■ CLINICAL SCIENCE ■

The Effect of Pupil Dilation on Scanning Laser Polarimetry With Variable Corneal Compensation

Amjad Horani, MD; Shahar Frenkel, MD, PhD; Eytan Z. Blumenthal, MD

■ **BACKGROUND AND OBJECTIVE:** The feasibility and reproducibility of scanning laser polarimetry performed through dilated pupils rather than through non-dilated pupils was tested.

■ **PATIENTS AND METHODS:** One eye each of 36 subjects (12 normal, 12 suspected glaucoma, and 12 glaucoma) was scanned using a single GDx unit with variable corneal compensator (GDx-VCC; Laser Diagnostic Technologies, Inc., San Diego, CA). Two scans prior to and two scans after dilation were performed on each study eye, resetting the cornea compensation prior to each scan. The dilated eye was viewed off-center, such that the whitish focusing patch was projected on the 9-o'clock peripheral iris. After adequate anteroposterior focus, the pupil was centered and a scan was acquired. Each of 5 GDx parameters was evaluated comparing the pre-dilation and post-dilation scans.

■ **RESULTS:** No statistically significant difference was found between pre-dilation and post-dilation measurements. There was a high pre-dilation to post-dilation correlation of 98%, 98%, 98%, 93%, and 95% for nerve fiber indicator, TSNIT average, TSNIT standard deviation, superior average, and inferior average, respectively. Less than 5% of the measurement variability was attributed to changes in pupil size (R^2 ranging from 0.024 to 0.047). Stratifying the data by diagnostic groups yielded similar results.

■ **CONCLUSIONS:** Pharmacologic mydriasis was not found to influence the retinal nerve fiber layer measurements acquired using the GDx-VCC. Results were comparable to scans achieved in the same eyes prior to dilation.

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INTRODUCTION

The GDx-variable corneal compensator (GDx-VCC; Laser Diagnostic Technologies, Inc., San Diego, CA) is a scanning laser polarimeter, combining a confocal scanning laser ophthalmoscope with an integrated polarimeter designed to evaluate the peripapillary retinal nerve fiber layer (RNFL) thickness. Polarized light undergoes a phase shift, also called retardation, as it passes through polarizing media such as the cornea, the crystalline lens, and the RNFL. This phase shift was previously shown to correlate with the thickness of the RNFL.[1]

A significant proportion of the total retardation signal from within the eye originates from the cornea.[2,3] Hence, standardizing and fully compensating for the corneal component would seem of prime importance. It can be pre-

From the Department of Ophthalmology, Hebrew University-Hadassah Medical Center, Jerusalem, Israel.

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Address reprint requests to Eytan Z. Blumenthal, MD, Department of Ophthalmology, Hadassah University Hospital, P. O. Box 12000, Jerusalem 91120, Israel.

sumed that the retardation properties of the cornea might not be homogeneous throughout, but rather change according to the thickness, curvature, and arrangement of lamella at any particular location across the cornea.

The GDx-VCC incorporates a two-step approach to compensate for the retardation component derived from the polarizing properties of the anterior structures of the eye (cornea and crystalline lens). The GDx-VCC first compensates for the anterior segment polarization component by scanning the foveal area. It is believed that because the fovea is devoid of axons, and contains a symmetric arrangement of Henle fibers, any non-uniform light shift detected around the fovea must be attributed to anterior segment (cornea and lens) polarization.[4] The second step involves a compensated scan of the peripapillary retina.

To correctly and reproducibly account for the corneal component of retardation, one would ideally wish to scan the eye traversing the exact same location of the cornea every time. In this way, the corneal retardation component as measured during the corneal scan would equate the retardation during the consequent peripapillary scan. Therefore, the manufacturer[5] recommends scanning only through non-dilated pupils, to reduce the variability stemming from a varying corneal component secondary to varying alignment.

However, a decision to scan a patient is often made when the pupil is already dilated, such as when optic disc or RNFL layer abnormalities are first encountered. It would be advantageous to be able to scan through dilated, as well as non-dilated, pupils, and to be able to compare across the two.

