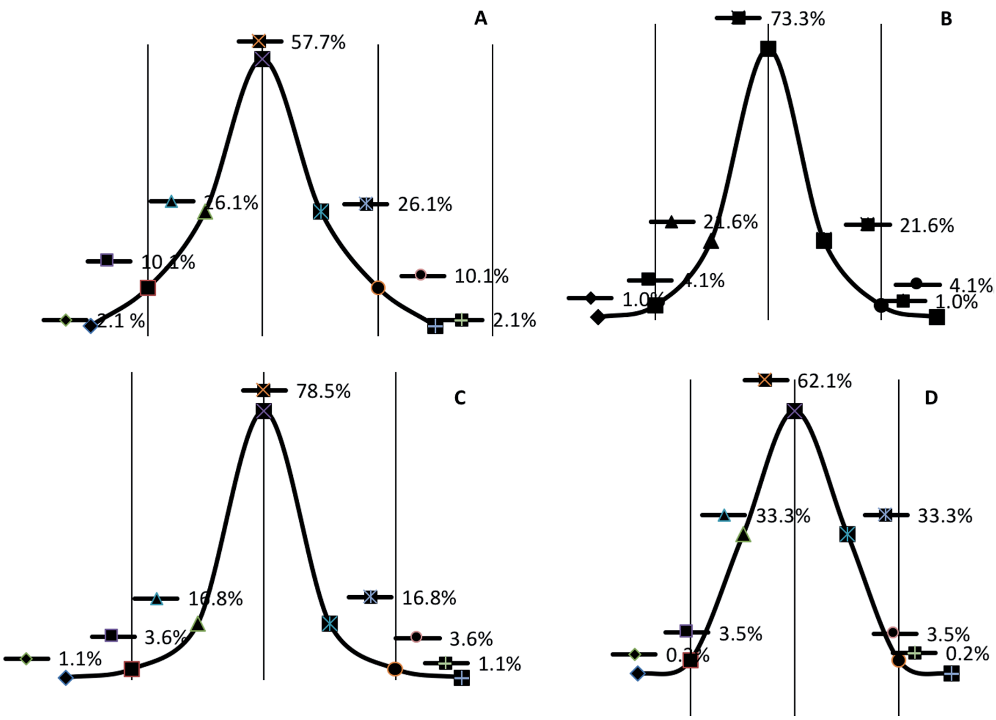

Figure 1 - Standard normal distribution curve for posterior elevation at **A)** 5mm, **B)** 8mm, **C)** apex, and **D)** the thinnest posterior elevation.

Table 2 - Comparing indices between the simple myopic and myopic astigmatism groups (N=1252).

