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Original Article

COMPARATIVE EVALUATION OF SCHEIMPFLUG TOMOGRAPHY PARAMETERS BETWEEN THIN NON-KERATOCONIC, SUBCLINICAL AND MILD KERATOCONIC CORNEAS

Samaan, Y.[(*)], Ezz Eldawla, M., M Mostafa, E. & Abdellatif, I.
Ophthalmology dept., Faculty of Medicine, Sohag Univ., Egypt

[*]*E-mail: youstinazekry@yahoo.com*

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Abstract

The purpose: *This paper aimed to analyze the keratometric, topometric and pachymetric features of keratoconic suspect and clinical keratoconic eyes from normal thin ones using a Scheimpflug imaging camera.* ***Patient and methods:*** *The study was retrospective and cross-sectional and examined the eyes of candidates seeking refractive surgery at Sohag ophthalmologic Centre. The study included 26 normal subjects with 31 eyes with thin corneas (<480 µm), 14 subjects with 18 eyes diagnosed as keratoconus suspects, and 18 patients with 39 eyes keratoconus (stage 1 and 2). The approval of the ethical committee of Sohag University Hospital was acquired.* ***Results:*** *showed that a possible indicator to distinguish between thin corneas and keratoconus grade 1 & 2 was provided by information on the corneal height, particularly in the case of applying the enhanced ectasia presentation. Parameters from BAD display (e.g., anterior, posterior elevation differences and final D), topographic parameters (such as Q value, KI, K2, Kmean, Kmax and cylinder), topometric parameters (such as KI, IHD, IVA, IHA, CKI, and ISV values), and pachymetric parameters (such as average PPI and ARTmax) helped discriminate the keratoconus cases with the highest prediction accuracy.* ***Conclusions****: This study shows that these eyes may be discriminated efficiently using different tomographic (BAD, pachymetry, and elevation) parameters and topometric indices from Pentacam Scheimpflug tomography. It addresses non-keratoconic thin corneas and keratoconus subclinical or mildly evolved. CT at apex, thinnest CT, IVA, IHD and PE differences tended to be the most appropriate for distinguishing subclinical keratoconic eyes and normal thin corneas.*

Keywords: *Pentacam Scheimpflug tomography, keratoconus*

1. Introduction

One of the ectatic corneal disorders is Keratoconus (KC), which is often bilateral. KC is best known for the progressive thinning in the cornea, causing reduced vision, irregular astigmatism, as well as corneal protrusion [1-4]. Although it is hard to be detected in preclinical or early stages, KC clinical screening is easy because of its findings associated with corneal topography and biomicroscopy, retinoscopy and pachymetry [5-8]. Detecting KC early relates to the care provided clinically to the cases that must not be transferred to the treatment by refractive laser but have to be screened more regarding the ectatic disorders to identify progressive ectasia.

Some studies reported that ectasia development is highly related to age and abnormal topography before operation [9-11]. Subclinical keratoconus indicates the very early preclinical stage of KC that cannot be identified but when using diagnostic examinations, e.g., corneal topography [11]. Nevertheless, diagnosing ScKC exactly is hard to attain because the well-defined threshold standards are lacking. It is mainly difficult because cases with suspected bilateral KC are still suspected until the definitive evolution of KC in one eye. Researchers concluded differences in the topographic corneal pattern between normal and ScKC eyes, as shown by the fellow eyes or families of KC patients or eyes with post LASIK ectasia [12-14]. In the present study, the Scheimpflug camera we employed because of being the most sensitive to detecting KC early forms. This camera utilizes different indices from the evaluation parameters of tomographic thickness and pachymetric data to detect ectatic changes [15-17].

2. Patients and Methods

The study presents a retrospective, cross-sectional study of the eyes of candidates who sought refractive surgery at Sohag Ophthalmologic Centre. It included 26 normal subjects with 39 eyes with thin corneas (<480 µm), 14 subjects with 18 eyes diagnosed as keratoconus suspects, and 18 patients with 31 eyes keratoconus (stages 1 and 2). The approval of the ethical committee of Sohag University Hospital was acquired.