Hoh et al. evaluated the effect of pupillary dilation on RNFL thickness as measured by a previous version of the GDx instrument, using a fixed corneal compensation correction.[6] Although no statistically significant difference was found in the RNFL measurements in this study, up to one-fifth of dilated eyes had a change of more than 10% in RNFL thickness. Their recommendation was to perform GDx scans prior to dilation whenever possible to minimize the impact of misalignment errors. It is important to note that the newer GDx-VCC is a different device, employing different hardware and scanning algorithms, and hence the impact of scanning through a dilated pupil might differ between the two devices. In this study, we evaluated the effect of pupillary dilation on measurements obtained with the GDx-VCC device.

PATIENTS AND METHODS

Patients

Thirty-six patients were recruited for this study at the glaucoma clinic of the Hebrew University-Hadassah Medical Center. Twelve had glaucoma, 12 had suspected glaucoma, and 12 had normal eyes. Prior to commencing the study, each subject underwent a full eye examination by an ophthalmologist trained in glaucoma, including a slit-lamp evaluation, intraocular pressure measurement, and dilated fundus examination. Inclusion criteria were a best-corrected visual acuity of 0.5 (20/40) or better and no prior surgery to the study eye. Patients with non-dilatable pupils (e.g., those receiving pilocarpine or with marked pseudoexfoliation) were excluded.

Eyes with glaucoma were defined as having a standard full-threshold (or SITA) visual field with a glaucoma hemifield test "outside normal limits," as well as optic disc contour changes typical of glaucoma, such as excavation, rim thinning, notching, or RNFL wedge-shaped defects. Eyes with suspected glaucoma were defined as having ocular hypertension (intraocular pressure higher than 21 mm Hg) or subjects with discs that appeared suspicious but lacked a visual field defect. Normal eyes were defined as those with intraocular pressure within normal limits, normal-appearing disks, and normal visual fields. Informed consent was obtained from all participants, and the Human Subject Committee approved the methodology.

One eye was randomly chosen for each subject. Each volunteer underwent a total of four scans (two prior to and two after pupil dilation) using one GDx-VCC device by a single experienced operator. The corneal compensation routine was repeated for each scan. The operator was instructed to achieve a high-quality scan, as judged by his subjective impression, as well as a machine-produced quality score of at least 8 of 10. Each good quality scan was saved and a printed copy was made. The pupil diameter was measured in room light, after which the initial two "pre-dilation" scans were taken. The study eye was then dilated using one drop each of tropicamide 0.5% and phenylephrine hydrochloride 10%. Once the pupil was dilated, the pupil diameter was measured again, and each subject underwent two additional "post-dilation" scans.

Scanning a Dilated Eye

The difficulty in scanning dilated eyes lies in the fact that the whitish focusing patch that is shined on the iris,

TABLE 1
Demographic Data

Characteristic	Glaucoma	Suspected Glaucoma	Normal	Total
No. of subjects	12	12	12	36
Mean age (y)	65.4 ± 7.2	58.5 ± 11.6	50.0 ±14.7	58.0 ± 12.9
Male/female ratio	6/6	6/6	4/8	17/19

just to the left of a non-dilated pupil, now falls within the margin of the dilated pupil, and hence cannot be seen on the device monitor. To overcome this obstacle, which prevents adequate anteroposterior focusing, we employed the following technique. First, the operator off-centered the eye, as seen on the device monitor, to the right (via a leftward joystick movement) such that the patch was forced to appear on the 9-o'clock peripheral iris, just to the left of the pupil margin. Once the patch was focused (the endpoint being that the horizontal red line was seen bisecting the focusing patch), the operator then centered the eye (via a rightward joystick movement) and acquired an image. We found this technique to be simple to learn and employ by operators skilled in scanning non-dilated eyes.

