· Original article ·

Corneal aberrations in normal and keratoconic eyes using an OPD-Scan Ⅱ

Mohammad Naderan[1], *Ali Jahanrad*[2], *Mahgol Farjadnia*[3]

[1]School of Medicine, Tehran University of Medical Sciences, Tehran 1417653761, Iran
[2]AJA University of Medical Sciences, Tehran 1411718541, Iran
[3]School of Medicine, Iran University of Medical Sciences, Tehran 1449614535, Iran
Correspondence to: Mohammad Naderan. School of Medicine, Tehran University of Medical Sciences, Tehran 1417653761, Iran. Moh@Naderan.com
Received: 2017-02-18 Accepted: 2018-03-12

OPD-Scan Ⅱ检测正常眼和圆锥角膜眼的角膜像差

Mohammad Naderan[1], Ali Jahanrad[2], Mahgol Farjadnia[3]
(作者单位:[1]1417653761 伊朗,德黑兰,德黑兰医科大学医学院;[2]1411718541 伊朗,德黑兰,AJA 医科大学;[3]1449614535 伊朗,德黑兰,伊朗医科大学医学院)
通讯作者:Mohammad Naderan. Moh@Naderan.com

摘要

目的:评估正常眼和圆锥角膜眼的角膜高阶像差(HOAs)。

方法:使用 OPD-Scan Ⅱ波前像差分析仪,评估 80 例 80 眼圆锥角膜(KC)患者和 91 例正常眼角膜表面参数。对两组受试者的 Zernike 系数第三阶到第六阶,原始彗差均方根(RMS),彗差和总高阶像差进行比较分析。

结果:圆锥角膜眼和正常眼间测得的像差具有显著差异(P<0.001),相较于正常眼,圆锥角膜患者像差参数显著较高(P<0.001)。

结论:通过 OPD-Scan Ⅱ测量角膜波前像差在圆锥角膜眼中显著高于正常眼。

关键词:像差;正常眼;圆锥角膜;OPD-Scan Ⅱ;波前

引用:Naderan M, Jahanrad A, Farjadnia M. OPD-Scan Ⅱ检测正常眼和圆锥角膜眼的角膜像差. 国际眼科杂志 2018;18(4):599-601

Abstract

• AIM: To evaluate higher order aberrations (HOAs) of the corneal surface in normal and keratoconic eyes.

• METHODS: Using an OPD-Scan Ⅱ wavefront analyzer, aberrometric parameters of the corneal surface in one eye of 80 patients with keratoconus (KC) and 91 participants with normal eyes were evaluated. The Zernike coefficients from third- to sixth-order as well as root mean square (RMS) of primary coma, coma-like aberrations, and total HOA were calculated and compared between both groups.

• RESULTS: Statistically significant differences were found in all aberrometric parameters between the measurements of the KC and normal participants (P<0.001). All of the aberrometric parameters were significantly higher in the KC patients compared to the normal group (P<0.001).

• CONCLUSION: Corneal wavefront measurements by means of OPD-Scan Ⅱ were significantly higher in keratoconic corneas than normal corneas.

• KEYWORDS: aberrations; healthy eyes; keratoconus; OPD-Scan Ⅱ; wavefront analysis
DOI:10.3980/j.issn.1672-5123.2018.4.01

Citation: Naderan M, Jahanrad A, Farjadnia M. Corneal aberrations in normal and keratoconic eyes using an OPD-Scan Ⅱ. *Guoji Yanke Zazhi* (*Int Eye Sci*) 2018;18(4):599-601

INTRODUCTION

Keratoconus (KC) is a usually bilateral corneal disorder, characterized by progressive corneal thinning and protrusion leading to irregular astigmatism[1-2]. The irregularity of the cornea induces corneal aberration that is among the most important factors of visual impairment in keratoconic patients[3]. The irregular astigmatism in KC patients results in increased higher order aberrations (HOAs) and subsequently vision deterioration[4-5]. Evaluation of the lower and higher order corneal aberrations has been used as a screening method to diagnose, grade the severity, and predict visual performance of KC corneas[6-7]. A significant difference in the refractive indices between air and cornea makes the anterior surface of the cornea the most influential surface in determining corneal aberration. Therefore, several studies have been conducted to evaluate the aberration induced by this surface and investigate whether these aberrations differ from those in normal eyes. Results of different studies showed that corneal aberrations of keratoconic eyes are significantly higher than these indices in normal eyes[5,7-15]. In this study, we aimed to evaluate corneal HOAs in normal and keratoconic eyes in more detail by using an OPD-Scan Ⅱ wavefront analyzer.