2.1. *Inclusion criteria*

Thin normal cornea: CT < 480 µm; no other clinical finding and no other topometric finding. *Keratoconus suspect KCS:* Keratoconus suspect, as a term, was reserved to express a normal cornea on slit lamp biomicroscopy with at least one sign of keratoconus suspect on tomography: steep keratometric curvature (>47.00 D), abnormal localized steepening, or one of the asymmetric bow-tie patterns, abnormal inferior superior difference keratometry (I-S) between 1.4 and 1.9, oblique cylinder over 1.50 D or clinical keratoconus in the fellow eye.

2.2. *Exclusion criteria*

Any eye with keratoconus stages 3 and 4, former operation in the eye, corneal scarring, trauma, lactation or pregnancy, glaucoma, and reasons for astigmatism other than corneal, namely lenticular astigmatism, e.g., early cataract, lenticonus or lens subluxation. All cases were exposed to full ophthalmological examination, including refraction, tonometry, examination by the slit-lamp, visual field testing, and ophthalmoscopy. The ophthalmologist made the patient look in the different directions to identify the function of the cranial nerves supplying the extra occularmuscles that cause the movement of the eyes Then, the examiner used the Scheimpflug topography (Pentacam HR (Ver 1.16. r:23) to take images of all eyes. A series of 50 Scheimpflug images (meridians) were obtained in the screening process. The patient's eye was aligned along the visual axis using a central fixation light in scotopic condition. Patients were instructed to blink between shots to maintain the moisture of their eyes.

2.3. *Statistic evaluation*

Quantitative data were provided in the form of range, median, standard deviation, and mean, making use of STATA v. 14.2 (Stata Statistical Software: Release 14.2 College Station, TX: StataCorp LP.). The student t-test was used to make comparisons between the means of data. When the data were not usually distributed, the Mann-Whitney test was used to make comparisons between the two groups.

Qualitative data were shown in the form of numbers and percentages and compared using the Chi-square test. Spearman correlations were used to find the correlation between some diameters. The curves of receiver operating characteristic (ROC) were utilized to evaluate the predictive accuracy of the various characteristics in the case of being employed as a test for the detection of eyes with keratoconus. The test's ability to accurately distinguish eyes with and without illness is measured by the area under the receiver operating curves (AUROCs). A flawless test has an area of 1.0, whereas a useless test has an area of 0.5. The parameters with the highest AUROC were analyzed for diagnostic specificity and sensitivity, and cutoff values were established. P value was significant in the case of scoring below 0.05

