Original Article

Effect of Photorefractive Keratectomy on Optic Nerve Head Topography and Retinal Nerve Fiber Layer Thickness Measured by Heidelberg Retina Tomograph 3

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Abstract

Purpose: To determine whether photorefractive keratectomy (PRK) has a significant effect on optic nerve head (ONH) parameters and peripapillary retinal nerve fiber layer (RNFL) thickness measured by the Heidelberg Retina Tomograph 3 (Heidelberg Engineering GmbH, Heidelberg, Germany) in eyes with low to moderate myopia.

Methods: This prospective, interventional case series, includes 43 consecutive myopic eyes which were assessed on the day of PRK and 3 months postoperatively using the HRT3. Among the stereometric parameters, we compared disc area, linear cup disc ratio, cup shape measure, global rim area, global rim volume, RNFL height variation contour and mean RNFL thickness; out of the Glaucoma Probability Score (GPS) we assessed changes in global value, rim steepness temporal/superior, and temporal/inferior, as well as cup size and cup depth before and after PRK.

Results: Mean refractive error before and after PRK were −3.24 ± 1.31 and −0.20 ± 0.42 diopters, respectively. No significant change occurred in disc area, linear cup disc ratio, cup shape measure, rim area and rim volume among the stereometric parameters; and in rim steepness temporal/superior and rim steepness temporal/inferior in the GPS before and after PRK using the default average keratometry. However, RNFL height variation contour, mean RNFL thickness, and cup size and depth were significantly altered after PRK ($P < 0.05$).

Conclusion: PRK can affect some HRT3 parameters. Although the most important stereometric parameters for differentiating normal, suspect or glaucomatous patients such as rim and cup measurements in stereometric parameters were not changed.

Keywords: Glaucoma; Heidelberg Retina Tomograph; Myopia; Photorefractive Keratectomy

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INTRODUCTION

The Heidelberg Retina Tomograph 3 (HRT; Heidelberg Engineering GmbH, Heidelberg, Germany) is the latest version of a confocal scanning laser ophthalmoscopy

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imaging system which uses a 670 nm diode laser source and yields three-dimensional analysis of the optic nerve head (ONH) and adjacent retinal nerve fiber layer (RNFL).[1] HRT measurements are highly reproducible apart from the variability of image quality. The Ocular Hypertension Treatment Study (OHTS) revealed that the HRT may diagnose glaucoma up to 8 years earlier than expert stereoscopic disc assessments or visual field loss, hence it is a good tool in discovering early structural changes before any evidence of functional alterations.[2] Certain data are imported into the device software before the imaging process, including the patient's refraction and keratometry. To facilitate the operation, an average keratometry of 7.7 mm is applied and used as a default value.

In photorefractive keratectomy (PRK), excimer laser is used to ablate corneal tissue, in particular the anterior stroma, leading to a change in the refractive power of the cornea, proportional to the amount of ablation. PRK is a widely practiced procedure, especially for correction of low to moderate myopia. On the other hand, myopia has been indicated to be a risk factor for primary open angle glaucoma.[3,4] Among patients who have had corneal refractive surgery, some may end up with glaucoma in the future. Therefore, obtaining reliable quantitative data of the ONH would be very helpful in both the diagnosis and follow-up of such patients.

Controversies exist whether RNFL thickness and ONH parameters acquired by scanning laser polarimetry (GDx) or confocal laser ophthalmoscopy change significantly after corneal refractive procedures.[5-8] Roberts et al reported a significant difference between pre- and post-operative RNFL thickness measurements obtained by scanning laser polarimetry in 30 post laser-assisted *in situ* keratomileusis (LASIK) patients.[5] This was consistent with the findings by Gürses-Ozden et al[6] But in another study, Gürses-Ozden et al reported no changes after LASIK by scanning laser polarimetry (SLP), optical coherence tomography (OCT), and scanning laser tomography (SLT).[7] Sharma et al also showed that LASIK and laser-assisted subepithelial keratectomy did not significantly affect postoperative RNFL thickness parameters measured by OCT.[8]

In clinical practice, one encounters patients with a past history of PRK who fail to report it to the practitioner or technician. On the other hand, in contrast to LASIK and RK which have specific signs during slit lamp examination and can be easily detected, PRK may go unnoticed by examination. Furthermore, some ophthalmologists are not aware of the importance of keratometry readings and or may forget to ask the operator to use the patient's actual keratometry values for image capturing.

