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Original research

Anterior segment characteristics in normal and keratoconus eyes evaluated with a combined Scheimpflug/Placido corneal imaging device

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Abstract

Purpose: To assess the anterior segment parameters of keratoconus (KC) eyes at different stages of the disease by a new Scheimpflug camera combined with Placido disk corneal topography (Sirius, CSO, Italy) in a sample of the Iranian population.

Methods: A total of 225 eyes of 225 individuals comprising 41 suspect KC, 40 mild KC, 71 moderate KC, 48 severe KC and 25 normal eyes were assessed for the following parameters: corneal thickness at the apex (CTA), thinnest corneal thickness (TCT), anterior chamber depth (ACD), corneal volume (CV), corneal keratometry (K), corneal asphericity (Q), and corneal elevation in the anterior and posterior surface. Also, the Zernike coefficients for the corneal aberrations including total root mean square (RMS), RMS Coma, RMS spherical aberration (SA), RMS Astigmatism, Baiocchi Calossi Versaci front index (BCV_f), and BCV back index (BCV_b) were noted for all eyes. Data was analyzed using analysis of variance (ANOVA) and post hoc Bonferroni test for comparison of the means of the five groups. P-value was considered significant if it was <0.05.

Results: The TCT, CTA and posterior corneal elevation were significantly different between all comparison groups ($P < 0.05$). ACD values showed inconsistent differences between groups. Mean value of CV in comparing normal eyes vs suspect KC group, normal eyes vs mild KC, and normal eyes vs moderate KC revealed statistically significant change ($P < 0.05$). Also, weak non-significant positive correlation was demonstrated between K and CV ($r = 0.08$). There were statistically significant differences in total RMS, RMS coma, BCV_f, and BCV_b for most groups ($P < 0.05$).

Conclusion: Posterior corneal elevation, corneal thickness and high order aberrations are important indices that need to be considered to diagnose different grades of keratoconus.

Keywords: Cornea; Keratoconus; Topography

Introduction

Detection of suspect keratoconus among refractive surgery candidates is important because keratorefractive procedures may lead to post-surgery ectasia in these eyes. The increasing volume of patients interested in refractive surgery and the new treatment options available for keratoconus have generated a higher interest in achieving a better characterization of this pathology.[1] Keratoconus is a bilateral non-inflammatory progressive disorder characterized by corneal ectasia and thinning.[2–4] Detecting moderate and advanced keratoconus is not difficult using corneal topography, biomicroscopic, retinoscopic and pachymetric findings.[3] Several indices have been proposed to help in the diagnosis of keratoconus and subclinical keratoconus with different topography systems.[5–13] They include quantitative descriptors such as the keratometry (K), inferior–superior (I–S) value, astigmatism (KISA)% index proposed by Rabinowitz and Rasheed[8] and the Keratoconus

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Prediction Index and Keratoconus Index proposed by Maeda et al[14] Smolek and Klyce,[7] developed a neural network classification based on corneal topography indices. Other detection schemes based on Zernike decomposition of the anterior corneal surface have been described by Schwiegerling et al[15] and Langenbucher et al[16] With the Scheimpflug imaging system, corneal elevation in the anterior and posterior corneal surface are being investigated and research debated which of the corneal surfaces had higher sensitivity in detecting keratoconus.[11,17–20] Incorporating corneal thickness, corneal volume, and corneal curvature using a Scheimpflug camera have been evaluated in several other articles.[21,22] The Sirius system is a relatively new Scheimpflug-Placido topographer that combines a single-Scheimpflug rotating camera with Placido disk topography to measure and image the anterior eye segment. Within a single scan, it can simultaneously acquire more than 30,000 points on the anterior and posterior corneal surface and 25 radial sections of the cornea and anterior chamber.[23] Evaluation of keratoconic and normal eyes to determine all tomographic parameters including keratoconus indices, pachymetric graph values, and the posterior corneal elevation values may help to identify at-risk corneas. The purpose of our study was to evaluate and compare changes in the anterior segment of keratoconus eyes at different stages of the disease, the anterior and posterior corneal surface parameters, thickness profile data, and data from enhanced elevation maps of keratoconic and normal eyes with the Sirius Scheimpflug-Placido corneal tomography and to determine the sensitivity of these parameters in discriminating early keratoconus from normal eyes.

