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Correlation between confocal scanning laser ophthalmoscopy and scanning laser polarimetry in open angle glaucoma

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PURPOSE. *To correlate the findings of confocal scanning laser ophthalmoscopy and scanning laser polarimetry in diagnosed cases of glaucoma with established visual field defects.*

METHODS. *A total of 53 diagnosed cases of primary open angle glaucoma that had at least two recorded of IOP more than 21 mm Hg on Goldmann applanation tonometry, open angles on gonioscopy and glaucomatous visual field defects on automated perimetry, were examined by confocal scanning laser ophthalmoscopy (HRT-II) and scanning laser polarimetry (GDx-NFA), in random order.*

RESULTS. *The number on GDx advanced analysis had a significant ($p<0.05$) correlation with the rim area ($r=-0.279$; $p=0.043$), cup area ($r=0.311$;$p=0.023$) and the vertical cup: disc ratio ($r= 0.376$; $p=0.006$). The correlation between HRT-II stereometric parameters and GDx advanced analysis parameters was significant ($p<0.05$) for more parameters targeting the inferior pole of the disc than the superior pole. Numerically, the worst values of GDx parameters were associated with a worse result on Moorfields regression analysis, but there was poor agreement between the diagnostic labels like within or outside normal limits as obtained on GDx and HRT-II.*

CONCLUSIONS. *Nerve fiber loss as detected on GDx correlates well with topographic optic nerve head changes as measured with the HRT-II. However, automated diagnosis on the two machines showed poor agreement. (Eur J Ophthalmol 2003; 13: 266-75)*

KEY WORDS. *Glaucoma, Scanning laser ophthalmoscopy, Scanning laser polarimetry, Optic nerve head, Nerve fiber layer*

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INTRODUCTION

In glaucoma, nerve fiber layer damage and neuroretinal rim changes such as narrowing and pallor occur initially, and these eventually progress to functional loss on visual fields (1-4). Although objective methods are available to evaluate both the retinal nerve fiber layer (RNFL) loss and optic disc cupping, the underlying principles of measurement are different, and extrapolation of measurements of the same structure on two machines may not be possible. As the search for a pre-perimetric diagnosis of glaucoma continues, it has become important to know the degree of correlation between optic nerve head and nerve fiber layer features measured by different methods.

In the current study, we evaluated the correlation between optic nerve head topographic parameters recorded by scanning laser ophthalmoscopy, with the Heidelberg retina tomograph II and the nerve fiber layer thickness by scanning laser polarimetry, with the GDx.

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MATERIALS AND METHODS

Fifty-three patients were consecutively recruited who had at least two records of IOP more than 21 mm Hg on Goldmann applanation tonometry, open angles on gonioscopy and glaucomatous visual field defects on automated perimetry, from the Glaucoma Service of our Center. The study was reviewed by the Section Review Committee, ensuring that it conformed to the tenets of the Declaration of Helsinki. Informed consent was obtained from all patients after explaining the nature of the procedures involved.

An ophthalmic history was obtained for all patients including duration of glaucoma, treatment taken and status of recent IOP control. All underwent an anterior segment slit-lamp examination, Goldmann applanation tonometry, Humphrey 30-2 full-threshold visual fields, 90-diopter stereoscopic fundus examination and refraction using an auto refractor (Retinomax 2, Nikon Corp. Japan).

Patients with a history of ocular trauma, uveitis, intraocular surgery, secondary glaucoma, diabetes, any posterior segment pathology or any other cause of media haze (e.g. cataract) were excluded from the study. Eyes with a best corrected visual acuity worse than 6/12 or ametropia more than 6 diopters were also excluded. One randomly selected eye of each patient was selected for the study if both eyes met the selection criterion. If only one eye met the criteria, that eye was used. All patients that satisfied these criteria underwent scanning laser polarimetry using the GDx nerve fiber layer analyzer (NFA-GDx) and scanning laser ophthalmoscopy using the Heidelberg Retinal Tomograph II (HRT-II) with software version 1,5,0. The order of the two tests was randomized.

On the HRT-II, a single experienced observer acquired all the images, at an imaging head/eye distance of 10 mm, with the patient fixating on the internal fixating target of the instrument that automatically centers the optic nerve head in the image. The eye's refractive error (spherical error) was set on the camera to achieve a clear image with the lowest achievable camera sensitivity. In HRT-II the parameters of the image were fixed at 15 degrees and a resolution of 10µm per pixel. Sixteen images per mm scan depth were acquired and digitized in frames of 384 x 384 pixels. Three acquired image series were saved on the hard disk and the topographic images, with the mean images were computed. In case of any problem with the image acquisition process (such as excessive scan depth, overexposed series, empty series, blink or loss of fixation and wrong focus), the instrument provided an error message and the image was not saved on the hard disc. The contour line was plotted on the baseline image by consensus of two experienced observers assisted by stereoscopic examination of the disc.