The aim of this study was to determine whether PRK has any significant effect on ONH topographic parameters and RNFL thickness measured by the Heidelberg Retina Tomograph 3 (HRT3) when using default keratometry (K) values both before and after PRK. Although K values should be individualized for each patient, we were curious to know what would happen to HRT parameters when using the default keratometry in low to moderate myopic patients and to see which parameters will be more affected. The results of this study can help better understand possible errors that may occur because of not changing the default keratometry and whether such differences are clinically important. To the best of our knowledge this subject has not been evaluated in previous studies. This could be important for myopic patients that are seeking laser refractive surgery and are at risk of glaucoma in future.

METHODS

Forty-three eyes undergoing PRK at Rassoul Akram Hospital, Tehran, Iran were enrolled in this interventional case series. The study protocol adhered to the tenets of the Declaration of Helsinki and was approved by the ethics committee at Iran University of Medical Sciences. Written informed consent was obtained from all participants. Inclusion criteria were patient age ≥20 years, best corrected visual acuity (BCVA) ≥20/30, spherical equivalent refraction between −1.00 to −6.00 diopters, and astigmatism less than 1 diopter. Patients with the following criteria were excluded: Any ocular finding suggesting glaucoma, e.g. cup-disc ratio ≥0.6, inter-eye cup-disc ratio asymmetry >0.2, general or focal rim thinning, or peripapillary hemorrhage, abnormal Humphrey visual field test, intraocular pressure (IOP) >21 mmHg, HRT standard deviation ≥40 µm, and history of intraocular surgery.

All participants underwent a comprehensive ophthalmic evaluation including medical and family history, refraction and determination of BCVA, slit lamp examination, Goldmann applanation tonometry, gonioscopy, dilated fundus examination using a +78 diopter lens, Humphrey visual field test using 24-2 SITA Standard program, and Pentacam corneal topography. At the preoperative examination and postoperative visit, IOP was measured by the same calibrated Goldmann applanation tonometer.

HRT 3 imaging (Heidelberg Engineering, GmbH, Heidelberg, Germany) was performed in one randomly selected eye from each participant without pupillary dilation, once before and then 3 months after PRK by one experienced operator (PA). An average of 3 consecutive scans was obtained and aligned to compose a single mean topography for analysis. The optic disc margin was outlined the operator (PA) on the mean topographic image. Re-scanning was performed at the same visit if motion artifacts were detected immediately after imaging. The same preset average keratometry was used for both scans. All scans were assessed subjectively for good ONH centration, focus and uniform illumination and standard deviation of less than 40 µm. All images were assessed by an experienced glaucoma specialist (NN) for misalignment or incorrect contour line placement.

Among HRT3 parameters included in this study, we employed the Glaucoma Probability Score (GPS), a discriminatory parameter that is defined without the need for subjective determination of the disc margin.[9] The Moorfields regression analysis,[10,11] was not used because its clinical output is categorical, as opposed to the other analyses, which provide continuous numerical values.

For PRK, ablation was performed using a Technolas 217 flying spot excimer laser system (Bausch and Lomb, Rochester, NY, USA) using the Plano Scan software and an active eye tracker system. After PRK, a soft contact lens was placed on the cornea which was removed 3-5 days later after complete healing of the corneal epithelium. Medications started after PRK included fluorometholone 4 times a day for 2 weeks, which was tapered over the next 4-6 weeks, ciprofloxacin 4 times a day for 1 week and artificial tear every 2-3 hours until the end of the follow up.

