Changes of wavefront aberrations and corneal surface regularity in dry eye patients measured with OPD Scan III

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Abstract

Background

To evaluate changes of wavefront aberrations and corneal surface regularity in dry eye (DE) patients with OPD Scan-III (NIDEK, JPN).

Methods

Twenty-seven right eyes of 27 DE patients and 23 right eyes of normal subjects were included. The examinations for ocular surface including the Ocular Surface Disease Index (OSDI), tear film breakup time (TBUT) and corneal fluorescein staining (CFS). OPD Scan-III was used to measure anterior corneal aberrations including total corneal aberrations, high order aberration (HOA), spherical aberration (SA), coma and trefoil aberration, standard deviation of corneal power (SDP), surface regularity index (SRI) and surface asymmetry index (SAI). Statistical analysis were assessed with one sample t-test. Correlations between those parameters were also analyzed.

Results

Wavefront aberrations parameters including total corneal aberrations, HOA, SA, coma and trefoil in DE group were significantly higher than in normal group ($P < 0.05$). Corneal surface regularity parameters including SRI and SAI in DE group were significantly higher than in normal group ($P < 0.05$). TBUT had negative correlations with total corneal aberrations and coma ($P < 0.05$). Both CFS scores and central CFS scores had no correlations with wavefront aberrations parameters and had positive correlations with SDP and SRI (P 0.05). Central CFS scores also positively correlated with SAI ($P < 0.05$).

Conclusions

Wavefront aberrations and corneal surface irregularity are increased in DE patients. OPD Scan III was have potential to be a new instrument to evaluate the severity of DE and monitor the treatment of DE.

Background

Dry eye (DE) is gradually considered as a public health problem and one of the most frequent reasons for seeking eye care[1]. According to the Dry Eye Work Shop II (DEWS II) report in 2017, DE is defined as a multifactorial disease of the ocular surface characterized by a loss of homeostasis of the tear film, and accompanied by ocular symptoms, in which tear film instability and hyperosmolarity, ocular surface inflammation and damage, and neurosensory abnormalities play etiological roles[2]. The ocular surface including tear film which serves as the first refractive surface of the eye and is an important element in

preserving visual quality[3]. Also, corneal fluorescein staining is a common sign in DE patients which lead to the corneal surface irregularity and might have effects on the visual quality[4].

Visual disturbance is also a common ocular symptom of DE patients and several studies evaluating the visual disturbance of DE patients based on the tear film instability and corneal surface irregularity[5, 6]. Studies concluded that DE patients have larger wavefront aberration values than normal patients[7, 8]. It have been demonstrated that there are increased high order aberration (HOA) in patients with DE and artificial tears could improve the visual quality[9, 10]. Currently, there are multiple aberrometers to measure HOA while there still no gold standard measurement. Different aberrometers based on variety of principles such as ray tracing, Hartmann-Shack, Tscherning, and automatic retinoscopy. Therefore, a meaningful measurement for HOA evaluation in DE patients is urgently needed[11]. As for corneal irregularities in DE patients, studies showed that the indices of surface regularity index (SRI) and surface asymmetry index (SAI) could be used as objective diagnostic method for DE as well as for evaluating the severity of this disease[12, 13].

OPD Scan III (Nidek, Tokyo, Japan) is a multifunctional and comprehensive device which could not only measures the shape and curvature of the cornea but also evaluate the wavefront aberrations at the same time[14]. In this study, we compared the cornea surface regularity and wavefront aberrations of DE patients to the normal people using OPD Scan III and aimed to evaluate the appllication of OPD Scan III in diagnosis and monitor DE.

Methods

This observational study was conducted in 2019 which was approved by the biomedical ethics committee of Peking University and adhered to the tenets of the Declaration of Helsinki. Informed consents were obtained from all patients before the study.

Patient selection

We enrolled 27 right eyes of 27 DE patients and 23 right eyes of 23 normal subjects. Patients were diagnosed as DE according to the criteria provided by the Dry Eye Workshop (DEWS)[15]: (1) the Ocular Surface Disease Index (OSDI) > 13; (2) tear film breakup time (TBUT) ≤ 5 seconds or 5 seconds < TBUT ≤ 10 seconds with positive corneal fluorescein staining (CFS). The exclusion criteria are as follows subjects if they were under the age of 18 or over the age of 65; high myopia; a history of ocular surgery; any type of corneal scarring such as dystrophies or infections or any other ocular disease might have effects on the visual quality.