Variables	Simple myopia (n=848)			Myopic astigmatism (n=404)			*P*-values	
	Mean±SD	Median	(25-75%) Quartiles	Mean±SD	Median	(25-75%) Quartiles	Mean	Median
Age (years)	25.19±5.85	24.00	(20.00-28.00)	25.82±6.62	24.00	(21.00-29.00)	0.093	0.226
Sphere (Di)	-3.16±1.82	-2.75	(-4.00 - -2.00)	-3.31±2.20	-2.75	(-4.50 - -1.50)	0.216	0.946
Cylinder (Di)	-0.38±0.29	-0.50	(-0.50-0.00)	-1.70±0.84	-1.50	(-2.00 - -1.00)	<0.001*	<0.001*
AE 5mm (µm)	3.35±1.34	3.00	(2.00-4.00)	3.79±1.51	4.00	(3.00-5.00)	<0.001*	<0.001*
AE 8mm (µm)	4.20±1.71	4.00	(3.00-5.00)	6.60±2.56	6.00	(5.00-8.00)	<0.001*	<0.001*
AE apex (µm)	2.51±1.42	2.00	(2.00-3.00)	2.77±1.61	3.00	(2.00-4.00)	0.004*	0.003*
AE thinnest (µm)	2.49±1.62	2.00	(2.00-3.00)	2.72±1.79	3.00	(2.00-4.00)	0.024*	0.025*
PE 5mm (µm)	6.18±3.00	6.00	(4.00-8.00)	6.67±3.12	6.00	(4.00-9.00)	0.007*	0.005*
PE 8mm (µm)	9.85±3.42	10.00	(7.00-12.00)	12.89±4.35	12.00	(10.00-16.00)	<0.001*	<0.001*
PE Apex (µm)	3.59±3.55	3.00	(1.00-6.00)	3.85±3.65	3.00	(1.00-6.00)	0.229	0.207
PE thinnest (µm)	4.81±3.77	4.00	(2.00-7.00)	5.14±3.91	5.00	(2.00-8.00)	0.157	0.160
Front K1 (Di)	42.84±1.43	42.80	(41.9-43.80)	42.47±1.41	42.50	(41.50-43.40)	<0.001*	<0.001*
Front K2 (Di)	43.61±1.49	43.60	(42.6-44.50)	44.26±1.69	44.20	(43.20-45.30)	<0.001*	<0.001*
Back K1 (Di)	-6.08±0.24	-6.10	(-6.2 - 5.90)	-6.04±0.23	-6.00	(-6.20 - -5.90)	0.003*	0.007*
Back K2 (Di)	-6.34±0.26	-6.30	(-6.5 - -6.2)	-6.43±0.28	-6.50	(-6.60 - -6.20)	<0.001*	<0.001*
Central pachymetry(µm)	551.69±33.22	551	(529-575)	546.73±36.24	550	(520-572.75)	0.017*	0.028*
Apical pachymetry (µm)	552.43±33.52	552	(529-575.75)	547.17±36.68	550	(520-573)	0.012*	0.026*
Thinnest pachymetry (µm)	547.89±33.60	548	(525-571)	542.96±36.46	545	(515-569)	0.019*	0.030*
ACV (mm³)	204.49±31.46	204	(182.2-226)	199.89±31.19	199	(179-221)	0.015*	0.020*
ACD (mm)	3.26±0.26	3.27	(3.10-3.45)	3.21±0.27	3.22	(3.03-3.38)	0.001*	0.001*

SD: standard deviation, AE: anterior elevation, PE: posterior elevation, ACV: anterior chamber volume, ACD: anterior chamber depth, *statistically significant at 5% level of significance

Table 3 - Comparing the mild (<-3.00) and moderate (-3.00 to -5.75) myopia groups (N=1132).

Variables	Mild myopia (n=644)		Moderate myopia (n=488)		*P*-values
	Mean±SD	Median	Mean±SD	Median	
Age (years)	25.27±5.84	24.00	25.34±6.34	24.00	0.861
Sphere (Di)	-1.80±0.67	-1.75	-4.03±0.78	-4.00	<0.001*
Cylinder (Di)	-0.81±0.81	-0.50	-0.73±0.74	-0.50	0.218
AE 5mm (µm)	3.45±1.43	3.00	3.52±1.33	3.00	0.343
AE 8mm (µm)	5.05±2.42	5.00	4.84±2.11	4.00	0.297
AE Apex (µm)	2.52±1.54	2.00	2.67±1.41	3.00	0.037*
AE thinnest (µm)	2.54±1.73	2.00	2.56±1.64	3.00	0.648
PE 5mm (µm)	6.42±3.14	6.00	6.27±2.90	6.00	0.487
PE 8mm (µm)	11.04±4.20	10.50	10.61±3.84	10.00	0.167
PE apex (µm)	3.87±3.67	3.00	3.57±3.50	3.00	0.235
PE thinnest (µm)	5.14±3.93	5.00	4.81±3.64	4.50	0.219
Front K1 (Di)	42.54±1.40	42.50	42.89±1.46	42.90	<0.001*
Front K2 (Di)	43.64±1.65	43.60	43.94±1.49	43.90	<0.001*
Back K1 (Di)	-6.04±0.24	-6.00	-6.09±0.23	-6.10	<0.001*
Back K2 (Di)	-6.34±0.27	-6.30	-6.40±0.26	-6.40	<0.001*
Central pachymetry(µm)	547.77±33.62	548.00	551.70±35.46	552.50	0.079
Apical pachymetry (µm)	548.67±34.41	549.00	552.11±35.40	553.00	0.122
Thinnest pachymetry (µm)	543.80±34.09	544.00	548.02±35.53	548.00	0.060
ACV (mm³)	202.84±31.76	202.00	204.52±30.40	202.00	0.656
ACD (mm)	3.25±0.26	3.26	3.26±0.25	3.26	0.978

SD: standard deviation, AE: anterior elevation, PE: posterior elevation, ACV: anterior chamber volume, ACD: anterior chamber depth. *statistically significant at 5% level of significance

Table 4 - Comparing the moderate (-3.00 to -5.75) and severe (greater than or equal to -6.00) myopia groups (N=608).

