Reproducibility of keratometric measurements decreases with time after blinking

B. ERDÉLYI, B. CSÁKÁNY, J. NÉMETH

Department of Ophthalmology, Semmelweis University, Budapest - Hungary

PURPOSE. *The reproducibility of keratometry measurements was investigated in relation to the elapsed time after blinking.*
METHODS. *Thirty ophthalmologically healthy subjects were examined, using a standard corneal topographic instrument (17 women, 13 men, age 25.7±5.6 years). Photographs were taken in series of four: at 5, 15, 30, and 60 seconds after a complete blink. The series was repeated three times in each individual. The main outcome measures were the mean values, the standard deviation, and the reproducibility error of the simulated keratometric values (K_1, K_2), the surface regularity index (SRI), and the surface asymmetry index (SAI).*
RESULTS. *The mean of K_1 and K_2 values did not change (p=0.684 and p=0.982); however, the measurement error increased significantly for K_1 (p=0.007) and for K_2 (p=0.038). The mean values of SRI changed significantly (p=0.034) during the 1-minute pause in blinking together with a non-significant change in the standard deviation (p=0.106), without elevation of the measurement error (p=0.619). The elevation of SAI with time was not significant (p=0.093).*
CONCLUSIONS. *The break-up phenomenon of the tear film at the ocular surface induces significant deterioration of the reliability of keratometric measurements on prolonged gaze without blinking. The created error can exceed 0.6 D, which is unacceptably high in practice. Therefore care should be taken to avoid such circumstances during the examination. (Eur J Ophthalmol 2006; 16: 371-5)*

KEY WORDS. *Blinking, Keratometry, Ocular surface*

Accepted: November 30, 2005

INTRODUCTION

Computer-assisted corneal topography has been available for almost two decades in ophthalmologic practice. Several types of individual systems were developed over the years, with different imaging technologies (1). One of these uses the simple principle of the Placido-disk, the reflection of illuminated concentric rings from the corneal surface. The accuracy and reproducibility of the Placido-type instruments have been determined on test objects and normal and diseased corneas (2-4). These investigations consider the examined surface to be unchanged in time.

The ocular surface is not a constant microenvironment, due to the presence of the tear film. After blinking the physiologic processes of build up and break up are well known features. Meanwhile the thickness of the tear film is constantly changing. It gets thicker initially on opening the eye and then evaporation induces thinning, resulting in formation of dry spots, scattered unevenly on the cornea. All these occurrences at the corneal surface alter the reflected image – i.e., distort the concentric rings – and hence influence the acquired data during corneal topographic measurements (5-7).

Topographic indices were found to be sensitive indicators for the rapid alterations of the ocular surface after

1120-6721/371-05$15.00/0

blinking by various authors (5-7). Especially the surface regularity index (SRI) is a valuable quantitative measure for this purpose, which produces information about the regularity of the central corneal contour.

However, the alterations at the corneal surface are presumably not the same after each successive blink. Intermediate incomplete blinks decrease the thickness of the tears and dry spot formation may occur in different locations. These features may impair the consistency of topographic measures, especially at later times after blinking in situations requiring prolonged gaze. Corneal topography is one of those ophthalmologic examinations where the patient is asked to open the eyes wide and refrain from blinking.

In the present study our aim was to investigate the post blink-time-related reproducibility of corneal topographic measurements during 60 seconds after a complete blink.

METHODS

Thirty ophthalmologically healthy subjects were involved in the investigation. They comprised 17 women and 13 men, aged from 20 to 40 years (mean, 25.7±5.6 years). Criteria to enter the study were accepted as follows: full visual acuity, negative ophthalmologic status, no history of contact lens wear or ocular surgery. The results of tear film break-up time (TBUT) and Schirmer I test were in the normal range (>10 sec and >10 mm/5 min, respectively). For every individual subject, three separate series of topographic measurements were recorded, each consisting of images captured at 5, 15, 30, and 60 seconds after blinking. Centration was performed first and after a complete blink acquisition of the images was initiated. The subject was asked to avoid movements of the head and to fixate continuously. Between two series the sub-

TABLE I - MEAN TOPOGRAPHIC VALUES ± STANDARD DEVIATION AT FOUR DIFFERENT TIME POINTS AFTER THE LAST BLINK (N=30)