Questionnaire and Clinical evaluation

All subjects underwent a complete evaluation of the ocular surface. Subjective ocular symptoms of patients were evaluated by the OSDI questionnaire. Best-corrected distance visual acuity (BCVA) of all the subjects were registered. Measurement of TBUT and CFS was facilitated by viewing with a blue exciter

filter after instilling sodium fluorescein onto the bulbar conjunctiva with a fluorescein sodium ophthalmic strip (Liaoning Meizilin Pharmaceutical Co., Ltd.)[16]. CFS score was quantified according to the system provided by National Eye Institute (grades 0–15)[17]. Central CFS score was also recorded considering the central cornea overlying the entrance pupil is important in term of optical quality[18].

The examinations by OPD scan III aberrometer (NIDEK Co. Ltd., Gamagori, Japan) was performed in a dark room. OPD Scan III is a multifunctional device which projects Placido ring images onto the cornea for topographic measurements. The reflected image is captured

with a camera, and image analysis is done to determine the shape of the cornea. The device is also capable of wavefront aberration analysis using Zernike polynomials. In our study, it was used to measure anterior corneal aberrations over 4 mm analytical zones, including total corneal aberration, HOA, spherical aberration (SA), coma aberration and trefoil aberration root mean square (RMS). The corneal surface shape parameters including standard deviation of corneal power (SDP), SRI and SAI were attained.

Statistical analysis

Statistical analysis was performed with SPSS 22.0 software (SPSS, Inc., Chicago, IL). All values were given as the mean ± standard deviation. Differences of gender among groups were tested using Chi-Square test. Normality of data was confirmed using Kolmogarov–Smirnoff test. One sample t-tests were used for statistical analysis to compare data between two groups when conformed normality. Nonparametric tests were used for statistical analysis when the data did not conform normality. A Pearson correlation test was used to evaluate the correlation between OPD scan III parameters and the results of the ocular surface evaluation. A P value less than 0.05 was considered statistically significant.

Results

In this study, we enrolled 27 eyes of 27 DE patients (mean age 43.09±14.35 years) and 23 eyes of 23 normal subjects (mean age 46.13±13.02 years). The demographic data and results of ocular surface parameters are presented in Table 1. Age and gender of each group were matched (P=0.455 and P=0.468). The comparison results showed that logMAR BCVA in DE group significantly higher than in normal group (P=0.002). Also the results showed that OSDI scores of patients in DE group were significantly higher than in normal group (P<0.001) and TUBT of patients in DE group were significantly shorter than in normal group (P<0.001).

The comparisons of OPD scan III parameters between two groups were showed in Table 2. Wavefront aberrations including total corneal aberrations, HOAs, SA, coma and trefoil in DE group were all significantly higher than in normal group (P<0.05). Corneal surface regularity parameters including SRI and SAI in DE group were both significantly higher than in normal group (P<0.05). No differences was found in SDP in DE group and normal group (P=0.272).

The correlations between the OPD scan III parameters and ocular surface parameters including logMAR BCVA, TBUT, CFS scores and central CFS scores were evaluated in all the subjects and the results was showed in Table 3. It showed that logMAR BCVA had strong positive correlations with total corneal aberrations, HOAs, Coma, SRI and SAI (all P<0.001). Moderate positive correlations were showed between logMAR BCVA and trefoil, SA and SDP (all P<0.05). Besides, TBUT had a strong negative correlation with SA(P<0.001) and moderate negative correlations with total corneal aberrations and coma (both P<0.05). Interestingly, TBUT showed no correlations with corneal surface regularity parameters such as SDP and SAI and only a slightly negative correlation was found between TBUT and SRI. Both CFS scores and central CFS scores had no correlations with wavefront aberrations parameters including total corneal aberrations, HOA, Coma, trefoil and SA. However, CFS scores had a moderate positive correlation with SDP (P=0.015) and a strong positive correlation with SRI (P=0.002) . Central CFS scores showed strong positive correlations with SDP and SRI and a moderate positive correlation with SAI (P=0.004, P=0.001 and P=0.029).

