ORIGINAL ARTICLE

Correlation of Anterior Segment Parameters in Keratoconus Patients

Leonardo Torquetti, Guilherme Ferrara, Paulo Ferrara

ABSTRACT

Purpose: To evaluate the corneal asphericity, volume, thickness and keratometry and the correlation among these variables in keratoconus patients.

Materials and methods: A total of 1,071 eyes of 810 patients diagnosed with keratoconus were evaluated with a Pentacam (Oculus Optikgerate GmbH). Five groups were established according to the mean keratometry readings: Very mild [K < 44.0 diopters (D)], mild (K = 44.0-47.0D), moderate (K = 47.0-52.0D), severe (K = 52.0-60.0D) and very severe (K = 60.0 or higher). The following parameters were obtained: Anterior corneal asphericity (Q), corneal volume (CV) and thinnest corneal thickness (TCT).

Results: Sixty-six eyes had very mild keratoconus, 269 had mild keratoconus, 465 had moderate keratoconus, 233 had severe keratoconus and 38 had very severe keratoconus. As the severity of disease increases, there is an increment in K and CV values and reduction of Q and TCT. There was a statistically significant difference in values for all parameters, except the CV. The Pearson correlation index showed an inverse correlation between the degree of keratoconus and the asphericity (Q), i.e. the more severe the keratoconus the more negative the Q-value. Only in the very severe group there was no statistically significant correlation between K and Q. There was no correlation between severity of keratoconus and CV. There was an inverse correlation between keratoconus grade and TCT; the more advanced the disease the less the TCT value. Only in the very mild group there was no correlation between K and TCT.

Conclusion: The corneal asphericity and pachymetry are inversely correlated to keratometry in keratoconus patients. There is no correlation between CV and severity of keratoconus.

Keywords: Anterior segment, Pentacam, Tomography, Keratoconus.

How to cite this article: Torquetti L, Ferrara G, Ferrara P. Correlation of Anterior Segment Parameters in Keratoconus Patients. Int J Kerat Ect Cor Dis 2012;1(2):87-91.

Source of support: Nil

Conflict of interest: None

INTRODUCTION

Keratoconus is a clinical term used to describe a condition in which the cornea assumes a conical shape as a result of thinning and protrusion. Classically, the disease is described as a noninflammatory condition. However, recent studies have shown evidence that inflammatory mediators may play a role in the disease development and evolution.[1-3]

Corneal topography is a valuable tool for confirming the keratoconus diagnosis.[4] Significant corneal steepening in the anterior corneal surface of keratoconic eyes is always observed; the steepening is usually confined to 1 or 2 quadrants.[4,5] Therefore, detecting moderate and advanced keratoconus is not difficult using corneal topography and biomicroscopic, retinoscopic and pachymetric findings. Detection can be difficult with very early or preclinical stages of this ectatic disorder.

Accurate measurement of anterior segment parameters in keratoconic corneas is of paramount importance for monitoring the evolution of the disease as well as for surgical planning [e.g. in selection of intrastromal corneal ring segments (ICRS)].

The Pentacam (Oculus Optikgerate GmbH) instrument uses a rotating Scheimpflug camera system that provides three-dimensional scanning of the whole anterior segment of the eye. It has been used in the assessment of cataract[6] and for measuring corneal curvature and thickness.[7] From the images acquired, information regarding the anterior and posterior corneal elevation, pachymetry, asphericity, anterior chamber depth, angle and lens density can be measured quickly and noninvasively. Using this device, we can obtain important data, which are required for early diagnosis, follow-up and surgical planning in keratoconus patients.

The aim of the present study was to evaluate changes in the anterior corneal curvature, pachymetry, asphericity and corneal volume in eyes with different grades of keratoconus using a Scheimpflug imaging system. We also analyzed the degree of correlation between these parameters.

MATERIALS AND METHODS

In the present study, 1,073 eyes of 810 consecutive surgical patients from January 2006 to July 2008 were evaluated. The preoperative data of patients, which had a Ferrara ring implantation, was used for analysis. This study was approved by the institutional review board of Dr Paulo Ferrara Eye Clinic, Belo Horizonte, MG, Brazil, and followed the tenets of the declaration of Helsinki. The procedures were fully explained to each patient and each provided written informed consent.

An eye was diagnosed as having keratoconus, if there was central or paracentral steepening on computerized topography with at least one of the following slit lamp findings of keratoconus: Central or paracentral thinning, Fleischer's ring, Vogt's striae, Descemet's breaks, apical scars and subepithelial fibrosis. Five groups of patients were

established according to the mean anterior keratometry readings (severity of keratoconus): Very mild [K < 44.0 diopters (D)], mild (K = 44.0-47.0D), moderate (K = 47.0-52.0D), severe (K = 52.0-60.0D) and very severe (K = 60.0 or higher).