A single experienced observer imaged all patients undergoing scanning laser polarimetry. The NFA GDx consists of a laser source, a polarizer, a scanning unit, a polarization modulator, a compensator and a polarization detector. A total of 65,536 retinal locations are measured within 0.7 seconds to create a retardation map corresponding to RNFL thickness over a 15° x 15° (256x256 pixels) retinal area. The amount of polarization retardation in the reflected light correlates with RNFL thickness. Thus, retardation is a measure of relative, not absolute RNFL thickness. At least three good images were taken for each eye, and the mean was used for analysis, a good image being one that had even illumination, was properly focused and lacked red saturation.

A measuring ring placed around the inner margin of the peripapillary scleral ring by the operator approximated the optic disc margin. The outer ring was automatically placed 1.75 disc diameters away and concentric to the margins of the disc. Default region positions were applied with superior and inferior quadrants 120° each, nasal quadrant 70° and temporal segment of 50°. Although the instrument provides an array of parameters we used the advanced analysis program and the superior and inferior deviation from normal.

Linear correlations between continuous variables (all HRT-II stereometric parameters and GDx advanced analysis parameters) were studied using Pearsons' correlation coefficient. The difference in values of GDx parameters across diagnostic categories of Moorfields regression analysis (within normal limits, borderline and outside normal limits) was evaluated using analysis of variance. The agreement between the diagnostic labels provided by the GDx and HRT-II (within normal limits, borderline and outside normal limits) was evaluated using kappa statistics. In all cases the result was considered statistically significant at an alpha value of 0.05.

RESULTS

A total of 53 eyes of 53 patients were analyzed. Their d/- mean age was 50.06 ± 14.61 years). There were 30 males (56.6%) and 23 females (43.4%). Their mean IOP was 18 ± 2.1 mm Hg. The mean spherical refractive error was 0.92 ± 0.68 and the mean astigmatic correction was 0.51 ± 0.21. The average mean deviation on Humphrey 30-2 full-threshold visual field was -5.93 ± 5.31 dB. The average corrected pattern standard deviation (CPSD) was 5.02 ± 3.71 dB.

GDx-NFL parameters of average thickness (AT) and 'The Number' were correlated with HRT global parameters. The number showed a significant negative correlation with nearly all the HRT global parameters for the optic disc rim and the nerve fiber layer including rim area, rim; disc area ratio, rim volume, RNFL cross-sectional area and mean RNFL thickness (Tab. I). There was a significant positive correlation with cup area and cup: disc area ratio. The AT on GDx was significantly correlated with the rim area, rim volume, RNFL cross-sectional area and vertical cup: disc ratio on HRT.

Multivariate linear regression analysis was used to study the linearity or relationship between global parameters on GDx or HRT. The equations are as follows:

The number (GDx) = 94.91 - 19.41 x rim area on HRT (in mm^2) (SE = 13.2)
The number (GDx) = 90.41 - 110.29 x mean RNFL thickness on HRT (in mm^2) (SE = 8.5)
The number (GDx) = 90.05 - 19.05 x RNFL cross-sectional area on HRT (in mm^2) (SE = 8.9)
Average thickness (GDx) = 40.77 + 6.28 x rim area (in mm^2) (SE = 3.3)
Average thickness (GDx) = 45.39 + 19.80 x mean RNFL thickness on HRT (in mm^2) (SE = 2.26)
Average thickness (GDx) = 44.57 + 4.21 x RNFL cross-sectional area on HRT (in mm^2) (SE = 2.32)

The inferior GDx-NFL parameters studied were inferior deviation from normal (DN-I), inferior ratio (IR) and the inferior average (IA). These were correlated to the HRT-II parameters from the overall inferior quadrant, inferonasal and inferotemporal sub-sector from the inferior quadrant (Tab. II). The inferior deviation from normal (GDx) was significantly correlated with the cup area, cup: disc area ratio and rim: disc area ratio in the inferior sector, inferonasal sub-sector and the inferotemporal sub-sector on HRT. The rim area, rim volume, and mean RNFL thickness in the inferior sector and the inferonasal sub-sector and the RNFL cross-sectional area in the inferonasal sub-sector on HRT were significantly correlated with the inferior deviation from normal (GDx). The inferior ratio on the