Discussion

DE is characterized by symptoms of ocular dryness and discomfort, which can affect the visual performance. We conducted the present study to assess changes of wavefront aberrations and corneal surface regularity in DE patients measured with OPD Scan III. The comparisons between DE patients and normal subjects were performed and we also investigated the correlations between wavefront aberration parameters, corneal surface regularity parameters and ocular surface parameters respectively.

Visual disturbance is a main symptom of DE patients and common visual complaints associated with DE include fluctuating vision with blinking, blurred vision, glare and eye fatigue[6, 19]. In our study, logMAR BCVA was significantly higher in DE group than normal group. Besides, the logMAR BCVA positive correlated to all the wavefront aberration parameters and corneal surface regularity parameters which confirmed that the main courses of visual disturbance in DE patients could be tear film instability and ocular surface damage[5].

The stability of tear film plays an important role in the condition of visual performance. Change in optical aberrations created by tear-film breakup contributes to the reduction in retinal image quality[20]. This alteration in the visual performance is directly related to increased optical HOA and a direct link has been demonstrated between severity of the dry eye and the level of HOA[21]. TBUT is represented the tear film stability and previous study showed changes in some Zernike aberrations such as vertical coma and SA after blinking are associated with the changes in tear menisci and TBUT[22]. In our study, the wavefront aberrations parameters measured with OPD Scan III including total corneal aberrations, HOAs, coma, trefoil and SA in DE group were all significantly higher than in normal group. Besides TBUT had a strong negative correlation with SA and moderate negative correlations with total corneal aberrations and coma.

The SRI and SAI measured by corneal topography have been shown to be significantly worse in patients with DE than in normal subjects. The results of our study were consistent with previous study. Besides, it

showed that the CFS scores as well as central CFS scores did not correlate with wavefront aberration parameters while they are correlated well with SRI and SAI. In clinical practice, fluorescein dye is frequently used for ocular staining, and dry eye commonly appears as positive corneal fluorescein staining which showed corneal surface irregularity in these areas and associated with SRI and SAI.

According to the study, tear film instability and ocular surface damage are thought to be main courses of visual disturbance which resulted in the increased wavefront aberrations and corneal surface irregularity[24]. However, few study focused on evaluating both wavefront aberrations and corneal surface irregularity in DE patients. OPD Scan III is a multifunctional device that measures the shape and curvature of the cornea and wavefront aberrations which could provide more comprehensive evaluations for DE patients and might have potential to evaluate the severity of DE or monitor the treatment of DE[14].

There are some limitations in current study. The sample size is small and further larger sample study is still needed in the future. There are lots of parameters from OPD Scan III examinations and we only evaluated the wavefront aberrations and corneal surface regularity parameters and others might need be further investigated.

In conclusion, the wavefront aberrations and corneal surface irregularity are increased in DE patients. The OPD Scan III might have potential to be a new instrument to evaluate the severity of DE and monitor the treatment of DE in clinical.

Abbreviations

DE
dry eye
BCVA
best-corrected distance visual acuity
OSDI
ocular surface disease index
TFBUT
tear film breakup time
HOA
high order aberration
RMS
aberration root mean square
SDP
standard deviation of corneal power
SRI
surface regularity index
SAI
surface asymmetry index

SA
spherical aberration

Declarations

Ethics approval and consent to participate

This study was approved by the Medical Ethics Committee of Peking University Third Hospital and followed the tenets of Declaration of Helsinki. Written informed consents were obtained from all patients before the study.

Consent for publication

Not applicable.

Availability of data and materials

The datasets used and/or analyzed during the current study available from the corresponding author on reasonable request.

Competing interests

The authors have declared that no competing interests exist.

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Authors' contributions

HQ and RJL have made contributions to the design of the study.YFG and YYL have made contributions to the literature research and data acquisition. RJL and BKM collected and analyzed the patient data. RJL,BKM,YFG and YYL made the manuscript preparations. RJL drafted the work and revised by HQ and BKM. RJL and BKM contributed equally to this work and they should be regarded as co-first author. All authors have read and approved the manuscript.