Variable	Moderate myopia (n=488)		Severe myopia (n=120)		*P*-values
	Mean±SD	Median	Mean±SD	Median	
Age (years)	25.34±6.34	24.00	26.22±6.55	24.00	0.169
Sphere (Di)	-4.03±0.78	-4.00	-7.45±1.87	-6.88	<0.001*
Cylinder (Di)	-0.73±0.74	-0.50	-1.10±1.04	-0.75	<0.001*
AE 5mm (µm)	3.52±1.33	3.00	3.59±1.63	3.00	0.635
AE 8mm (µm)	4.84±2.11	4.00	5.11±2.46	5.00	0.373
AE Apex (µm)	2.67±1.41	3.00	2.68±1.51	2.00	0.253
AE Thinnest (µm)	2.56±1.64	3.00	2.72±1.54	2.00	0.981
PE 5mm (µm)	6.27±2.90	6.00	6.15±3.18	6.00	0.552
PE 8mm (µm)	10.61±3.84	10.00	10.57±3.43	10.00	0.763
PE Apex (µm)	3.57±3.50	3.00	2.99±3.36	3.00	0.111
PE Thinnest (µm)	4.81±3.64	4.50	4.14±3.78	4.00	0.060
Front K1 (Di)	42.89±1.46	42.90	43.04±1.39	42.90	0.363
Front K2 (Di)	43.94±1.49	43.90	44.29±1.49	44.30	0.020*
Back K1 (Di)	-6.09±0.23	-6.10	-6.10±0.22	-6.10	0.792
Back K2 (Di)	-6.40±0.26	-6.40	-6.43±0.25	-6.40	0.370
Central pachymetry(µm)	551.70±35.46	552.50	555.98±32.10	556.50	0.206
Apical pachymetry (µm)	552.11±35.40	553.00	556.16±32.11	557.00	0.231
Thinnest pachymetry (µm)	548.02±35.53	548.00	552.73±32.53	553.00	0.163
ACV (mm^3)	204.52±30.40	202.00	197.70±33.38	199.50	0.083
ACD (mm)	3.26±0.25	3.26	3.19±0.29	3.22	0.037*

SD - standard deviation, AE - anterior elevation, PE - posterior elevation, ACV - anterior chamber volume, ACD - anterior chamber depth. *statistically significant at 5% level of significance.

Table 5 - Comparing the mild (less than -3.00) and severe (greater than or equal to -6.00) myopia groups (n=764).

Variable	Mild myopia (n=644)		Severe myopia (n=120)		*P*-values
	Mean±SD	Median	Mean±SD	Median	
Age (years)	25.27±5.84	24.00	26.22±6.55	24.00	0.176
Sphere (Di)	-1.80±0.67	-1.75	-7.45±1.87	-6.88	<0.001*
Cylinder (Di)	-0.81±0.81	-0.50	-1.10±1.04	-0.75	0.002*
AE 5mm(µm)	3.45±3.00	3.00	3.59±1.63	3.00	0.931
AE 8mm (µm)	5.05±2.42	5.00	5.11±2.46	5.00	0.789
AE apex (µm)	2.52±1.54	2.00	2.68±1.51	2.00	0.925
AE thinnest (µm)	2.54±1.73	2.00	2.72±1.54	2.00	0.731
PE 5mm (µm)	6.42±3.14	6.00	6.15±3.18	6.00	0.317
PE 8mm (µm)	11.04±4.20	10.50	10.57±3.43	10.00	0.548
PE apex (µm)	3.87±3.67	3.00	2.99±3.36	3.00	0.021*
PE thinnest (µm)	5.14±3.93	5.00	4.14±3.78	4.00	0.011*
Front K1 (Di)	42.54±1.40	42.50	43.04±1.39	42.90	0.001*
Front K2 (Di)	43.64±1.65	43.60	44.29±1.49	44.30	<0.001*
Back K1 (Di)	-6.04±0.24	-6.00	-6.10±0.22	-6.10	0.004*
Back K2 (Di)	-6.34±0.27	-6.30	-6.43±0.25	-6.40	<0.001*
Central pachymetry(µm)	547.77±33.62	548.00	555.98±32.10	556.50	0.016*
Apical pachymetry (µm)	548.67±34.41	549.00	556.16±32.11	557.00	0.030*
Thinnest pachymetry (µm)	543.80±34.09	544.00	552.73±32.53	553.00	0.009*
ACV (mm^3)	202.84±31.76	202.00	197.70±33.38	199.50	0.142
ACD (mm)	3.25±0.26	3.26	3.19±0.29	3.22	0.037*

