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A Novel scoring system for distinguishing keratoconus from normal eyes☆

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ABSTRACT

Purpose: To evaluate the accuracy of a novel scoring system in differentiation of keratoconus (KC) eyes from normal eyes using a Scheimpflug camera system tomography.
Setting: Marmara University Hospital, Istanbul, Turkey and Birinci Eye Hospital, Istanbul, Turkey.
Design: Retrospective case-control study.
Methods: The study included 624 keratoconus eyes and 512 healthy eyes. Thirty nine significant parameters obtained from the Scheimpflug imaging system (Pentacam-Oculus Optikgeräte GmbH, Wetzlar, Germany) were studied. The cut-off value and area under receiver operating characteristic (AUROC) curve analysis for each studied parameter were established in the previous study. Minus three and plus three standard deviations of the cut-off value were scored after multiplication of AUROC for each parameter. The sum of all scores (TKS; Total Keratoconus Score) was compared between keratoconus and normal eyes.
Results: Average TKS value was -29.57 ± 5.65 (Range from -43.11 to -7.09) in normal eyes and 36.23 ± 24.3 (Range from -16.82 to 97.45) in keratoconus eyes ($p < 0.001$). Receiver operating characteristic curve analyses showed perfect predictive accuracy for TKS (ROC 1.0 (95% CI: 0.999–1.0)). The TKS distinguished the keratoconus group from the normal group with 99% sensitivity and 99% specificity at the best cut-off point of -12.45.
Conclusions: The new scoring system measured by the Scheimpflug imaging system provides perfect discrimination of keratoconus from normal corneas.

1. Introduction

Keratoconus (KC) is described as a non-inflammatory ectatic corneal dystrophy characterized by progressive corneal thinning that results in corneal steepening, protrusion, irregular astigmatism, and gradual impairment of vision [1]. Detection of keratoconus among refractive surgery candidates is important because keratorefractive procedures may worsen their condition. Placido disk–based topography systems are sensitive for detecting subtle changes of topography on the anterior corneal surface. It provides us to the ability to analyze anterior corneal irregularity in the early stages of keratoconus. Anterior-surface irregularity indices have been developed to help for detecting and staging keratoconus [2,3]. However, it was also reported that early changes in eyes with KC are also present on the posterior corneal surface [4,5]. Scheimpflug imaging provides the measurement of the entire corneal thickness by determining the front and back surfaces of the cornea taken by a rotating Scheimpflug camera. This analysis allows a highly sensitive and specific diagnostic modality for the early diagnosis of keratoconus by combining topographic and pachymetric data [6]. Keratoconic eyes have thinner corneas than normal eyes, with less volume and a more gradual increase in these parameters from the thinnest point toward the periphery [7]. The combination of the pachymetric graphs and the enhanced elevation maps provided by the Belin-Ambrosió enhanced ectasia display (BAD) of the Scheimpflug system show high sensitivity and specificity in the screening of patients with forme fruste keratoconus eyes [8].

☆ The authors do not have any proprietary interest in the products and drugs mentioned in this manuscript.
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In the previous study of ours the area under receiver operating characteristic (AUROC) and cut-off values for 39 parameters obtained from the Scheimpflug imaging system (Pentacam-Oculus Optikgeräte GmbH, Wetzlar, Germany) were assessed in distinguishing keratoconus from normal eyes [9]. In this study standard deviations of cut-off value were scored after multiplication of AUROC for each parameter. The sum of the scores was analyzed in differentiation of keratoconus eyes.

The purpose of this study was to describe a novel scoring system in differentiating eyes with keratoconus from normal eyes using the Scheimpflug imaging system.

2. Patients and methods

This is a retro-prospective clinic-based observational study of 513 eyes of 268 subjects (48.1% were male and 51.9% were female) with a mean age of 33.0 years (ranging from 8 to 74 years old), in the normal group and 656 eyes of 338 subjects (63.2% were male and 36.8% were female.) with a mean age of 31.0 years (ranging from 13 to 64 years old), in the keratoconus group. The mean spherical refraction of normal eyes was −0.88 D. The protocol of this study is adhered to the tenets of the Declaration of Helsinki, and was approved by the Ethics Committee, Marmara University Hospital, Istanbul, Turkey.

All patients included in the study were explained the purpose of the study and provided informed consent. Subjects were recruited consecutively from September 2013 to April 2014 as they presented at the university hospital (Marmara University Hospital, Istanbul, Turkey) or the private eye hospital (Birinci Eye Hospital, Istanbul, Turkey) for ocular examination.

Exclusion criteria were previous eye trauma, corneal or intraocular surgery, glaucoma, corneal scarring, severe eye dryness, pregnancy or breast feeding, current corneal infections as well as the use of topical medications. Soft contact lens users were included in the study after discontinuation of lens wear for at least 7 days.

Keratoconus was diagnosed mainly on the basis of clinical slit lamp findings, keratometry, and associated characteristic topographic patterns. Eyes were considered normal if they had no ocular pathology, no previous ocular surgery, and no irregular corneal pattern.

All eyes had a comprehensive ocular examination. Corneal tomography was measured with a high-resolution rotating Scheimpflug imaging system. This system provides a multitude of corneal refractive (keratometric), topometric, tomographic, and pachymetric data. All measurements were taken between the hours of 9:00 am and 6:00 pm The room lights were switched off for all examinations to get a reflex-free image. The subjects were asked to position themselves, blink a couple of times, and fixate on the black target in the center of the blue fixation beam. Patients were instructed to close their eyes between shots for at least 10 seconds to moisten the eyes. The Rotating Scheimpflug imaging was automatically performed when the image was in focus and the corneal vertex was correctly aligned. The camera rotated 180°, obtaining 25 slit images of the anterior segment, and generated a three-dimensional model of the anterior eye. Eye movement of the subject was constantly monitored by the system, and quality factor was automatically evaluated. Only the scans with a quality specification (QS) of >95% were saved.