SUBJECTS AND METHODS

This was a prospective observational comparative study conducted at the cornea clinic of the AJA University Hospital, Tehran, Iran in 2015 and 2016. This study was in accordance

with the tenets of the Declaration of Helsinki and the ethics committee of our clinic approved the study design and protocol. Verbal informed consent was obtained from those who agreed to participate in the study. Participants were divided into two groups of KC and normal controls. The diagnosis of the KC was based on corneal topographic map and anterior and posterior elevation pattern by optical path difference - Scan Ⅱ (OPD - Scan Ⅱ; Nidek Co. Ltd., Gamagori, Japan) as well as at least one of the clinical diagnostic signs such as Fleischer ring, Vogt's striae, Munson's sign, Rizzuti's sign, conical protrusion of the cornea at the apex, and corneal thinning by means of slit - lamp biomicroscopy. The normal group consisted eyes of the patients attended at the clinic for refractive surgeries with no signs of KC or any other ocular diseases except refractive errors. Subjects with history of ocular surgery or trauma, corneal cross linking, and other eye diseases such as dry eye, corneal scars, as well as pregnancy or nursing were excluded from the study. Corneal aberrometry and wavefront measurements were performed using the OPD-Scan Ⅱ. The OPD-Scan Ⅱ aberrometer by using Placido-based topography and principle of scanning retinoscopy/skiascopy measures corneal and whole eye aberrations. Patients wearing contact lenses were asked to stop using them at least three weeks before performing aberrometry. To avoid any possible diurnal variations, the aberrometry examinations were performed between 9 and 12 a.m. Only the right eye of each participant was examined. All the OPD - Scan measurements were performed under dark examination for a 6 mm pupil diameter centered on the corneal vertex, and after 2min of dark adaptation. For each patient, three consecutive measurements were taken and the average values were recorded in the database. The Zernike coefficients for wavefront parameters from third- to sixth-order were calculated. Furthermore, root mean square (RMS) for primary coma (Z_3^{-1} and Z_3^1 terms), coma - like aberrations (Z_3^{-1}, Z_3^1, Z_5^{-1}, and Z_5^1 terms) corresponding with primary and secondary coma, and total HOA (all terms included in the 3rd, 4th, 5th, and 6th order) were calculated. Detailed information regarding the Zernike polynomials has been discussed elsewhere[16].

Statistical Analysis Statistical analysis was performed using IBM SPSS Statistics software (Version 22; IBM Inc., New York, USA). The data are presented as mean ± SD. The normal distribution of the data was rejected using the Kolmogorov - Smirnov test. The chi - square test and the Mann- Whitney *U* test were used to compare categorical variables and continuous variables between the groups, respectively. A *P* value less than 0.05 was considered statistically significant.

RESULTS

There were 80 patients with KC and 91 normal participants. The mean age of the KC patients and the normal participants was 30.1±6.3 and 29.8±7.3y, respectively. There were 47 (58.8%) males in the KC group and 50 (54.9%) males in the normal group. No significant differences were observed regarding age and sex of the patients with KC and normal participants (*P*=0.380 and 0.365, respectively). In the KC group, there were 38 patients (47.5%) with mild disease, 25 patients (31.2%) with moderate disease, and 17 patients (21.2%) with severe disease based on the McMahon's Keratoconus Severity Score[17-18]. Table 1 presents the clinical findings of the study population.

Table 1 Demographic and clinical findings of the keratoconus patients and normal participants

Parameter	Keratoconus (*n*=80)	Normal (*n*=91)	*P*
Age (y)	30.1±6.3	29.8±7.3	0.380
Sex (M)	47(58.8%)	50(54.9%)	0.365
Mean K (D)	49.7±3.4	44.1±1.1	<0.001
CCT (μm)	453±38	545±49	<0.001
Astigmatism (D)	3.89±1.87	0.91±0.65	<0.001
Sphere (D)	-2.90±3.74	-0.68±2.57	<0.001
Cylinder (D)	-3.76±2.80	-1.48±1.82	<0.001

Mann-Whitney *U* test; Data are presented as mean ± SD; CCT: Central corneal thickness; D: Diopter; K: Keratometry.