Participant exclusion criteria were any previous corneal or ocular surgery, any eye disease other than keratoconus and chronic or continuous use of topical medications. Contact lenses (soft or rigid) had to be removed at least 72 hours before the examination.

PENTACAM MEASUREMENTS

The Pentacam is a combined device consisting of a slit illumination system and a Scheimpflug camera, which rotates around the eye. A thin layer within the eye is illuminated through the slit. Being not entirely transparent the cells scatter the slit light. In doing so, they create a sectional image, which is then photographed in side view by a camera. This camera is oriented according to the Scheimpflug principle, thus creating an image of the illuminated plane, which appears completely sharp from the anterior surface of the cornea right up to the posterior surface of the crystalline lens.

The sectional images are saved, corrected in relation to a common reference point and then put together to create a three-dimensional model of the entire anterior eye chamber. This makes it possible to generate reproducible tomographic images of the anterior eye chamber in any desired plane.

After correction for Scheimpflug distortion and light refraction at tissue interfaces the exact of location of image edge points in the eye is determined by means of ray tracing.[8] Eye movements during image acquisition are captured by a second camera (pupil camera) and also taken into account in the mathematical evaluation. This produces a set of three-dimensional measurement data, which gives a precise geometric description of the anterior eye segment. This data in turn can be used to generate data on elevation, curvature, pachymetry and depth of the anterior chamber in the well-known form of color maps. We used the HR version of Pentacam, which has a precision and reproducibility of 0.1D for keratometry measurements. For the Q evaluation, we considered the 4.5 mm optical zone values.

STATISTICAL ANALYSIS

All data were analyzed using the SPSS software (SPSS, Chicago, IL) and reported as means ± standard deviation. The analysis of variance (ANOVA) test was used for comparison of a given variable among the groups. The Pearson correlation test was used to evaluate the correlation of parameters. A p-value less than 0.05 was considered statistically significant.

RESULTS

Sixty-six eyes had very mild keratoconus, 269 had mild keratoconus, 465 had moderate keratoconus, 233 had severe keratoconus and 38 had very severe keratoconus. The mean age of patients was 29.4 ± 9.4 years.

Table 1 shows the patient's demographic data. Table 2 shows the mean K, asphericity (Q), corneal volume (CV) and thinnest corneal thickness (TCT) values.

As the severity of disease increases, there is an increment in K and CV values and reduction of TCT and Q (the Q-value becomes more negative). There was a statistically significant difference in values for all parameters, except the CV (Table 2).

The Pearson correlation index showed an inverse correlation between the grade of keratoconus and the asphericity (Q) (Table 3), i.e. the more severe the keratoconus the more negative the Q value (Fig. 1). Only in the very severe group there was no statistically significant correlation between K and Q. There was no correlation between severity of keratoconus and CV (Fig. 2). There was an inverse correlation between keratoconus degree and TCT (Fig. 3); the more advanced the disease the less the TCT value. Only in the very mild group there was no correlation between K and TCT.

Table 1: Demographic data of patients

Group (KC)	Eyes (n)	Age (Y)	Sex (F/M)
Very mild	66	30 ± 10.8	22/44
Mild	269	29.4 ± 8.95	106/163
Moderate	465	29.4 ± 8.82	217/248
Severe	233	29.0 ± 9.88	113/120
Very severe	38	26.9 ± 10.75	19/19

KC: Keratoconus; Age: Mean ± SD

Table 2: Anterior segment parameters

Group (KC)	K_m (D)	Q (μm)	CV (mm³)	TCT (μm)
Very mild	42.99 ± 0.72	− 0.35 ± 0.45	56.34 ± 3.56	486.3 ± 40.6
Mild	45.50 ± 0.86	− 0.53 ± 0.30	56.81 ± 3.78	473.1 ± 34.90
Moderate	49.29 ± 1.39	− 0.97 ± 0.36	56.87 ± 3.57	447.2 ± 35.12
Severe	54.58 ± 2.01	− 1.31 ± 0.39	57.50 ± 3.92	412.4 ± 39.34
Very severe	63.14 ± 2.84	− 1.70 ± 0.79	58.96 ± 3.23	362.0 ± 41.86
p-value	<0.001	0.05	0.019	< 0.001

KC: Keratoconus; K_m: Mean keratometry; Q: Asphericity; CV: Corneal volume; TCT: Thinnest corneal thickness