Parameters were derived from topographic, topometric and Belin-Ambrosio enhanced ectasia display maps (BAD). Parameters of the printout retained for the analysis were keratometry readings, topographic astigmatism and asphericity for the anterior and posterior corneal surface, pachymetry, cornea volume, and anterior chamber volume, angle and depth, topometric indices, data from corneal thickness spatial profiles and Belin-Ambrosio enhanced ectasia display. The abbreviations for these parameters are used in this paper and are explained in the Appendix A.

The corneal thickness was defined as the thinnest location in the corneal thickness map. Corneal volume is reported as the volume of the cornea in a diameter of 10 mm, centered on the anterior corneal apex. Anterior chamber depth was defined as the distance from the corneal endothelium to the anterior surface of the lens capsule. The anterior chamber volume is calculated from endothelium down to iris, and lens over a 12-mm diameter centered on the anterior corneal apex. The default angle displayed is the smallest angle in the horizontal position calculated from Scheimpflug image. For elevation data measurements, the best fit sphere served as a reference body using the float option and the diameter of the reference surface was 8 mm. Front and back elevation difference values were taken as the differential changes in corneal elevation between the best fit sphere (BFS) and the enhanced BFS obtained via the BAD display software. The progression index is calculated as the average progression value at the different pachymetric rings, referenced to the mean curve. The asphericity data provided by the Scheimpflug imaging system was taken from 8 mm central cornea with reference to the anterior corneal apex.

The AUROC and cut-off values with sensitivity and specificity were calculated for 39 parameters in the previous study (Table 1)

Table 1
The cut-off value and standard deviation for each parameter for keratoconus and normal eyes.

Pentacam parameter	−2.0 SD	−1.0 SD	Cut-off+SD	+1.0 SD	+2.0 SD
Kflat (Ant)	37.02	41.08	45.15 ± 4.06	49.21	53.27
Ksteep(Ant)	36.39	41.42	46,45 ± 5.02	51.47	56.50
Kmean (Ant)	36.36	40.80	45.25 ± 4.44	49.69	54.13
Astigmatism (Ant)	−2.05	−0.20	1.65 ± 1.85	3.50	5.35
Asphericity (Ant)	0.37	−0.10	−0.56 ± 0.46	−1.03	−1.50
Kflat (Post)	−4.92	−5.73	−6.55 ± 0.81	−7.37	−8.18
Ksteep (Post)	−4.92	−5.88	−6.85 ± 0.96	−7.49	−8.33
Kmean (Post)	−4.97	−5.81	−6.65 ± 0.83	7.49	−8,33
Astigmatism (Post)	−0.36	0.04	0.45 ± 0.40	0.85	1.26
Asphericity (Post)	0.37	−0.09	−0.55 ± 0.46	−1.02	−1.48
CCT	636.43	571.47	506.5 ± 64.96	441.53	376,57
Cornea Vol	67.09	68.82	58.55 ± 4.26	54.28	50.01
AC Vol	89.85	129.67	169.5 ± 39.82	209.32	249.15
ACD	2.32	2.74	3.15 ± 0.41	3.56	3.98
AC Angle	18.48	25.86	33.25 ± 7.38	40.63	48.01
Topometric					
ISV	−54.96	−11.73	31.5 ± 43.23	74.73	117.96
IVA	−0.67	−0.21	0.25 ± 0.46	0.72	1.19
KI	0.78	0.92	1.05 ± 0.13	1.18	1.32
CKI	0.91	0.96	1.01 ± 0.04	1.06	1.11
IHA	−25.62	−8.48	8.65 ± 17.13	25.78	42.92
IHD	−0.10	−0.04	0.01 ± 0.06	0.08	0.14
Rmin	8.83	7.96	7.08 ± 0.87	6.21	5.34
HOR Q	0.44	−0.03	−0.49 ± 0.46	−0.96	−1.43
VERT Q	0.34	−0.14	−0.62 ± 0.48	−1.11	−1.59
BAD Display					
FRONT DİFF	−13.85	−2.67	8.5 ± 11.17	19.67	30.86
BACK DIFF	−36.64	−12.12	12.5 ± 24.62	37.12	61.64
Kmax	31.17	39.11	47.05 ± 7.94	54.98	62.92
F.Ele.Th	−22.69	−8.59	5.5 ± 14.09	19.59	33.69
B.Ele.Th	−45.71	−16.10	13.5 ± 29.60	43.10	72.70
ProgMin	−1.05	−0.06	0.92 ± 0.99	1.91	2.90
ProgMax	−3.56	−0.94	1.67 ± 2.62	4.29	6.91
ProgAvg	−1.91	−0.36	1.18 ± 1.55	2.73	4.28
ARTmac	632.87	471.93	311 ± 160.9	150.07	−10.87
Df	−13.43	−5.42	2.57 ± 8.00	10.57	18.58
Db	−16.17	−7.22	1.72 ± 8.94	10.66	19.61
Dp	−18.68	−8.41	1.85 ± 10.26	12.12	22.39
Dt	−4.58	−1.81	0.95 ± 2.77	3.72	6.49
Da	−1.28	0.16	1.62 ± 1.45	3.07	4.52
D	−9.32	−3.35	2.61 ± 5.96	8.58	14.55

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