3. Results

The thin cornea group was made from (39 eyes) and an average age of 30.61 ± 8.77 years, the keratoconus suspect included (18 eyes) with a mean age of 29.83 ± 14.98 years, and keratoconus group grade 1 & 2 (31 eyes) with a mean age of 24.5 ± 6.25 years, tab. (1). We discovered significant variations in terms of K1, K2, K means, and K max, cylinder, and Q value between keratoconus grade 1 & 2 and non-keratoconic thin cornea groups (P value < 0.05), Q value had significant differences comparing thin cornea groups with subclinical keratoconus tab. (2). Further diagnostic characteristics, including posterior and anterior difference, showed significant differences in elevation disparities between the posterior and anterior elevation differences, PPI average, final D, ISV, IVA, KI, as well as IHD (p < 0.05). The disparity between the CT's apex and thinnest CT was significant in all types of keratoconus and thin cornea. The mean difference was 475.28 ± 19.49 μ m in thin cornea eyes, 518.33 ± 36.62 μ m in keratoconus suspect eyes, and 462.52 ± 44.07 in keratoconic grade 1, 2 eyes, correspondingly. Distributing the pachymetric parameters is shown in tab. (2), fig_s. (1-a:c). The parameters from the BAD display of PE difference also were significantly different in all keratoconus groups and thin cornea. The mean distinction was 4.74 ± 3.7 μ m in thin cornea eyes, 11.06 ± 6.66 μ m in keratoconus suspect eyes, and 33.58 ± 11.72 in keratoconic grade 1, 2 eyes, correspondingly. Distributing the BAD display parameters is presented in tab. (3), fig_s. (2-a:e). The parameters from the topometric parameters of ISV, IVA and IHD likewise were noticeably different in all keratoconus groups and thin cornea. The mean distinction of IVA was 0.19 ± 0.18 μ m in thin cornea eyes, 0.29 ± 0.11 μ m in keratoconus suspect eyes, and 0.68 ± 0.28 in keratoconic grade 1 & 2 eyes, respectively. The pachymetric parameter distributions, tab. (4), fig_s. (3-a:d). The findings of the ROC curve analysis, standard deviation, 95% confidence intervals, and significance level for each parameter were assessed in eyes with thin corneas versus those with suspected keratoconus and moderate keratoconus. Utilizing the pachymetric indices or elevation parameters shows that 100% of cases with keratoconus grade 1,2 may be diagnosed, and most parameters were strong sufficiently (area under the curve (AUC) > 0.90), tab. (5), fig_s. (4-a:d). The PE difference demonstrated outstanding AUROCs with specificity100% and sensitivity 100% in discrimination eyes with keratoconus grade 1 or 2 from those with normal thin corneas. AE difference, KI, and all other parameters with excellent AUROCs, Q value, final D value, IHD, IVA, ISV, CK1, and K max >90% sensitivity, but only slightly lower specificity, managed to detect keratoconus grade 1,2. Table 1-5 provides a summary of the sensitivity and specificity together with the ideal cutoff values taken from high AUROCs samples. CT at apex (0.843) showed good AUROCs, followed by the thinnest CT (0.835), IVA (0.835), D value (0.882), EAdif (0.880), IVA (0.874), and IHD (0.805). The suggested cutoff points for these values and their specificity and sensitivity are shown in tab. (6), fig. (5).

Table 1: Age and gender distribution of the studied population

Variable	Thin cornea N=39	Keratoconus suspect N=18	Keratoconus grade 1& 2 N=31	KC suspect vs. thin cornea (p-value)	KC grade 1& 2 vs. thin cornea (p-value)
Age/year • Mean ± SD • Median (range)	30.61±8.77 29 (10:48)	29.83±14.98 24.5 (16:66)	24.42±6.25 25 (16:41)	0.17	0.001
Gender • Female • Male	21 (53.85%) 18 (46.15%)	12 (66.67%) 6 (33.33%)	12 (38.71%) 19 (61.29%)	0.36	0.21
Eye • Left • Right	17 (43.59%) 22 (56.41%)	9 (50.00%) 9 (50.00%)	16 (51.61%) 15 (48.39%)	0.65	0.50

Table 2: The topographic parameters of studied population and the differences between keratoconus and thin cornea subjects

Variable	Thin cornea N=39	Keratoconus suspect N=18	Keratoconus grade 1&2 N=31	KC suspect vs. thin cornea (p value)	KC grade 1 & 2 vs. thin cornea (p value)
K1 • Mean ± SD • Median (range)	43.42±2.78 43.1 (34.7:50.7)	43.22±1.56 42.7 (41.5:46.9)	45.06±2.23 44.7 (41.4:49.3)	0.78	0.01
K2 • Mean ± SD • Median (range)	45.27±2.92 44.8 (35.6:51.2)	45.79±1.54 45.55 (42.7:47.8)	49.45±3.98 48.7 (44.2:59.1)	0.48	<0.0001
K mean • Mean ± SD • Median (range)	44.31±2.76 44.2 (35.1:50.9)	44.49±1.28 44.6 (42.4:47.1)	46.91±2.82 46.4 (43:52.7)	0.80	0.0002
K max • Mean ± SD • Median (range)	46.98±3.66 46.4 (43.6:65.9)	47.62±2.09 47.65 (43.5:52.3)	53.65±5.33 52.7 (45.2:68)	0.49	<0.00001
Sphere • Mean ± SD • Median (range)	-3.04±5.96 -2 (-15:7.25)	-0.94±2.22 -1.38 (-4:3.5)	-2.82±2.14 -2.25 (-10.5:-0.25)	0.25	0.71
Cylinder • Mean ± SD • Median (range)	-1.48±1.97 -1.5 (-6.5:4.7)	-2.88±2.02 -2.88 (-7.5:- 0.25)	-3.41±3.60 -3.5 (-11.5:4.1)	0.03	0.0003
Q-value • Mean ± SD • Median (range)	-0.15±0.42 -0.28 (-0.59:1.34)	-0.34±0.21 -0.37 (-0.85:0.17)	-0.86±0.31 -0.83 (-1.52:-0.21)	0.04	<0.0001