GDx Parameters

From the 16 parameters appearing on the GDx printout (software version: GDx-VCC 5.1.0), we chose the 5 parameters appearing on the first printout page, which are those chosen by the manufacturer to be the most informative and that are best able to discriminate between normal and glaucomatous eyes. Temporal, superior, nasal, inferior, temporal (TSNIT) average is the average RNFL thickness within a concentric ring set at a machine-determined distance of the optic disc, such that values obtained at this ring are used by the software to calculate the different GDx parameters. Superior average is the average of the RNFL thickness values of the points within the ring along the superior 120° section. Inferior average is the average of the RNFL thickness values of the points within the ring along the inferior 120° section. TSNIT standard deviation is the standard deviation of the data points within the measured ring. Nerve fiber indicator (NFI) is a support vector machine-derived parameter indicating the likelihood that the eye is glaucomatous. Each parameter was analyzed separately, such that for each parameter for every subject, the two pre-dilation values were compared to the two post-dilation values.

Statistical Analysis

Mean pre-dilation and post-dilation measurements were compared using a paired *t* test and a Pearson correlation, and the stratification by diagnosis was tested using analysis of variance (ANOVA). The effect of the initial pupil diameter and the absolute change in pupil diameter (post-dilation minus pre-dilation) on each of the GDx parameter measurements were each tested separately using regression analysis. Data were analyzed using JMP statistical software version 5.0 (SAS Institute, Cary, NC).

RESULTS

Demographic data on the study subjects appear in Table 1. The mean time interval between the two sessions (± standard deviation [SD]) was 37 ± 15 minutes. The mean pupil diameter pre-dilation and post-dilation was 3.6 ± 0.8 and 7.6 ± 1.1 mm, respectively, with a mean change of 4.0 ± 0.9 mm (range: 2 to 6 mm).

The mean average of each of 5 GDx parameters evaluated is listed in Table 2. Of the 5 GDx-VCC parameters evaluated, none showed a statistically significant difference when comparing the pre-dilation to the post-dilation measurements (Table 3). The two groups showed a high correlation: 98%, 98%, 98%, 93%, and 95% for the NFI, TSNIT average, TSNIT standard deviation, superior average, and inferior average, respectively. The figure demonstrates the pre-dilation to post-dilation changes observed for each individual, as well as an averaged value. Stratification of the measurements by diagnosis did not show any statistically significant difference for any of the 5 parameters (Table 4).

Regression analysis of the effect of the pupil size on the GDx parameters' measurements revealed dependence (*P* values ranging from .0684 to .1906) for less than 5%

TABLE 2
Summary of the Means and Standard Deviations of the 5 GDx Parameters

GDx Parameter	Pre-dilation 1	Pre-dilation 2	Post-dilation 1	Post-dilation 2
NFI				
Mean	31.2	30.8	30.3	30.0
SD	16.5	16.6	17.3	17.4
TSNIT average				
Mean	50.5	50.6	51.0	50.8
SD	6.2	6.1	6.3	6.3
Superior average (μm)				
Mean	61.2	61.4	62.3	61.6
SD	9.2	9.2	9.7	10.0
Inferior average (μm)				
Mean	56.1	56.4	56.9	57.3
SD	7.6	8.0	7.7	7.6
TSNIT standard deviation				
Mean	18.9	19.2	19.6	19.3
SD	4.1	4.7	4.7	4.8

NFI = nerve fiber indicator; SD = standard deviation; TSNIT = temporal, superior, nasal, inferior, temporal.
The GDx is manufactured by Laser Diagnostic Technologies, Inc., San Diego, CA.

TABLE 3
Pre-dilation and Post-dilation Paired *t* Test With Correlations

GDx Parameter	*t* Ratio	*P* > *t*	Correlation
NFI	-1.26	.22	0.98
TSNIT average	1.44	.16	0.98
TSNIT standard deviation	1.38	.16	0.98
Superior average	1.38	.18	0.93
Inferior average	1.82	.08	0.95

NFI = nerve fiber indicator; TSNIT = temporal, superior, nasal, inferior, temporal.
The GDx is manufactured by Laser Diagnostic Technologies, Inc., San Diego, CA.

of the measurements' variability (R^2 ranging from 0.024 to 0.047). Of note, by first acquiring focus over the edge of the dilated pupil and later shifting to the center of the pupil, we were able to acquire high-quality scans with a machine-calculated quality score of 8 and above, similar to the quality scores obtained for non-dilated pupils.