Table 3: Pearson correlation values of keratometry with Q, CV and TCT

	Q (μm)	CV (mm³)	TCT (μm)
Group (KC)	r (p-value)	r (p-value)	r (p-value)
Very mild	−0.309 (0.049)	0.177 (0.151)	0.147 (0.236)
Mild	−0.200 (0.010)	0.079 (0.195)	−0.129 (0.034)
Moderate	−0.433 (0.000)	0.008 (0.865)	−0.227 (0.000)
Severe	−0.427 (0.000)	0.091 (0.164)	−0.236 (0.000)
Very severe	0.077 (0.748)	−0.014 (0.934)	−0.602 (0.000)

KC: Keratoconus; Q: Asphericity; CV: Corneal volume; TCT: Thinnest corneal thickness
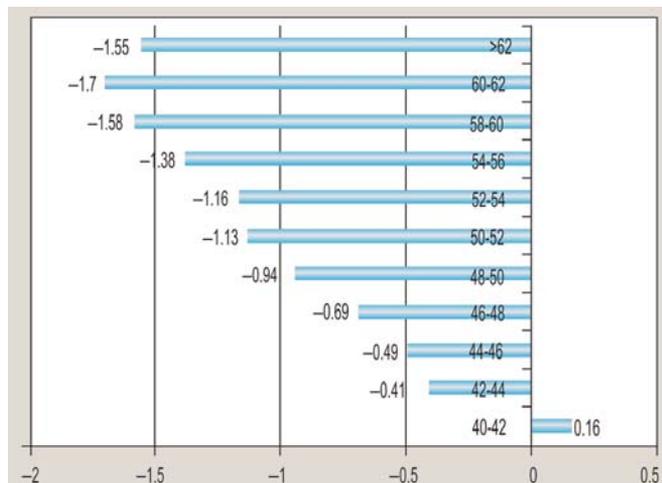

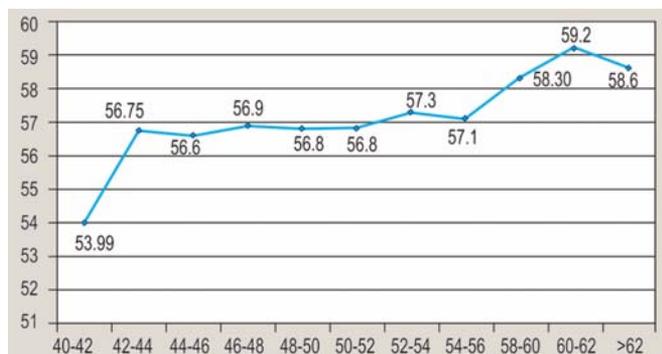**Fig. 1:** Correlation between Q (X-axis) and K (Y-axis)

Fig. 2: Correlation between K (X-axis) and CV (Y-axis)
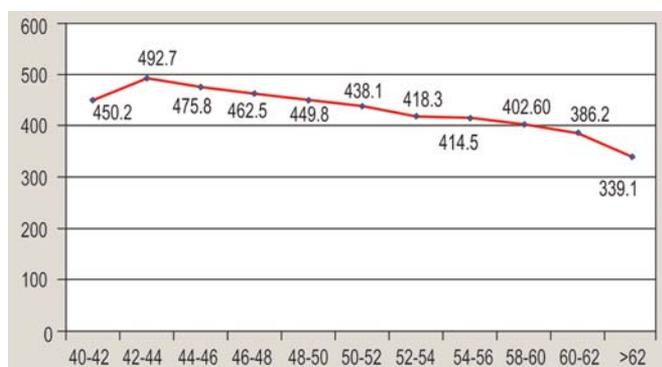

Fig. 3: Correlation between K (X-axis) and TCT (Y-axis)

DISCUSSION

Adequate and reliable measurement of anterior segment parameters in keratoconus patients is crucial for the follow-up and surgical planning, especially in cases of ICRS implantation. The Pentacam is one of the more reliable devices commercially available for anterior segment image acquisition and analysis, as its resolution is 0.1D.

The corneal stromal structure in keratoconus is not based on an orthogonal lamellar matrix, as in normal corneas. There are regions of highly aligned collagen intermixed with regions in which there is little aligned collagen.[9,10] As a consequence, the corneal shape can be distorted more easily (corneal steepening, aberrometric increase and asphericity decrease).

A significant decrease in asphericity values (more negative) in progressive degrees of severity of keratoconus was found in this study. The mean Q-value ranged from −0.35 for the very mild group to –1.70 for the very severe group. Only in the very severe group we did not found a statistically significant correlation between Q and severity of the disease. This can be explained by the fact that in highly irregular corneas, the asphericity profile of the cornea is lost, i.e. the deformity of the cornea does not allow a reliable definition on how really prolate is that cornea.