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References

1. Farrand KF, Fridman M, Stillman IO, Schaumberg DA. Prevalence of Diagnosed Dry Eye Disease in the United States Among Adults Aged 18 Years and Older. AM J OPHTHALMOL. 2017;182:90–8.
2. Craig JP, Nichols KK, Akpek EK, Caffery B, Dua HS, Joo CK, Liu Z, Nelson JD, Nichols JJ, Tsubota K, et al. TFOS DEWS II Definition and Classification Report. OCUL SURF. 2017;15(3):276–83.
3. Rieger G. The importance of the precorneal tear film for the quality of optical imaging. Br J Ophthalmol. 1992;76(3):157–8.
4. Kaido M, Matsumoto Y, Shigeno Y, Ishida R, Dogru M, Tsubota K. Corneal fluorescein staining correlates with visual function in dry eye patients. Invest Ophthalmol Vis Sci. 2011;52(13):9516–22.
5. Koh S. Mechanisms of Visual Disturbance in Dry Eye. CORNEA. 2016;35(Suppl 1):83–8.
6. Benitez-Del-Castillo J, Labetoulle M, Baudouin C, Rolando M, Akova YA, Aragona P, Geerling G, Merayo-Lloves J, Messmer EM, Boboridis K: **Visual acuity and quality of life in dry eye disease**: **Proceedings of the OCEAN group meeting**. *OCUL SURF* 2017, **15**(2):169–178.
7. Montes-Mico R, Caliz A, Alio JL. Wavefront analysis of higher order aberrations in dry eye patients. J REFRACT SURG. 2004;20(3):243–7.
8. Denoyer A, Rabut G, Baudouin C. Tear film aberration dynamics and vision-related quality of life in patients with dry eye disease. OPHTHALMOLOGY. 2012;119(9):1811–8.
9. Huang FC, Tseng SH, Shih MH, Chen FK. Effect of artificial tears on corneal surface regularity, contrast sensitivity, and glare disability in dry eyes. OPHTHALMOLOGY. 2002;109(10):1934–40.
10. Lu N, Lin F, Huang Z, He Q, Han W. Changes of Corneal Wavefront Aberrations in Dry Eye Patients after Treatment with Artificial Lubricant Drops. J OPHTHALMOL. 2016;2016:1342056.
11. Charman WN. Wavefront aberration of the eye: a review. Optom Vis Sci. 1991;68(8):574–83.
12. Liu Z, Pflugfelder SC. Corneal surface regularity and the effect of artificial tears in aqueous tear deficiency. OPHTHALMOLOGY. 1999;106(5):939–43.
13. Liu Z, Xie Y, Zhang M, Pflugfelder SC. [The effect of artificial tears on corneal surface regularity in dry eye]. Zhonghua Yan Ke Za Zhi. 2000;36(2):131–4.
14. McAlinden C, Moore JE. Higher order aberrations using the NIDEK OPD-Scan and AMO WaveScan. J REFRACT SURG. 2010;26(8):605–8.
15. **Methodologies to diagnose and monitor dry eye disease: report of the Diagnostic Methodology Subcommittee of the International Dry Eye WorkShop (2007)**. *OCUL SURF* 2007, 5(2):108–152.
16. **The definition and classification of dry eye disease: report of the Definition and Classification Subcommittee of the International Dry Eye WorkShop (2007)**. *OCUL SURF* 2007, 5(2):75–92.
17. Lemp MA. Report of the National Eye Institute/Industry workshop on Clinical Trials in Dry Eyes. CLAO J. 1995;21(4):221–32.
18. Koh S, Maeda N, Ikeda C, Asonuma S, Ogawa M, Hiraoka T, Oshika T, Nishida K. The Effect of Ocular Surface Regularity on Contrast Sensitivity and Straylight in Dry Eye. Invest Ophthalmol Vis Sci. 2017;58(5):2647–51.