	5 sec	15 sec	30 sec	60 sec	Significance (ANOVA)
K_1	43.8±1.2	43.7±1.2	43.8±1.2	44.1±1.4	NS
K_2	42.8±1.2	42.8±1.2	42.9±1.2	42.9±1.3	NS
SRI	0.37±0.29	0.40±0.27	0.42±0.27	0.57±0.31	0.034
SAI	0.34±0.15	0.36±0.21	0.40±0.20	0.47±0.23	NS

In normal subjects, the mean values of the surface regularity index (SRI) increased significantly during a 1 minute pause in blinking. SAI, K_1, and K_2 were constant
ANOVA = Analysis of variance; SAI = Surface asymmetry index

TABLE II - STANDARD DEVIATION (SD) OF THREE REPEATED MEASUREMENTS AT EACH TIME POINT

	5 sec	15 sec	30 sec	60 sec	Significance (ANOVA)
K_1	0.3	0.3	0.3	0.7	0.006
K_2	0.2	0.2	0.2	0.4	0.034
SRI	0.15	0.15	0.17	0.22	NS
SAI	0.11	0.11	0.15	0.17	NS

The SDs of keratometric measurements (K_1, K_2) were elevated significantly during the 60 seconds postblink. ANOVA = Analysis of variance; SRI = Surface regularity index; SAI = Surface asymmetry index

TABLE III - COVARIANCE (COV) OF THREE REPEATED MEASUREMENTS AT FOUR DIFFERENT TIME POINTS

	5 sec	15 sec	30 sec	60 sec	Significance (ANOVA)
K_1	0.7	0.6	0.6	1.5	0.007
K_2	0.5	0.4	0.6	0.8	0.038
SRI	54.0	46.1	48.1	43.5	NS
SAI	28.0	25.3	33.6	32.1	NS

The COV remained unchanged for surface regularity index (SRI) and surface asymmetry index (SAI). The keratometry measures (K_1, K_2) were significantly elevated with time. ANOVA = Analysis of variance jects were requested to blink normally, to allow adequate refreshment of the tear film.

Images with a fixation error exceeding 0.125 mm in either the horizontal or the vertical plane were excluded from the analysis. The temperature and humidity of the room did not vary significantly throughout the experiments. All procedures were approved by a local ethics committee and an informed consent was signed by all subjects.

Our system was a conventional Placido-type corneal topograph (TMS-1; Computed Anatomy Inc., New York, NY, USA).

The analysis of the acquired images included the calculation of Klyce corneal statistics (8) (surface regularity index [SRI]; surface asymmetry index [SAI]) together with the simulated keratometry values (K_1 the power in the meridian with greatest curvature and K_2 the power in the meridian perpendicular to it).

We performed statistical analysis using one-way analysis of variance implemented in the SPSS software package (SPSS, version 10.0; SPSS, Chicago, IL, USA).

A p value less than 0.05 was considered statistically significant. The standard deviations (SD) of SRI, SAI, K_1, and K_2 were counted from the values of the three subsequent measurements. The error of reproducibility (COV) was calculated for each time point according to the following formula: (SD/mean) x 100.

RESULTS

The mean K_1 and K_2 remained stable ($p=0.684$ and $p=0.982$, respectively; Tab. I) in time. The mean values of SRI and SAI were smallest during the sessions at 5 seconds after blinking (0.37 and 0.34, respectively).

At later times these measures increased, significantly in the case of SRI ($p=0.034$ for SRI and $p=0.093$ for SAI). The highest values were observed at 60 seconds (0.57 and 0.47).

The SD of K_1 and K_2 were elevated significantly between 5 and 60 seconds after blinking ($p=0.006$ and 0.034, respectively; Tab. II). The SD of SRI and SAI also increased with time, but this was not significant ($p=0.106$ and $p=0.352$).

The COV showed a significant alteration for K_1 and K_2 ($p=0.007$ and $p=0.038$). SRI and SAI measures were found equally reproducible at all time points ($p=0.619$ and $p=0.356$; Tab. III).