Most studies agree that the human cornea Q (asphericity) values ranges from –0.01 to –0.80.[11-13] Currently, the most commonly accepted value in a young adult population is approximately –0.23 ± 0.08.[14] As the asphericity can be considered as one of markers of quality of vision,[15] turning it closer to normal or at least reducing the excess of prolateness usually found in keratoconus, could be a predictor of improvement of vision. The Q-value has been used as an important parameter for ICRS selection.[16,17]

Alió et al[18] found in a recently published paper, that the mean K was correlated with corneal asphericity, which makes sense because central or paracentral localized corneal steepening would, by definition, be associated with an increase in negative corneal asphericity. We think that corneal asphericity could be a useful tool in keratoconus diagnosis because it provides a general overview of the corneal shape (mathematical adjustment), whereas the information provided by the K_m value is more limited; it only tells whether there is or is not corneal steepening but does not tell the degree of corneal asymmetry or the peripheral changes of curvature. The relationship between

mean K and asphericity is consistent with outcomes in previous studies.[19]

There are several methods for grading the severity of keratoconus.[18,20,21] In this study, we used the simplest possible grading system of severity of keratoconus, which is based only on the average K values. This system was chosen in order to facilitate the extrapolation of data for use by clinicians.

We found progressively lower pachymetry values from the very mild to the very severe group. Only in very mild group it was not found a correlation between TCT and K. In corneas with very low K values, as in very mild keratoconus, the cornea thickness can be similar to a non-keratoconic cornea, in which usually there is no correlation between pachymetry and keratometry. Pinero et al[22] evaluated the differences in pachymetry and corneal volume among different keratoconus groups. They found progressively lower pachymetric readings in subclinical, early and moderate keratoconus cases, with the lowest values in the latter group. Therefore, corneal thinning in eyes with ectatic corneal disease can be accurately monitored using the Scheimpflug imaging system. Emre et al[23] obtained similar outcomes using the same system.

A corneal biomechanics study, found that keratoconic patients also had significantly steeper corneas of less volume and significantly higher corneal astigmatism, based on the central keratometric, corneal volume and corneal astigmatism measurements.[24] In addition, the central corneal thickness was statistically lower in the mild keratoconus group compared with the control group. Ambrosio et al[25] showed that the corneal-thickness spatial profile, corneal-volume distribution, percentage of increase in thickness and percentage of increase in volume are different in keratoconic eyes and normal eyes. Keratoconic eyes have thinner corneas than normal corneas, with less volume and a more abrupt increase in these parameters from the thinnest point toward the periphery. In that paper, the authors described the corneal thickness and volume in different optical zones. In the current paper, we evaluated the corneal thickness only in its thinnest point and the total corneal volume. We did not find significant differences in corneal volume among the five groups studied. Similar results have been found in another studies.[22,23] Therefore, the CV could be a less reliable factor to evaluate in the follow-up of keratoconus patients.

Anterior segment parameters determination is of crucial importance, in order to provide an earlier diagnosis, proper follow-up (to detect disease evolution) and surgical planning in keratoconus patients. The presented data could be used, in future studies, to aid in the development of new keratoconus diagnostic and follow-up criteria. The inter relation between these parameters can help to define the role of each of it in the pathophysiology of the disease, its course and treatment.