TABLE I - LINEAR BIVARIATE CORRELATION BETWEEN GLOBAL NERVE FIBER LAYER (NFL) ADVANCED ANALYSIS PARAMETERS AND GLOBAL HRT PARAMETERS. (Bold type indicates significant correlations)

HRT Parameters	GDx NFA parameters			
	Average thickness		The number	
	r	p	r	p
Cup area	-0.107	0.445	**0.311**	**0.023**
Rim area	**0.352**	**0.010**	**-0.279**	**0.043**
Cup: disc area ratio	-0.228	0.101	**0.338**	**0.013**
Rim: disc area ratio	0.228	0.101	**-0.338**	**0.013**
Cup volume	-0.015	0.915	0.161	0.248
Rim volume	**0.377**	**0.005**	**-0.383**	**0.005**
Mean cup depth	0.035	0.805	0.018	0.898
Maximum cup depth	0.086	0.540	-0.150	0.285
Vertical cup: disc area ratio	**-0.344**	**0.012**	**0.376**	**0.006**
Horizontal cup: disc ratio	-0.217	0.119	0.241	0.083
RNFL cross- sectional area	**0.297**	**0.031**	**-0.346**	**0.011**
Mean RNFL thickness	0.257	0.064	**-0.367**	**0.007**

r = Pearson's correlation coefficient; p = p value; RNFL = Retinal nerve fiber layer

GDx-NFA had a significant correlation with the rim volume, RNFL cross-sectional area and the RNFL thickness in the inferior sector, inferonasal sub-sector and the inferotemporal sub-sector on HRT. The inferior ratio on GDx had a significant correlation with the cup area, cup: disc area ratio and the rim: disc area ratio in the inferonasal sub-sector on HRT. The inferior average on GDx was significantly correlated with the cup area, rim area, cup: disc area ratio, rim: disc area ratio, rim volume, RNFL cross-sectional area and the mean RNFL thickness in the inferior sector, inferonasal sub-sector and the inferotemporal sub-sector on HRT.

The superior GDx-NFL parameters studied were superior deviation from normal (DN-S), superior ratio (SR), superior vs. nasal ratio (S/N) and superior average (SA). These were compared to HRT-II parameters from the overall superior quadrant, superonasal and superotemporal sub-sector (Tab. III). The superior average on GDx had a significant positive correlation with rim volume in the superior sector (p=0.016), su-

TABLE II - LINEAR BIVARIATE CORRELATION BETWEEN INFERIOR NFL ADVANCED ANALYSIS PARAMETERS AND HRT PARAMETERS FROM INFERIOR QUADRANT. (Bold type indicates significant correlations)

		GDx NFA parameters								
HRT parameters		**DN-I**			**IR**			**IA**		
		IT	**IN**	**INF**	**IT**	**IN**	**INF**	**IT**	**IN**	**INF**
Cup area	**r**	**0.265**	**0.326**	**0.297**	-0.228	**-0.286**	-0.258	**-0.312**	**-0.385**	**-0.350**
	p	**0.050**	**0.017**	**0.031**	0.101	**0.036**	0.063	**0.023**	**0.004**	**0.010**
Rim area	**r**	-0.250	**-0.267**	**-0.272**	0.259	0.201	0.240	**0.369**	**0.367**	**0.386**
	p	0.071	**0.050**	**0.049**	0.061	0.149	0.084	**0.007**	**0.007**	**0.004**
Cup: disc area ratio	**r**	0.298	0.342	0.329	-0.254	**-0.270**	-0.270	**-0.380**	**-0.413**	**-0.408**
	p	**0.030**	**0.012**	**0.016**	0.066	**0.050**	0.051	**0.005**	**0.002**	**0.002**
Rim: disc area ratio	**r**	**-0.298**	**-0.342**	**-0.329**	0.254	**0.270**	0.270	**0.380**	**0.413**	**0.408**
	p	**0.030**	**0.012**	**0.016**	0.066	**0.050**	0.051	**0.005**	**0.002**	**0.002**
Cup volume	**r**	0.170	0.244	0.203	-0.180	-0.229	-0.204	-0.183	**-0.314**	-0.240
	p	0.225	0.078	0.144	0.197	0.098	0.143	0.188	**0.022**	0.084
Rim volume	**r**	**-0.255**	**-0.350**	**-0.327**	**0.288**	**0.333**	**0.329**	**0.395**	**0.465**	**0.456**
	p	0.065	**0.010**	**0.017**	**0.036**	**0.015**	**0.016**	**0.003**	**0.000**	**0.001**
Mean cup depth	**r**	0.112	0.143	0.139	-0.059	-0.002	-0.032	-0.113	-0.204	-0.173
	p	0.426	0.306	0.322	0.675	0.987	0.820	0.422	0.143	0.215
Maximum cup depth	**r**	0.025	0.002	0.029	0.164	0.156	0.186	0.046	-0.063	-0.002
	p	0.857	0.990	0.835	0.241	0.226	0.181	0.741	0.653	0.986
RNFL cross-sectional area	**r**	-0.229	**-0.316**	-0.292	**0.324**	**0.313**	**0.331**	**0.335**	**0.358**	**0.364**
	p	0.100	**0.021**	0.034	**0.018**	**0.023**	**0.015**	**0.014**	**0.009**	**0.007**
Mean RNFL thickness	**r**	-0.243	**-0.317**	**-0.298**	**0.327**	**0.332**	**0.342**	**0.337**	**0.341**	**0.352**
	p	0.079	**0.021**	**0.030**	**0.017**	**0.015**	**0.012**	**0.014**	**0.012**	**0.01**