Statistical Analysis

Demographic data included age, gender, pre- and post-operative refractive error, and K readings. Seven stereometric parameters (disc area, linear cup disc ratio, cup shape measure, global rim area, global rim volume, RNFL height variation contour, and mean RNFL thickness) and 5 parameters from the GPS (global value, rim steepness temporal/superior, rim steepness temporal/inferior, cup size, and cup depth) were selected for statistical analysis. The paired *t*-test was used for comparison between pre- and post-operative values. Statistical analysis was performed using SPSS software (Version 16.0, IBM Co., Chicago IL, USA) with significance set at 0.05. Sample size was calculated based on finding more than 5% difference between pre and post PRK data. This was based on our knowledge that the coefficients of variation of stereometric parameters are around 5%.[12,13]

RESULTS

Mean age of the study subjects was 29.6 ± 7.5 years (range 20-45 years). Forty-three eyes from 43 patients were included in the study including ten male (23.3%) and thirty-three female cases (76.7%). Mean preoperative refractive error was −3.24 ± 1.31 diopters with statistically significant difference compared with the mean postoperative refractive error of −0.20 ± 0.42 diopters ($P < 0.001$). Mean preoperative K reading (KR) was 44.02 ± 1.34 diopters was significantly different from its postoperative values of 41.74 ± 1.15 diopters ($P < 0.001$). Mean refractive correction was 3.03 ± 1.24 (range: 1-5.37) diopters and mean change in KR was 2.28 ± 0.92 (range 1-4.1) diopters.

After PRK, no significant change was noted in disc area, linear cup disc ratio, cup shape measure, rim area, and rim volume among the stereometric parameters; and in rim steepness temporal/superior and rim steepness temporal/inferior among GPS measurements ($P > 0.05$). However, RNFL height variation contour and mean RNFL thickness among the stereometric parameters, and cup size and cup depth among GPS parameters were significantly altered after PRK ($P < 0.05$) [Table 1].

No complications related to PRK were observed. Mean preoperative IOP was 15.09 ± 1.60 and mean postoperative IOP was 14.37 ± 1.25 mmHg ($P < 0.001$). Intraocular pressure did not rise over 21 mmHg among the participants and no patient required IOP lowering medications. Also no detectable structural damage was found in clinical examination of the ONH after PRK.

DISCUSSION

PRK is an ablative refractive surgery that has gained popularity for correction of low to moderate myopia over the past few years. Apart from myopia which is a risk factor for glaucoma (e.g. juvenile primary open angle glaucoma), positive family history and pigment dispersion syndrome are among other established glaucoma risk factors in people who seek refractive surgery.[14-16] Since PRK alters corneal curvature and thickness, the normative parameters of conventional

Table 1. Heidelberg retina tomograph 3 parameters before and after photorefractive keratectomy in 43 eyes

Variable	Mean±SD		*P*
	Preoperation	Postoperation	
Refractive error	−3.24±1.31	−0.20±0.42	<0.001
Keratometry reading	44.02±1.34	41.74±1.15	<0.001
Linear cup disc ratio	0.40±0.15	0.41±0.15	0.16
Cup shape measure	−0.23±0.06	−0.22±0.08	0.33
Rim area	1.60±0.34	1.59±0.35	0.42
Rim volume	0.43±0.17	0.45±0.18	0.38
RNFL height variation contour	0.36±0.09	0.40±0.11	0.03
Mean RNFL thickness	0.25±0.07	0.27±0.09	0.03
Global glaucoma probability score	0.20±0.03	0.16±0.14	0.12
Rim steepness temporal superior	0.03±0.55	0.05±0.59	0.53
Rim steepness temporal inferior	−0.15±0.54	0.02±0.63	0.47
Cup size	0.30±0.02	0.32±0.14	0.01
Cup depth	0.54±0.02	0.59±0.21	<0.001

SD, standard deviation; RNFL, retinal nerve fiber layer glaucoma screening tools, such as tonometry or perimetry could change irreversibly which may affect proper diagnosis or follow up of the patients or glaucoma suspects. Although the effect of refractive surgery on perimetry has yet to be elucidated, its effect on Goldmann applanation tonometry and IOP measurement is well established.[17-19] On the other hand, tonometry or perimetry are not sensitive enough for detection of early glaucoma.[20]