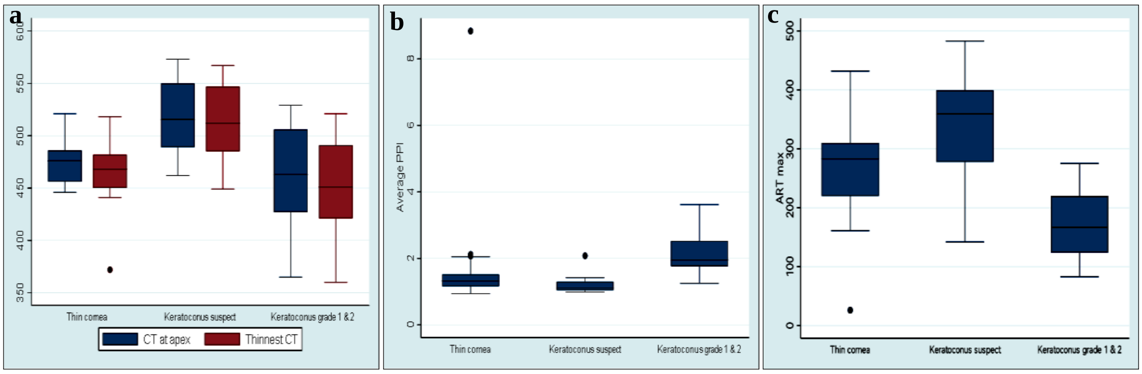


Figure 1: the distribution of **a.** CT at apex, thinnest CT, **b.** average PPI, **c.** ART max in thin corneal eye, KC suspect, and KC grade 1 & 2

Table 3: Parameters from BAD display parameters of the studied population

Variable	Thin cornea N=39	Keratoconus suspect N=18	Keratoconus grade 1 & 2 N=31	KC suspect vs. thin cornea (p-value)	KC grade 1 & 2 vs. thin cornea (p-value)
A.E • Mean ± SD • Median (range)	3.87±6.78 4 (-17:30)	3.72±4.81 5 (-10:7)	11.03±17.40 15 (-36:37)	0.19	<0.0001
P.E • Mean ± SD • Median (range)	6.33±6.66 6 (-16:30)	8.44±9.53 9 (-20:24)	27.74±36.23 37 (-72:81)	0.07	<0.0001
AE diff • Mean ± SD • Median (range)	0.90±6.04 3 (-19:7)	3.17±3.99 4 (-8:8)	14.74±4.95 14 (7:26)	0.06	<0.0001
PE diff • Mean ± SD • Median (range)	4.74±3.70 4 (-4:10)	11.06±6.66 9.5 (-1:24)	33.58±11.72 29 (13:66)	0.001	<0.0001
Final D • Mean ± SD • Median (range)	2.87±2.63 2.18 (0.68:17.38)	2.47±1.09 2.04 (1.22:5.13)	7.78±2.54 7.16 (3.79:13.39)	0.70	<0.0001