DISCUSSION

We used a conventional Placido-type corneal topograph to assess the time-related changes in the reproducibility of measurements after blinking. The mean values of SAI, K_1, and K_2 were not changed, while SRI values changed significantly. This is in accordance with our earlier findings (6, 7, 9). Those changes were attributed to the alterations of the tear film. The findings of Koh et al and Montes-Mico et al supported this phenomenon by wavefront aberrometry (10-14). They presented significant changes in corneal aberrations with time after the blink (10-12) and also after instillation of artificial tears in dry eye patients (13). Another aspect of the alterations of the tear film is the evaporation with consequential changes in temperature which can be detected by thermography (15). The optical effect of those changes can be observed in practice when visualizing the posterior segment (16). Furthermore patients with dry eye (17) or after photorefractive procedures (18) may experience fluctuations in their visual acuity caused by transient worsening of the stability of the tear film.

The SD changed significantly for the keratometric parameters (K_1 and K_2). There was a tendency of the SD of SRI and SAI to increase at 60 seconds in 19 subjects for SRI and 21 subjects for SAI. This may draw a false conclusion that in those cases the accuracy of the methodology for SRI and SAI measurement declined with time. However, as the mean values were increasing with time, a parallel elevation of the SD can be accepted reasonably. Therefore we introduced COV measures to exclude the above effect. We found that the SRI and SAI measurements remained reliable during the 1 minute pause in blinking, although this was not true for the K_1 and K_2 values. The COV for these parameters was significantly elevated on extended opening of the eye. The error induced by the prolonged gaze exceeded 0.6 D at 60 seconds. This unacceptably deteriorates the predictability of refractive surgical procedures, which was 1.01 D for photorefractive keratectomy and 1.22 D for laser-assisted in situ keratomileusis in a multicenter clinical trial (19).

The first studies of reproducibility of the Placido-type instruments were executed on calibrated PMMA spheres. The mean difference of three readings was within ±0.25 D only for a 43.0 diopter sphere, while much worse for spheres differing largely from the normal human corneal refractive power (3). On aspheric surfaces the reproducibility was shown to be high (2). The short-term variability (in diopters) of three different topographs in another study ranged from 0.61 to 3.31 D for axial distance maps and from 0.79 to 6.82 D for tangential curvature maps on irregular surfaces in keratoconus. These results supported the notion of a loss in repeatability of these instruments when corneal irregularity is present, which reduces retest reliability (4).

Our measurements were executed on normal human corneas; therefore, high reproducibility was expected, although this was experienced only in part. The rapid alterations in the tear film deteriorated the reproducibility of the keratometric measurements. The circumstances of our examination resembled a standard corneal topographic measurement, apart from the fact that the subject was to gaze for an extended period. However this can also happen at a unit during conventional clinical practice.

Our study had some limitations. We had a relatively small number of subjects, there was a lack of automated positioning, and there were alterations in lid fissure width during measurements. However, eyelid fissure width was found in our previous study not to influence the measured corneal topographic parameters (6).

Our findings suggest that prolonged opening of the patient's eye generates high risk for errors in measurement, which grows to an unacceptable range at 60 seconds. Therefore even in subjects with an intact tear film topographic image capture should be done shortly after blinking.

Several theories have been introduced for explanation of the normal tear film dynamics by various authors (20-24). Common in them is that evaporation leads to thinning and dry spots form with time. However, the potential location of these spots varies from one blinking to another. At the place of a dry spot the tear becomes irregular and induces a local distortion in power. Goto et al used these localized changes of keratometric power for estimating break-up time (TBUT) (5). These local changes influence the simulated keratometry measurements and result in decreased retest-reproducibility.

Therefore, the examination is supposed to take into account the TBUT of the patient. If a significant decrease in TBUT is expected this should alert the investigator to be more cautious when performing corneal topography to achieve reliable results. Furthermore we found earlier that the topographic pattern of the ocular surface was more regular at 15 seconds than at any of the other three time points investigated in the present examination (5, 30, and 60 seconds after blinking) (9). Using high-speed videotopography the ocular surface was found to be the most regular between 4 and 9 seconds after the blink (7). In conclusion, it seems a good choice to perform the topographic measurements between 5 and 10 seconds after a blink.

ACKNOWLEDGEMENTS

Supported by grant no. T034483 from the Hungarian Scientific Research Fund and grant no. 2/020/04 from Research and Technology Innovation Fund, Hungary.

All authors had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.
The authors have no proprietary interests connected with this article.