As clearly shown, all the ophthalmic parameters were significantly different between the KC and normal participants (*P*<0.001, all comparisons). Table 2 shows the comparison of the corneal aberration data in keratoconic and normal eyes. All aberrometric parameters were significantly higher in the KC patients than the normal group (*P* < 0.001, all comparisons).

DISCUSSION

Optical aberrations could cause visual impairments[19]. In addition to defocus and astigmatism as the well-known reasons for visual distortions and their correction as the goal of refractive surgeries for decades, HOAs have become important in interpreting the visual status of ophthalmic patients. It has been postulated that the complaint of halo, glare and decreased contrast sensitivity could be attributed to the HOAs[20]. Based on our findings, all the HOAs in the keratoconic eyes were significantly higher than those of the normal eyes. This finding is in consistent with that of other researchers who demonstrated that KC could change the refractive aspects of the cornea and consequently the induced HOAs[10]. Chen *et al*[10] used Orbscan Ⅱz to measure corneal aberration in keratoconic eyes and compared them with those of normal ones, and reported higher HOAs in keratoconic eyes. Schlegel *et al*[8] by using the OPD-Scan Ⅲ, found a significantly higher corneal toricity in both KC and keratoconus suspect (KCS) eyes compared with the normal group. In a study by Nakagawa *et al*[9] on 24 normal and 28 keratoconic eyes using a rotating Scheimpflug camera, scientists reported higher HOAs in keratoconic than normal eyes. They also concluded that the residual irregular astigmatism in keratoconic eyes even after wearing rigid gas permeable (RGP) contact lenses could be attributed to the HAOs and by measuring these indices, residual irregular astigmatism could be estimated[9]. Lim *et al*[11] by using

Table 2 Comparison of the corneal aberration data in keratoconic and normal eyes

Parameter	Keratoconus (n=80)	Normal (n=91)	P
Z_3^1(Horizontal coma)	0.183±0.412	0.054±0.623	<0.001
Z_3^{-1}(Vertical coma)	−1.914±1.781	0.065±0.253	<0.001
Z_3^3(Horizontal trefoil)	−0.245±0.583	0.075±0.325	<0.001
Z_3^{-3}(Vertical trefoil)	0.086±1.458	0.032±0.125	<0.001
Z_4^0(Spherical aberration)	−0.532±1.432	0.23 ±0.231	<0.001
Z_4^2(Secondary horizontal astigmatism)	−0.467±1.125	−0.09 ±0.123	<0.001
Z_4^{-2}(Secondary vertical astigmatism)	−0.567±1.352	0.025±0.128	<0.001
Z_4^4(Horizontal tetrafoil)	−0.498±0.843	0.187±0.153	<0.001
Z_4^{-4}(Vertical tetrafoil)	−0.268±0.712	0.015±0.348	<0.001
Z_5^1(Secondary horizontal coma)	0.139±0.387	0.035±0.074	<0.001
Z_5^{-1}(Secondary vertical coma)	1.153±0.941	−0.082±0.345	<0.001
Z_6^0(Secondary spherical aberration)	0.064±0.181	−0.035±0.055	<0.001
Coma(RMS)	2.353±0.793	0.237±0.125	<0.001
Coma-like(RMS)	2.401±0.756	0.242±0.214	<0.001
HOA(RMS)	2.645±1.432	0.435±0.118	<0.001

Data are presented as mean±SD; Mann-Whitney U test; RMS: Root mean square.

Zywave aberrometer reported significantly higher values of the HOAs in KC and KCS patients than normal patients. Bühren *et al*[7] reported similar results. In another study, Piñero *et al*[12] investigated corneal aberrations in keratoconic and normal eyes using the Pentacam system and found higher aberrations values in keratoconic than normal eyes. In conclusion, the study findings provide data that support greater higher and lower order aberrations in keratoconic eyes than in normal eyes in a population of the Middle East geographical region with Caucasian ethnicity. Although there have been attempts regarding the standardization of definitions and conventions for a consistent report of ocular aberrations, they do not seem to be sufficient and further detailed protocols are required to harmonize the outcomes of different commercially available instruments.