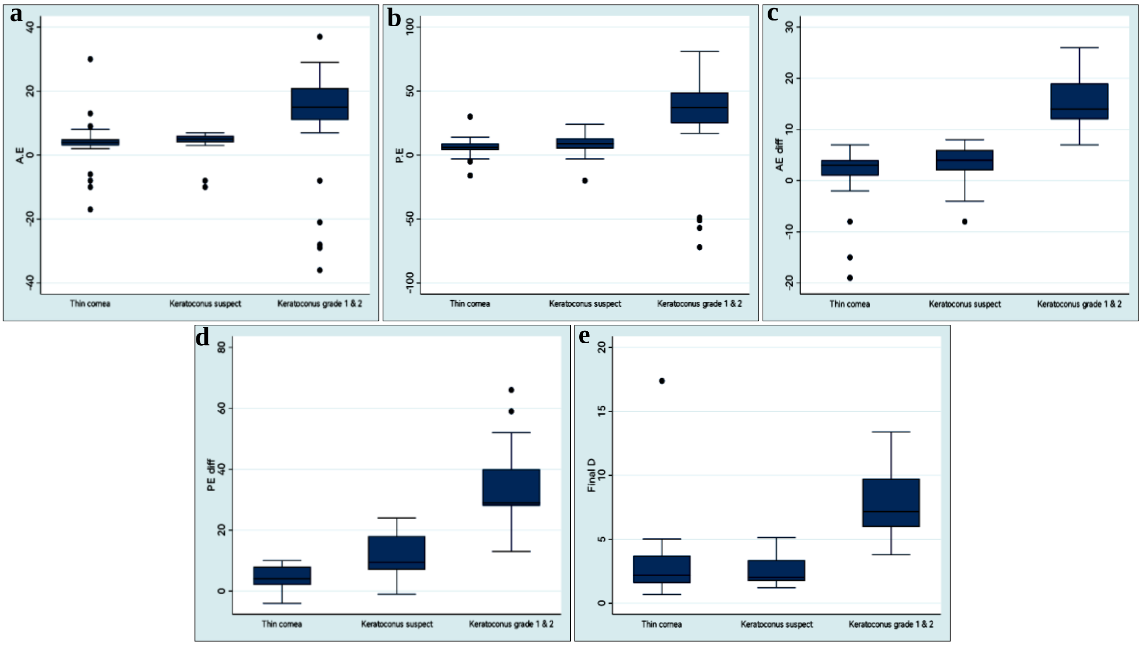


Figure 2: the distribution of **a**. A.E, **b**. P.E, **c**. AE diff, **d**. PE diff, **e**. Final D in thin corneal eyes, KC suspect, and KC grade 1 & 2

Table 4: Topometric parameters of the studied population

Variable	Thin cornea N=39	Keratoconus suspect N=18	Keratoconus grade 1&2 N=31	KC suspect vs. thin cornea (p-value)	KC grade 1&2 vs. thin cornea (p-value)
ISV • Mean ± SD • Median (range)	29.41±16.92 25 (15:96)	36.56±9.93 38 (21:51)	69.23±17.48 68 (44:126)	0.004	<0.0001
IVA • Mean ± SD • Median (range)	0.19±0.18 0.15 (0.03:1.01)	0.29±0.11 0.25 (0.16:0.54)	0.68±0.28 0.67 (0.18:1.72)	0.0001	<0.0001
KI • Mean ± SD • Median (range)	1.01±0.05 1.01 (0.85:1.19)	1.03±0.07 1.05 (0.86:1.09)	1.17±0.06 1.17 (1.03:1.31)	0.03	<0.0001
CKI • Mean ± SD • Median (range)	1.01±0.02 1.01 (0.96:1.07)	1.01±0.01 1.01 (0.98:1.02)	1.05±0.04 1.04 (1:1.14)	0.79	<0.0001
IHA • Mean ± SD • Median (range)	9.44±10.40 5.9 (0.2:55.3)	14.82±10.29 14.85 (0.5:36.6)	30.85±17.45 30.1 (3.4:74.2)	0.04	<0.0001
IHD • Mean ± SD • Median (range)	0.02±0.03 0.02 (0:0.19)	0.03±0.01 0.03 (0.01:0.06)	0.08±0.03 0.08 (0.02:0.19)	0.0002	<0.0001