Methods

This study is a retrospective study of 200 patients (200 eyes) who were seeking refractive surgery in Bahman Hospital and had been diagnosed as clinical keratoconus. Twenty-five normal volunteer subjects (25 eyes) were included as a control group. This study adhered to the tenets of the Declaration of Helsinki and was approved by the Ethics Committee, Tehran University of Medical Sciences, Iran. All patients included in the study were informed about the purpose of the study and provided informed consent. Subjects were recruited from consecutive patients who were admitted to the private hospital (Bahman Hospital, Tehran, Iran) for ocular examination between October 2014 and October 2015. For analysis, keratoconus eyes have been classified into 4 subgroups according to Amsler-Krumeich classification.[24] Keratoconus suspect is a catchall term to indicate a patient with inferior or central steepening on topography with abnormal localized steepening or an asymmetrical bow-tie pattern, a normal-appearing cornea on slit-lamp biomicroscopy, and at least 1 of the following signs: steep keratometric curvature (>47.00 D), oblique cylinder greater than 1.50 D, central corneal thickness less than 500 mm, or clinical keratoconus in the fellow eye.[12,13,17,25,26] Eyes were considered normal if they had no ocular pathology, no previous ocular surgery, no significant refractive error, and no irregular corneal pattern. For this study, only one eye of each subject was chosen for the study according to a random-number sequence (dichotomic sequence 0 and 1). Exclusion criteria were: previous ocular surgery, corneal scarring, trauma, pregnancy or lactation, glaucoma, and causes of ocular astigmatism other than corneal i.e. lenticular astigmatism such as early cataract, lens subluxation, or lenticonus. Individuals with connective tissue disease, such as Marfan or Stickler syndrome, were also excluded from the study. In the current study, a comprehensive ocular examination including Scheimpflug-Placido topography (Sirius, CSO, Italy) using software version 1.0.5.72 was performed on all eyes. The Sirius is a new topography device that combines a monochromatic rotating Scheimpflug camera and a Placido disk. The scanning process acquires a series of 25 Scheimpflug images (meridians) and 1 Placido top-view image to analyze the anterior segment by obtaining 25 radial sections of the cornea and anterior chamber. Anterior surface data from Placido and Scheimpflug images are merged using a proprietary method. All other measurements for internal structures are derived solely from Scheimpflug data. A 475 nm ultraviolet-free blue light–emitting diode light is used to measure 35,632 points for the anterior corneal surface and 30,000 points for the posterior cornea. The system acquires the radius curvature measurements in the flat and steep meridians on a 3.0 mm-diameter field of the central cornea. The corneal power and astigmatism were calculated using the 1.3375 keratometric refractive index. Corneal aberrometry is obtained using the ray-tracing technique.[23,27] Measurements were performed by a single optometrist. The patient's eye was aligned along the visual axis using a central fixation light. Patients were instructed to blink between shots to keep eyes moist. The images were obtained with the automatic mode. Eye movement of the subject was constantly monitored by the system, and quality factor was automatically evaluated. In case of a poor-quality scan with movement artifacts and irregularities (e.g. due to misalignment or blinks during the scan), 1 more measurement was taken. In eyes with scans not attainable, artificial tears were added to allow better acquisition. In this study, the following parameters were evaluated: corneal thickness at the apex (CTA), the thinnest corneal thickness (TCT) defined as the thinnest point in the corneal thickness map, anterior chamber depth (ACD) defined as the distance from the corneal endothelium to the anterior surface of the lens capsule, corneal volume (CV) reported as the volume of the cornea in a diameter of 9 mm, centered on the anterior corneal apex, K in both the anterior and posterior corneal surface as well as steep and flat keratometry, corneal asphericity (Q) reported as the asphericity data provided by the Sirius and taken from 8 mm central cornea with reference to the anterior corneal apex, corneal elevation in both the anterior and posterior corneal surfaces with aspherotoric surface as a reference, and total root mean square (RMS) as quantitative comparisons of aberrations between different eyes. The compensation between corneal and internal aberrations was defined as: (total eye aberration RMS) that is calculated out to the 6th Zernike order for a 6.0-mm pupil diameter, RMS Coma, RMS spherical aberration (SA), RMS Astigmatism, Baiocchi Calossi Versaci front index (BCV_f) and BCV back