REFERENCES

1 Romero-Jiménez M, Santodomingo-Rubido J, Wolffsohn JS. Keratoconus: a review. *Cont Lens Anterior Eye* 2010;33(4):157-166

2 Naderan M, Shoar S, Rezagholizadeh F, Zolfaghari M, Naderan M. Characteristics and associations of keratoconus patients. *Cont Lens Anterior Eye* 2015;38(3):199-205

3 Applegate RA, Hilmantel G, Howland HC, Tu EY, Starck T, Zayac EJ. Corneal first surface optical aberrations and visual performance. *J Refract Surg* 2000;16(5):507-514

4 Schlegel Z, Lteif Y, Bains HS, Gatinel D. Total, corneal, and internal ocular optical aberrations in patients with keratoconus. *J Refract Surg* 2009;25(10 Suppl):S951-S957

5 Gordon-Shaag A, Millodot M, Ifrah R, Shneor E. Aberrations and topography in normal, keratoconus-suspect, and keratoconic eyes. *Optom Vis Sci* 2012;89(4):411-418

6 Alió JL, Shabayek MH. Corneal higher order aberrations: a method to grade keratoconus. *J Refract Surg* 2006;22(6):539-545

7 Bühren J, Kook D, Yoon G, Kohnen T. Detection of subclinical keratoconus by using corneal anterior and posterior surface aberrations and thickness spatial profiles. *Invest Ophthalmol Vis Sci* 2010;51(7):3424-3432

8 Schlegel Z, Hoang-Xuan T, Gatinel D. Comparison of and correlation between anterior and posterior corneal elevation maps in normal eyes and keratoconus-suspect eyes. *J Cataract Refract Surg* 2008;34(5):789-795

9 Nakagawa T, Maeda N, Kosaki R, Hori Y, Inoue T, Saika M, Mihashi T, Fujikado T, Tano Y. Higher-order aberrations due to the posterior corneal surface in patients with keratoconus. *Invest Ophthalmol Vis Sci* 2009;50(6):2660-2665

10 Chen M, Yoon G. Posterior corneal aberrations and their compensation effects on anterior corneal aberrations in keratoconic eyes. *Invest Ophthalmol Vis Sci* 2008;49(12):5645-5652

11 Lim L, Wei RH, Chan WK, Tan DT. Evaluation of higher order ocular aberrations in patients with keratoconus. *J Refract Surg* 2007;23(8):825-828

12 Piñero DP, Alió JL, Aleson A, Escaf M, Miranda M. Pentacam posterior and anterior corneal aberrations in normal and keratoconic eyes. *Clin Exp Optom* 2009;92(3):297-303

13 Safarzadeh M, Nasiri N. Anterior segment characteristics in normal and keratoconus eyes evaluated with a combined Scheimpflug/Placido corneal imaging device. *J Curr Ophthalmol* 2016;28(3):106-111

14 Colak HN, Kantarci FA, Yildirim A, Tatar MG, Goker H, Uslu H, Gurler B. Comparison of corneal topographic measurements and high order aberrations in keratoconus and normal eyes. *Cont Lens Anterior Eye* 2016;39(5):380-384

15 Feizi S, Einollahi B, Raminkhoo A, Salehirad S. Correlation between corneal topographic indices and higher-order aberrations in keratoconus. *J Ophthalmic Vis Res* 2013;8(2):113-118

16 Thibos LN, Bradley A, Hong X. A statistical model of the aberration structure of normal, well-corrected eyes. *Ophthalmic Physiol Opt* 2002;22(5):427-433

17 McMahon TT, Szczotka-Flynn L, Barr JT, Anderson RJ, Slaughter ME, Lass JH, Iyengar SK. A new method for grading the severity of keratoconus: the keratoconus severity score (KSS). *Cornea* 2006;25(7):794-800

18 Naderan M, Shoar S, Kamaleddin MA, Rajabi MT, Naderan M, Khodadadi M. Keratoconus clinical findings according to different classifications. *Cornea* 2015;34(9):1005-1011

19 Applegate RA, Thibos LN, Hilmantel G. Optics of aberroscopy and super vision. *J Cataract Refract Surg* 2001;27(7):1093-1107

20 Bailey MD, Mitchell GL, Dhaliwal DK, Boxer Wachler BS, Zadnik K. Patient satisfaction and visual symptoms after laser in situ keratomileusis. *Ophthalmology* 2003;110(7):1371-1378