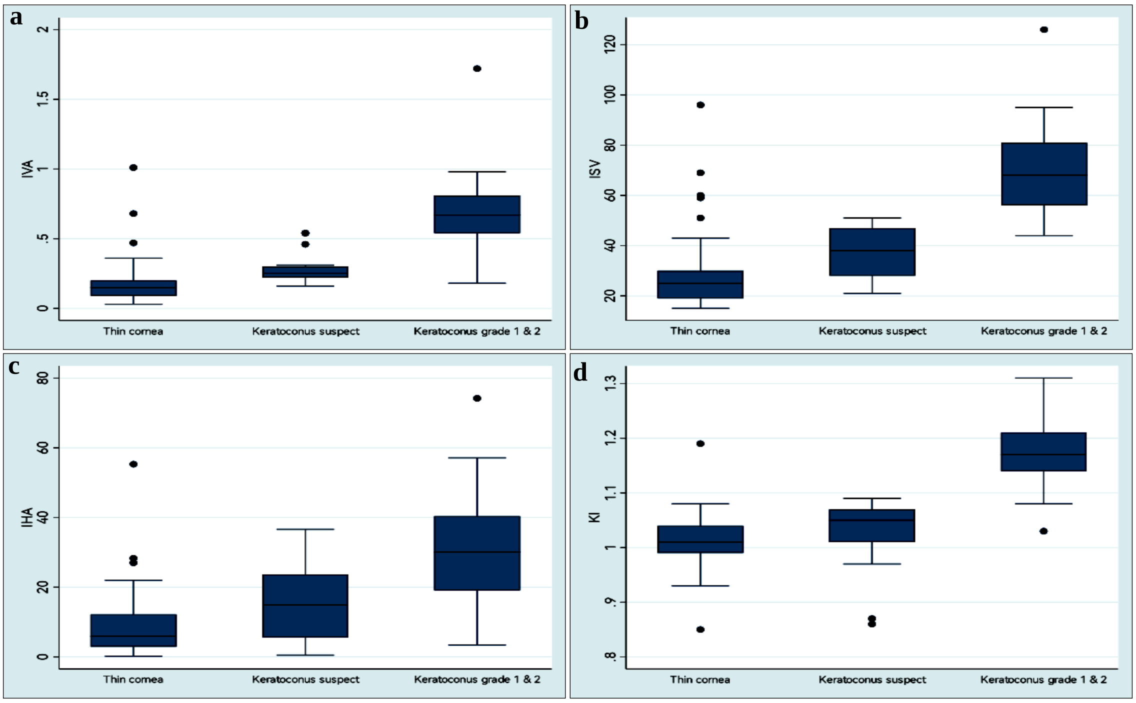
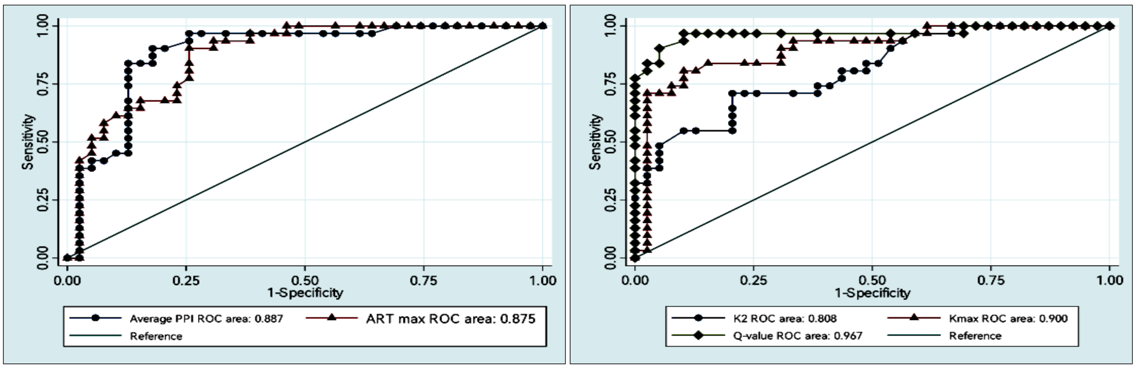


Figure 3: the distribution of **a**. ISV, **b**. IVA, **c**. KI, **d**. IHA in thin corneal eye KC suspect, and KC grade 1 & 2

Table 5: Values with the greatest cutoffs, sensitivity, and specificity obtained from the values of the ROC curve analysis with the highest AUROC for keratoconus grade 1 & 2 versus thin cornea.