19. Goto E, Yagi Y, Matsumoto Y, Tsubota K. Impaired functional visual acuity of dry eye patients. AM J OPHTHALMOL. 2002;133(2):181–6.
20. Montes-Mico R. Role of the tear film in the optical quality of the human eye. J Cataract Refract Surg. 2007;33(9):1631–5.
21. Koh S, Maeda N, Kuroda T, Hori Y, Watanabe H, Fujikado T, Tano Y, Hirohara Y, Mihashi T. Effect of tear film break-up on higher-order aberrations measured with wavefront sensor. AM J OPHTHALMOL. 2002;134(1):115–7.
22. Xu J, Bao J, Deng J, Lu F, He JC. Dynamic changes in ocular Zernike aberrations and tear menisci measured with a wavefront sensor and an anterior segment OCT. Invest Ophthalmol Vis Sci. 2011;52(8):6050–6.
23. Ozkan Y, Bozkurt B, Gedik S, Irkec M, Orhan M. Corneal topographical study of the effect of lacrimal punctum occlusion on corneal surface regularity in dry eye patients. EUR J OPHTHALMOL. 2001;11(2):116–9.
24. Koh S, Tung CI, Inoue Y, Jhanji V. Effects of tear film dynamics on quality of vision. Br J Ophthalmol. 2018;102(12):1615–20.

Tables

Table 1. Demographic and ocular surface characteristics of study subjects in DE and normal groups.

	Dry eye	Normal	p value
Numbers of Patients (N)	27	23	/
Gender (M/F)	7/20	4/19	0.468
Age (years)	43.09±14.35	46.13±13.02	0.455
logMAR BCVA	0.099±0.126	0.005±0.021	0.002
OSDI scores	39.73±15.00	6.41±3.59	0.001
TBUT (S)	4.22±2.49	11.74±3.37	0.001
CFS Scores	8.07±5.20	0	/
Central CFS Scores	1.32±1.38	0	/

All data are expressed as mean±SD; OSDI, ocular surface disease index; BUT, break up time; CFS, cornea fluorescent staining.

Table 2. Comparisons of OPD Scan III parameters of study subjects in DE and normal groups.

	Dry eye	Normal	p value
Total corneal aberrations	2.24±1.92	0.56±0.18	<0.001
Corneal HOA	0.60±0.64	0.38±1.03	<0.001
Corneal Coma	0.36±0.41	0.03±0.03	<0.001
Corneal Trefoil	0.27±0.47	0.03±0.03	0.018
SA	0.25±0.15	0.03±0.03	<0.001
SDP	1.18±0.46	1.07±0.22	0.272
SRI	0.55±0.34	0.39±0.19	0.044
SAI	0.50±0.30	0.36±0.08	0.023

All data are expressed as mean±SD;HOA, high-order aberration; SA: Spherical aberrations; SDP, standard deviation of corneal power; SRI, surface regularity index; SAI, surface asymmetry index.

Table 3.Correlations between the OPD scan III parameters and ocular surface parameters.

	OSDI Scores	logMAR BCVA	TBUT (S)	CFS Scores	Central CFS Scores
Total corneal aberrations					
r	.354*	.547**	-.445**	.306	.170
p value	.012	.000	.001	.121	.416
Corneal HOAs					
r	.025	.571**	-.155	.280	.181
p value	.864	.000	.284	.157	.385
Corneal Coma					
r	.364**	.657**	-.422**	.323	.312
p value	.009	.000	.002	.100	.129
Corneal Trefoil					
r	.094	.479**	-.275	.232	.199
p value	.516	.001	.053	.244	.339
SA					
r	.535**	.357*	-.591**	.097	-.203
p value	.000	.014	.000	.629	.331
SDP					
r	.145	.456**	-.181	.472*	.570**
p value	.322	.001	.214	.015	.004
SRI					
r	.242	.579**	-.286*	.582**	.614**
p value	.093	.000	.047	.002	.001
SAI					
r	.163	.662**	-.261	.355	.445*
p value	.263	.000	.070	.075	.029

HOAs, high-order aberrations; SA, Spherical aberrations; SDP, standard deviation of corneal power; SRI, surface regularity index; SAI, surface asymmetry index;The r and p values were determined with Pearson correlation coefficient.

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