DISCUSSION

The GDx-VCC is a noninvasive scanning laser polarimeter that allows measurement of the RNFL thickness at the posterior pole. The GDx-VCC focusing apparatus incorporates a light beam that creates a reflection seen as a round white patch on the iris, assisting in focusing the device. However, this white reflection is not seen when the pupil is fully dilated, making focusing impossible. To overcome this, the following maneuver was performed: the operator was instructed to acquire focus over the edge of the dilated pupil at the 9 o'clock orientation, and then shift the fixation, by rightward movement of the joystick, across to the center of the pupil.

TABLE 4
Pre-dilation and Post-dilation ANOVA Segregated by Diagnosis

	Normal		Suspected Glaucoma		Glaucoma	
GDx Parameter*	**F Ratio**	***P***	**F Ratio**	***P***	**F Ratio**	***P***
NFI	0.385	.542	0.009	.924	0.004	.953
TSNIT average	0.236	.632	0.004	.951	0.001	.953
TSNIT standard deviation	0.022	.885	0.135	.717	0.040	.843
Superior average	0.169	.685	0.011	.918	0.016	.901
Inferior average	0.054	.818	0.225	.640	0.035	.852

ANOVA = analysis of variance; NFI = nerve fiber indicator; TSNIT = temporal, superior, nasal, inferior, temporal.
**For each of the 5 GDx parameters, each scan pair (6 pairs in total) was compared for statistical significance across all 36 subjects.*
The GDx is manufactured by Laser Diagnostic Technologies, Inc., San Diego, CA.

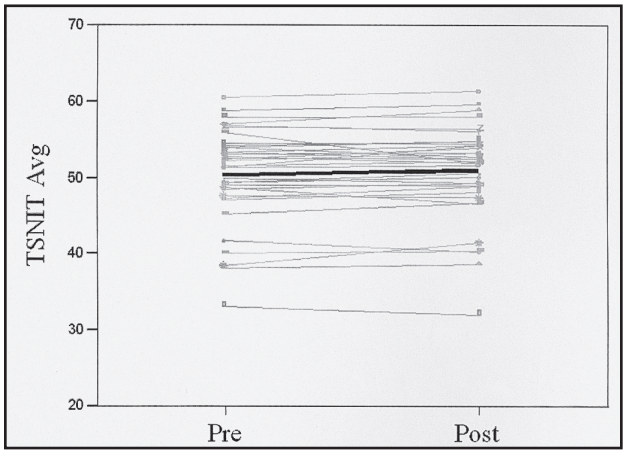

Figure. The mean of the two pre-dilation (Pre) and post-dilation (Post) temporal, superior, nasal, inferior, temporal average (TSNIT Avg) measurements of each subject is presented. The thick line represents the grand mean for all subjects.

Hoh et al.[6] evaluated a previous version of the GDx confocal scanning laser polarimeter, with a fixed corneal compensator. They concluded that the GDx could not be recommended for routine use through dilated pupils due to more than 10% change in RNFL thickness after dilation in approximately one-fifth of the subjects tested. The variability found was presumed to be due to increased intertest variability and misalignment errors during image acquisition, raising the chance of scanning through the non-central cornea, resulting in retardation exceeding the range compensated for by the device.

The results of our study show that pharmacologic mydriasis did not significantly alter the RNFL measurements acquired using the GDx-VCC, and that misalignment can be avoided if focus (anteroposterior movement of the joystick) is first achieved over the edge of the dilated pupil before shifting to the center of the pupil. We believe that little experience is needed to master the modification in scanning technique needed to scan dilated eyes. Our study results favor a recommendation that scanning patients with dilated pupils using the GDx-VCC produces results comparable to scans achieved in the same eyes prior to dilation. The diagnostic status of the eye (glaucoma, suspected glaucoma, or normal) did not appear to influence these results.

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