SD: standard deviation, AE: anterior elevation, PE: posterior elevation, ACV: anterior chamber volume, ACD: anterior chamber depth. *Statistically significant at 5% level of significance is gaining increasing popularity among practitioners is the Pentacam Scheimpflug.[17] Many previous studies have reported the performance of this machine in obtaining and analyzing corneal topographic maps. It is considered to be advantageous to utilize analytical technology that is able to detect subclinical ectatic changes in the corneal topography, enabling specialists to diagnose certain conditions, such as formefruste keratoconus, and refine treatment strategies.[16,17]

Most of the previously published data on the normal values of the anterior segment parameters have been defined using data from subjects within a limited geographical area and using other modalities, such as the Orbscan (Bausch & Lomb, Orbtek Inc., Salt Lake City, UT, USA).[10,11,18-20] These are used to establish normal cutoff values for important indices, such as the corneal elevation and thickness, which are pertinent to the clinical approach in refractive surgery and the diagnostic criteria of corneal ectasias. Moreover, numerous studies have compared the accuracy of the Orbscan to the Pentacam in providing corneal topographic data, and they have found both to individually provide highly repeatable and dependable results, particularly regarding the corneal thickness and PE, but the values are not interchangeable between these devices.[20,21] Additionally, the Pentacam has been proven to provide specialists with corneal thickness values highly correlated to those provided by ultrasound pachymetry, which is generally regarded to be the gold standard investigation for the corneal thickness.[22] This allows us to conclude that establishing a reference range for normal eyes, especially those with an abnormal refractive status (like myopia), unique to the Pentacam is preferable.

Studies in the literature have reported topographic findings among those individuals with refractive errors with varying results.[5,12-14] In our study findings, we reported that the spatial and topographic parameters of all of the Saudi myopes were comparable in terms of the elevation, thickness, and ACD to international and established databases, but they differed in others. Feng et al,[10] published a series of international multicenter cross-sectional studies examining the corneal elevation, central corneal thickness, and ACD of normal eyes, including those with different types of myopia, in order to study the applicability of the current normative cutoff values for these parameters.[11,19] Our series showed that the median AEs and PEs at the apex and the thinnest points were 1-2 degrees higher than those reported in their study, whereas our upper limit values did not correlate to international values, and they were relatively higher.[11] Similarly, the upper limits of the apical AE and thinnest AE values together with the apical PE value were 2-3 degrees higher in our cohort of patients when compared to those reported by Kim et al,[23] (max apical AE=4.00, thinnest AE=6.00, and max apical PE=6 versus max apical AE=9.00, thinnest AE=9.00, and max apical PE=21 in our cohort). Nevertheless, the PE range at the thinnest point in our study (-6.00-18 μm) was equivalent to that reported by Kim et al.[23] The upper limit values of the PE are generally used as clinical screening threshold values for corneal ectasias. The higher values within our sample when compared to the other studies could suggest that internationally accepted reference values do not necessarily apply to our population.[11] Additionally, it is noteworthy to mention that the study conducted by Feng et al,[19] included 555 adult subjects recruited from centers in different countries, none of which were located in KSA. Therefore, the higher corneal elevation values observed in our cohort could be partly attributed to the variations between different ethnic groups, and this further highlights the importance of establishing a normative database specific for each population.

The results obtained from our study cohort suggest that greater than 95% of the normal myopic corneas (2 SDs) had PE values as follows: <12.4 μm at 5 mm, <18.8 μm at 8 mm, <10.8 μm at the apex, and <12.5 μm at the thinnest point. Therefore, when screening Saudi subjects for refractive surgery, those with PE values exceeding these cutoffs should receive further evaluations for corneal ectasias.