Reprint requests to:
Prof. János Németh
Department of Ophthalmology
Semmelweis University
Tömö u. 25-29
H-1083 Budapest, Hungary
nj@szem1.sote.hu

REFERENCES

1. American Academy of Ophthalmology. Ophthalmic procedure preliminary assessment. Corneal topography. Ophthalmology 1999; 106: 1628-38.
2. Dave T, Ruston D, Fowler C. Evaluation of the EyeSys model II computerized videokeratoscope. Part II: The repeatability and accuracy in measuring convex aspheric surfaces. Optom Vis Sci 1998; 75: 656-62.
3. Legeais JM, Ren Q, Simon G, Parel JM. Computer-assisted corneal topography: accuracy and reproducibility of the topographic modeling system. Refract Corneal Surg 1993; 9: 347-57.
4. McMahon TT, Anderson RJ, Joslin CE, Rosas GA, Collaborative Longitudinal Evaluation of Keratoconus (CLEK) Study Topography Analysis Group. Precision of three topography instruments in keratoconus subjects. Optom Vis Sci 2001; 78: 599-604.
5. Goto T, Zheng X, Klyce SD, et al. A new method for tear film stability analysis using videokeratography. Am J Ophthalmol 2003; 135: 607-12.
6. Németh J, Erdélyi B, Csákány B. Corneal topography

changes after a 15 seconds pause in blinking. J Cataract Refract Surg 2001; 27: 589-92.
7. Németh J, Erdélyi B, Csákány B, et al. High-speed videotopographic measurement of tear film build-up time. Invest Ophthalmol Vis Sci 2002; 43: 1783-90.
8. Wilson SE, Klyce SD. Quantitative descriptors of corneal topography. A clinical study. Arch Ophthalmol 1991; 109: 349-53.
9. Erdélyi B, Csákány B, Németh J. Spontaneous alterations of the corneal topographic pattern. J Cataract Refract Surg 2005; 31: 973-8.
10. Koh S, Maeda N, Kuroda T, et al. Effect of tear film break-up on higher-order aberrations measured with wavefront sensor. Am J Ophthalmol 2002; 134: 115-7.
11. Montes-Mico R, Alio JL, Munoz G, Perez-Santonja JJ, Charman WN. Postblink changes in total and corneal ocular aberrations. Ophthalmology 2004; 111: 758-67.
12. Montes-Mico R, Alio JL, Charman WN. Dynamic changes in the tear film in dry eyes. Invest Ophthalmol Vis Sci 2005; 46: 1615-9.
13. Montes-Mico R, Caliz A, Alio JL. Changes in ocular aberrations after instillation of artificial tears in dry-eye patients. J Cataract Refract Surg 2004; 30: 1649-52.
14. Montes-Mico R, Caliz A, Alio JL. Wavefront analysis of higher order aberrations in dry eye patients. J Refract Surg 2004; 20: 243-7.
15. Morgan PB, Soh MP, Efron N, Tullo AB. Potential applications of ocular thermography. Optom Vis Sci 1993; 70: 568-76.
16. Tutt R, Bradley A, Begley C, Thibos LN. Optical and visual impact of tear break-up in human eyes. Invest Ophthalmol Vis Sci 2000; 41: 4117-23.
17. Goto E, Yagi Y, Matsumoto Y, Tsubota K. Impaired functional visual acuity of dry eye patients. Am J Ophthalmol 2002; 133: 181-6.
18. Chen S, Wang IJ. Effect of tear film stability on fluctuation of vision after photorefractive keratectomy. J Refract Surg 1999; 15: 668-72.
19. Hersh PS, Brint SF, Maloney RK, et al. Photorefractive keratectomy versus laser in situ keratomileusis for moderate to high myopia. A randomized prospective study. Ophthalmology 1998; 105: 1512-22.
20. Brown SI, Dervichian DG. In vitro study of the interaction of the superficial oily layer and the tears. Arch Ophthalmol 1969; 82: 541-7.
21. Holly FJ. Formation and rupture of the tear film. Exp Eye Res 1973; 15: 515-25.
22. Benedetto DA, Clinch TE, Laibson PR. In vivo observation of tear film dynamics using fluorophotometry. Arch Ophthalmol 1984; 102: 410-2.
23. Gorla MS, Gorla RS. Nonlinear theory of tear film rupture. J Biomech Eng 2000; 122: 498-503.
24. Torens S, Berger E, Stave J, Guthoff R. Imaging of the microarchitecture and dynamics of the break-up phenomena of the preocular tear film with the aid of laser scanning microscopy. Ophthalmologe 2000; 97: 635-9.