Variable	AUC	Sensitivity	Specificity	Cut off
PE diff	1.00	100	100	>10
AE diff	0.999	96.8	100	>7
KI	0.98	93.6	97.4	>1.08
Q-value	0.967	96.8	89.7	≤-0.43
Final D	0.966	96.8	92.3	>4.52
IHD	0.956	93.6	94.5	>0.039
IVA	0.944	93.6	92.3	>0.36
ISV	0.941	100	87.18	>43
CKI	0.928	83.87	94.87	>1.02
K max	0.900	80.65	89.7	>49.2
Average PPI	0.887	90.32	82.1	>1.53



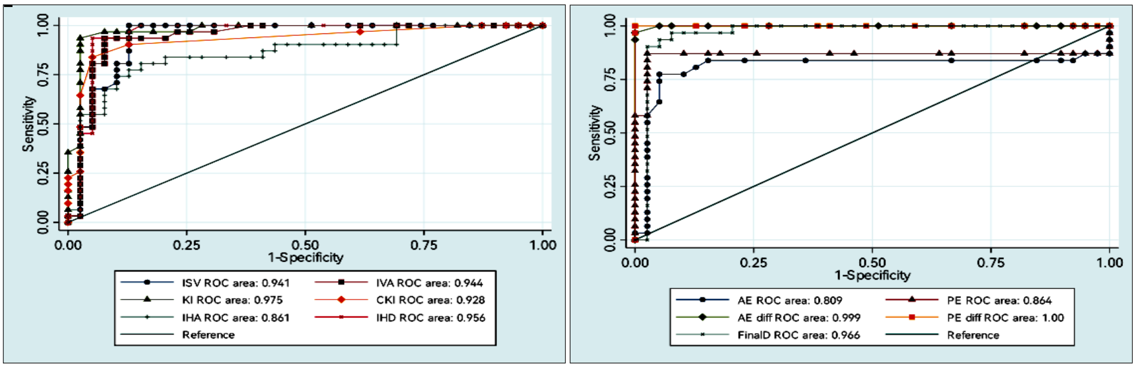


Figure 4: the distribution of **a.** Keratoconus receiver operator characteristic curves together ROC for grade 1 & 2 versus thin corneas for **a.** K2, K max and Q-value, b. Average PPI, and ART max, **c.** receiver operator characteristic curves for keratoconus grade 1 & 2 versus thin corneas, **d.** Keratoconus receiver operator characteristic curves together ROC for grade 1 & 2 versus thin corneas for ISV, IVA, KI, CKI, IHA, and IHD

Table (6) Values of the greatest cutoffs, sensitivity, and specificity determined using ROC curve analysis AUROC versus thin cornea for keratoconus suspicion

Variable	AUC	Sensitivity %	Specificity %	Cut off
CT at apex	0.843	77.8	79.5	>487
Thinnest CT	0.835	77.8	82.1	>483
IVA	0.835	88.9	74.4	>0.19
IHD	0.805	83.3	76.9	>0.021