In addition, the Saudi myopes exhibited higher mean thinnest (546 μm) and apical (551 μm) corneal thickness measurements when compared to the reported international means thinnest of 536 μm and apical of 539 μm.[10] Furthermore, the mean ACD in our sample was higher than the mean reported by Feng et al,[19] (3.25 mm - 3.11 mm), but it fell within the normal variations recorded for numerous population groups. Likewise, higher mean corneal thickness and ACD values were observed in Arabs compared to South Asian eyes in a study conducted by Parkash et al,[24] who looked at the differences in the anterior segment measurements between these 2 groups. Evaluating the differences in these parameters between the various Arab countries would be an interesting area for future studies.

We reported differences between the simple myopia and myopic astigmatism groups within our sample, in which we found statistically significant differences in the AE, corneal thickness, ACD, and ACV. The simple myopes showed a trend toward lower elevation values but higher pachymetry, ACD, and ACV values when compared to the astigmatic patients. Similarly, the PEs at the apex and the thinnest point also exhibited tendencies toward lower values in the simple myopic group when compared to the myopic astigmatism group, although the results did not reach a statistical significance level (p>0.05). These findings correspond with those reported by Ucakhan et al [5] and Hashemi et al.[15] The higher elevation values in the astigmatic eyes may be attributed to the shape of the astigmatic band in the cornea; therefore, using the best fittoric ellipsoid shape instead of the BFS is recommended, and it may help to eliminate the effects of astigmatism on elevation maps.[15]

There is an ongoing debate on the relationships between the varying degrees of myopia and the topography findings.[5,15] A topographic analysis of high myopia in relation to the corneal thickness, in particular, has been thoroughly explored in the scientific literature.[5,13-15] In our study, we compared 3 degrees of myopia: mild, moderate, and high. We found no statistically significant differences in any of the parameters recorded when comparing the mild to the moderate groups, with the exception of the apical AE (2.52±1.54 - 2.67±1.41) (p<0.05) together with the front and back keratometry readings. However, comparing the moderate to high myopia values showed statistically signficant higher mean values in the ACD measurements: 3.26±0.26 in the moderate group and 3.19±0.29 in the high myopia group.

When comparing the mild to highly myopic eyes, there was a statistically significant difference in the corneal thickness at the central, apical, and thinnest points, with the highly myopic group exhibiting thicker corneas overall. Interestingly, our central corneal readings among the mildly myopic sample were comparable to those reported by Uçakhan et al,[5] but they differed in that their findings showed that the highly myopic eyes had thinner corneas overall when compared to the mildly myopic eyes. In one large prospective study including 982 myopic eyes, Al-Mezainee et al,[14] found no correlation between the degree of myopia and the central corneal thickness, suggesting that corneal thickness is not altered by the pathogenic process of myopia. Moreover, the ACD was found to be deeper in the mild myopia group when compared to the highly myopic subjects (3.25±0.26 mm, - 3.19±0.29 mm) (p<0.05). These findings are quite comparable to the ACD values reported in these 2 groups by Hashemi et al,[5] but they are in contrast to those reported by Uçakhan et al.[15] We would rationally expect high myopes to have deeper anterior chambers; however, the opposite was observed in this study. This could be explained by the fact that most of the subjects in the high myopia subgroup were supposedly of the refractive type, and this is supported by the higher curvature readings in the high myopia group when compared to the mild and moderate subgroups. Alternatively, the higher ACDs in the mild and moderate myopes may be attributed to an increased axial length, but this measurement was not recorded in our study. However, further studies looking at this relationship can be conducted in the future.

One advantage of this study was the large sample size of myopic subjects when compared to previously published reports exploring corneal topography among those with a myopic refractive status.[5,10-12,15,19,20] This allows us to better reflect the values pertaining to this population, particularly in those with high myopia.[22]

Study limitations. One of the limitations of this study was its retrospective nature, which might imply a selection bias; however, the Al-Hokamah Eye Hospital is a tertiary eye center that receives Saudi patients not only within the capital but also from the periphery of the country.

In conclusion, the corneal elevation indices and pachymetry values specific to Saudi myopes were found to be comparable to the international databases in terms of the elevation and thickness in some parameters only. The novel epidemiological data on the national topographic corneal findings obtained in this study will provide a general estimate of the anterior segment parameter values for Saudi myopes, and they will aid specialists in screening and planning for refractive surgery.

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