REFERENCES

1. Lema I, Sobrino T, Durán JA, Brea D, Díez-Feijoo E. Subclinical keratoconus and inflammatory molecules from tears. Br J Ophthalmol 2009 Jun;93(6):820-24.
2. Lema I, Durán JA, Ruiz C, Díez-Feijoo E, Acera A, Merayo J. Inflammatory response to contact lenses in patients with keratoconus compared with myopic subjects. Cornea 2008 Aug;27(7):758-63.
3. Lema I, Durán JA. Inflammatory molecules in the tears of patients with keratoconus. Ophthalmology 2005 Apr;112(4): 654-59.
4. Rabinowitz YS. Keratoconus. Surv Ophthalmol 1998;42: 297-319.
5. Krachmer JH, Feder RS, Belin MW. Keratoconus and related noninflammatory corneal thinning disorders. Surv Ophthalmol 1984;28:293-322.
6. Hockwin O, Leman S, Orhloff C. Investigations on lens transparency and its disturbances by microdensitometric analyses of Scheimpflug photographs. Curr Eye Res 1984;3:15-22.
7. Barkana Y, Gerber Y, Elbaz U, et al. Central corneal thickness measurement with the Pentacam Scheimpflug system, optical low-coherence reflectometry pachymeter and ultrasound pachymetry. J Cataract Refract Surg 2005;31:1729-35.
8. Available from http://www.pentacam.com/sites/messprinzip.php. Assessed 5/March/2011.
9. Meek KM, Tuft SJ, Huang Y, Gill PS, Hayes S, Newton RH, Bron AJ. Changes in collagen orientation and distribution in keratoconus corneas. Invest Ophthalmol Vis Sci 2005;46: 1948-56.
10. Daxer A, Fratzl P. Collagen fibril orientation in the human corneal stroma and its implication in keratoconus. Invest Ophthalmol Vis Sci 1997;38:121-29.
11. Davis WR, Raasch TW, Mitchell GL, et al. Corneal asphericity and apical curvature in children: A cross-sectional and longitudinal evaluation. Invest Ophthalmol Vis Sci 2005;46: 1899-906.
12. Holmes-Higgin DK, Baker PC, Burris TE, Silvestrini TA. Characterization of the aspheric corneal surface with intrastromal corneal ring segments. J Refract Surg 1999;15:520-28.
13. Eghbali F, Yeung KK, Maloney RK. Topographic determination of corneal asphericity and its lack of effect on the refractive outcome of radial keratotomy. Am J Ophthalmol 1995;275-80.
14. Yebra-Pimentel E, González-Méijome JM, Cerviño A, et al. Asfericidad corneal en una población de adultos jóvenes. Implicaciones clínicas. Arch Soc Esp Oftalmol 2004;79: 385-92.
15. Cantú R, Rosales MA, Tepichín E, Curioca A, Montes V, Ramirez-Zavaleta JG. Objective quality of vision in presbyopic and nonpresbyopic patients after pseudoaccommodative advanced surface ablation. J Refract Surg 2005 Sep-Oct;21(5 Suppl):S603-05.
16. Torquetti L, Ferrara P. Corneal asphericity changes after implantation of intrastromal corneal ring segments in keratoconus. J Emmetropia 2010;1:178-81.
17. Ferrara P, Torquetti L. The new Ferrara ring nomogram: The importance of corneal asphericity in ring selection. Vision Panamerica 2010 Sep;92-95. Available from: http://www.paao.org/pdf/vpa/9.3_vpa.pdf

18. Alió JL, Piñero DP, Alesón A, Teus MA, Barraquer RI, Murta J, et al. Keratoconus-integrated characterization considering anterior corneal aberrations, internal astigmatism, and corneal biomechanics. J Cataract Refract Surg 2011 Mar;37(3):552-68.

19. Kim H, Joo CK. Measure of keratoconus progression using Orbscan II. J Refract Surg 2008;24:600-05.

20. McMahon TT, Szczotka-Flynn L, Barr JT, Anderson RJ, Slaughter ME, Lass JH, et al. CLEK study group: A new method for grading the severity of keratoconus: The keratoconus severity score (KSS). Cornea 2006 Aug;25(7):794-800.

21. Krumeich JH, Daniel J, Knulle A. Live-epikeratophakia for keratoconus. J Cataract Refract Surg 1998;24:456-63.

22. Pinero D, Alio J, Aleson A, Vergara ME, Miranda M. Corneal volume, pachymetry and correlation of anterior and posterior corneal shape in subclinical and different stages of clinical keratoconus. J Cataract Refract Surg 2010;36:814-25.

23. Emre S, Doganay S, Yologlu S. Evaluation of anterior segment parameters in keratoconic eyes measured with Pentacam system. J Cataract Refract Surg 2007;33:1708-12.

24. Fontes BM, Ambrosio Jr R, Jardim D, Velarde GC, Nose W. Corneal biomechanical metrics and anterior segment parameters in mild keratoconus. Ophthalmology 2010;117:673-79.

25. Ambrosio R Jr, Alonso RS, Luz A, Coca Velarde LG. Corneal-thickness spatial profile and corneal-volume distribution: Tomographic indices to detect keratoconus. J Cataract Refract Surg 2006;32:1851-59.

ABOUT THE AUTHORS

Leonardo Torquetti (Corresponding Author)

Department of Cornea, Paulo Ferrara Eye Clinic, Minas Gerais, Brazil
e-mail: leonardotorqueti@yahoo.com.br

Guilherme Ferrara

Department of Cornea and Keratoconus, Paulo Ferrara Eye Clinic Minas Gerais, Brazil

Paulo Ferrara

Department of Cornea and Keratoconus, Paulo Ferrara Eye Clinic Minas Gerais, Brazil