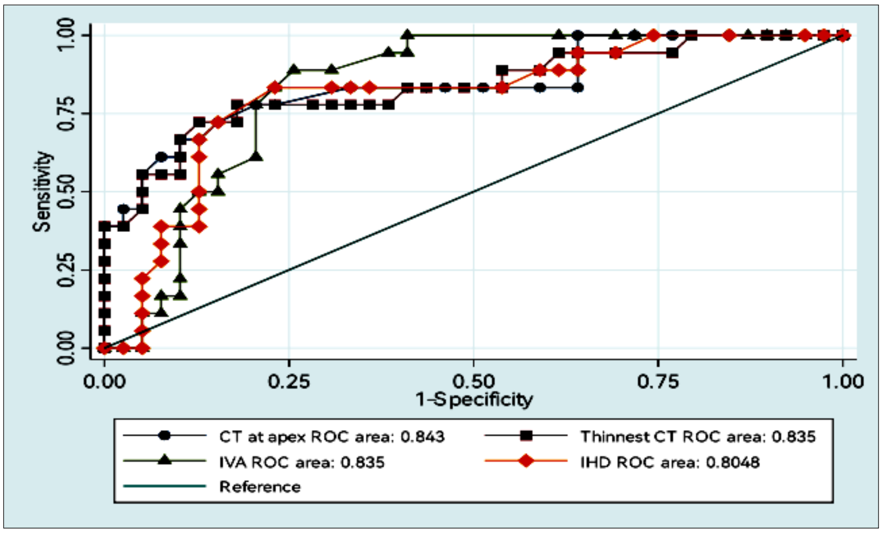


Figure 5: Keratoconus receiver operator characteristic curves ROC with suspect compared to thin corneas for CT at apex, thinnest CT, IVA, and IHD

4. Discussion

Corneal thinning has special considerations in refractive surgery and in diagnosis of keratoconus due to susceptibility or predisposition for ectasia developing. A quick modification of the cornea's shape and thickness from the Thinnest Point (TP) to the periphery in the earliest stages of keratoconus has been evaluated in different studies [15,16-18]. In this study, we exclusively compared tomographic and topographic features of nonkeratoconic thin corneas, keratoconus suspect and keratoconic grade 1,2 corneas using the Pentacam Scheimpflug corneal tomography and determined the usefulness of different tomographic parameters to differentiate keratoconus from normal eyes with thin cornea and to differentiate keratoconus suspect from normal eyes with thin cornea. Recently, several studies investigated Pentacam parameters in keratoconus suspect, keratoconus, and normal eyes, and this analysis indicated that a model combining corneal power, thickness, and elevation data produced the best predictive accuracy in keratoconus and subclinical keratoconus [17, 21-23]. In our study, we discovered that the ideal thre-shold for variations in posterior elevation when the thinnest point to >10 could distinguish keratoconus grade 1, 2, and normal thin ones with 100% sensitivity and 100% specificity also Ant. Elevation (AE) differences with 96.8% sensitivity and 100% specificity so these parameters with perfect AUROC curve (1 and 0.999 respectively) PE difference, AE differrence and final D were significantly more in the keratoconus compared to thin corneas and illustrated the highest AUROCs. between all variables with top AUROCs, Q value, KI, final D, IHD, IVA, ISV, ART max and average PPI had >90% sensitivity, but insignificantly declined specificity to diagnose mild keratoconus. To identify mild keratoconus, although with much lower sensitivity. It indicates that applying these parameters could result in false positives. When the finding is positive, it might be wise to monitor that eye before undergoing corneal refractive surgery, e.g., LASIK. In our study, we found that the best cutoff difference among the eyes with keratoconus suspect and the thin cornea was CT at apex with a reasonable sensitivity (77.8%) and specificity (79.5%) and thinnest CT with an estimated sensitivity (77.8%) and specificity (82.1%) and IVA with an estimated sensitivity (88.9%) and specificity (74.4%) and IHD with an estimated sensitivity (83.3%) and specificity (76.9%).

5. Conclusion

This study shows that these eyes may be discriminated efficiently using different tomographic (BAD, pachymetry, and elevation) parameters and topometric indices from Pentacam Scheimpflug tomography. It addresses non-keratoconic thin corneas and keratoconus subclinical or mildly evolved. CT at apex, thinnest CT, IVA, IHD and PE differences tended to be the most appropriate for distinguishing subclinical keratoconic eyes and normal thin corneas.

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