In LASIK a pressure of around 60-80 mmHg is induced when suction is applied to stabilize the eye during surgery. In few reports, this suction effect has been noted to cause true ganglion cell damage resulting in visual field defects in some cases, which implies that any decrease in RNFL thickness after LASIK should be carefully evaluated.[21-26] This also suggests that the short term investigations published to date on apparent RNFL thinning due to refractive surgery should be extended with longer follow up in order to define the course of the apparent thickness variation during the postoperative period, and in particular to determine the time needed for the change to stabilize, and establish whether RNFL thickness/ONH measurements are usable for diagnostic and follow up purposes. Nevertheless, in most other related reports, there has been no evidence of RNFL thinning or glaucomatous damage at the ONH assessed by different imaging modalities after LASIK surgery.[8,27,28] Iester et al showed that after PRK using Variable Corneal Compensation algorithm for GDx, most of the change in corneal birefringence induced by refractive surgery could be compensated; these authors concluded that it is necessary to obtain a new baseline after laser surgery on the cornea.[28]

In PRK, no suction is applied and the possible insult induced by the pressure rise is avoided, so theoretically an iatrogenic glaucomatous damage is not expected. Thus, the observed changes in some stereometric parameters cannot be attributed to real optic nerve changes. In our study mean preoperative IOP was 15.09 ± 1.60 and mean postoperative IOP was 14.37 ± 1.25. This difference is most probably due to corneal thinning and underestimation of IOP rather than true changes. However, there are dramatic corneal power changes after PRK in myopic eyes, and knowing that keratometry is one of the data used in the HRT software, and that using the new value is strongly recommended by the manufacturer; ignoring this fact after PRK by using the default values used for ordinary eyes may cause alterations in parameters and lead to aberrant results. Other studies using HRT before and after LASIK surgery have found no significant change in ONH and RNFL parameters,[7,27] yet it is not known whether a larger amount of ablation could significantly change other HRT parameters.

In our study, most stereometric and GPS parameters did not change significantly, indicating that preoperative HRT images could be valid for future follow-up, while four other parameters changed significantly: RNFL thickness increased while cup size and cup depth deteriorated on GPS. The status of the cornea is different in the early post refractive surgery period as compared to several months later and possible explanations are corneal surface changes, alteration of the tear film, or anterior stromal edema.[28-30] We obtained HRT3 imaging and evaluated the cornea 3 months after surgery, which seems long enough for edema to resolve and allow complete corneal clearance. Fortunately, corneal haze, a potential confounding factor, did not occur in any of our cases.

It seems that with the change of corneal curvature after PRK, some of the optic nerve head and retinal nerve fibers parameters measured by HRT3 also change. Although most of these changes were insignificant, we advise to inform the operator about history of corneal surface ablation and adjust K values based on actual postoperative values or acquire a new baseline imaging.

A major drawback of this study was the small sample size and the relatively short follow-up period. Also, we did not enter the actual postoperative K value for image acquisition which could have been a cause of magnification error and the differences between some pre-and postoperative values. However, using the latest version of HRT3 for image acquisition and including the newer GPS parameters for statistical analysis differentiate the present study from previous studies.

In glaucoma suspects with history of PRK who need HRT imaging, it must be kept in mind that any detectable RNFL or ONH change could be due to either previous refractive surgery or underlying glaucomatous changes so sequential imaging should be interpreted cautiously. The effect of PRK in eyes with pre-existing RNFL or ONH damage is yet to be determined.

In summary, the current series is the first to investigate the effect of PRK on HRT and its new parameters. We concluded that in HRT3 when using the default average keratometry, both before and after PRK, most parameters that are essential in differentiating normal, suspect, and glaucomatous patients in clinical practice such as rim and cup measurements in stereometric parameters were not changed. Therefore, even in image acquisition by using default keratometry, we are not misled by the measurements.

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Conflicts of Interest

There are no conflicts of interest.

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