IT = Inferotemporal HRT-II sector; IN = Inferonasal HRT-II sector; INF = Summation of parameters for IT and IN; DN-I = Inferior deviation from normal; IR = Inferior ratio; IA = Inferior average; r = Pearsons' correlation coefficient; p = p value; RNFL = Retinal nerve fiber layer peronasal sub-sector (p=0.019) and superotemporal sub-sector (p=0.029) on HRT-II. The superior average on GDx had a significant positive correlation with the mean RNFL thickness in the superior sector (p=0.047) and superonasal sub-sector (p=0.018) and the RNFL cross-sectional area thickness in the superior sector (p=0.025) and the superonasal sub-sector (p=0.041) on HRT. The superior/nasal (S/N) ratio on GDx was significantly correlated with the main rim parameters i.e. the rim area in the superior sector (p=0.034) and the superonasal sub-sector (p=0.019) and the rim volume in the superior sector (p=0.037) and the superonasal sub-sector (p=0.030) on HRT. The S/N ratio on GDx had a significant correlation with the main RNFL parameters too, namely the RNFL cross-sectional area in the superior sector (p=0.025) and the superonasal sub-sector (p=0.027) and the mean RNFL thickness in the superior sector (p=0.040) and the superonasal sub-sector (p=0.014) on HRT.

Based on the Moorfields regression analysis, the results of the HRT-II were classified as within normal limits (WNL), borderline (BL) and outside normal limits (ONL). On comparing the number and the average thickness at on the GDx with the global parameters

TABLE III - LINEAR BIVARIATE CORRELATION BETWEEN SUPERIOR NFL PARAMETERS AND HRT PARAMETERS FROM THE SUPERIOR QUADRANT. (Bold type indicates significant correlation)

		GDx-NFL parameter											
HRT-II parameter			**DN-S**			**SR**			**S/N**			**SA**	
		ST	**S/N**	**Sup**	**ST**	**SN**	**Sup**	**ST**	**SN**	**Sup**	**ST**	**SN**	**Sup**
Cup Area	**r**	-0.030	-0.011	-0.021	-0.079	-0.062	-0.073	-0.103	-0.175	-0.143	-0.021	-0.040	-0.031
	p	0.829	0.937	0.879	0.575	0.658	0.604	0.464	0.210	0.307	0.884	0.776	0.824
Rim Area	**r**	0.101	0.098	0.109	0.130	0.162	0.161	0.203	**0.322**	**0.292**	0.185	0.232	0.231
	p	0.473	0.483	0.435	0.354	0.248	0.249	0.145	**0.019**	**0.034**	0.185	0.094	0.096
Cup: disc area ratio	**r**	-0.084	-0.068	-0.079	-0.082	-0.069	-0.080	-0.153	-0.244	-0.213	-0.106	-0.119	-0.119
	p	0.551	0.631	0.572	0.558	0.622	0.571	0.275	0.078	0.126	0.449	0.396	0.395
Rim: disc area ratio	**r**	0.084	0.068	0.079	0.082	0.069	0.080	0.153	0.244	0.213	0.106	0.119	0.119
	p	0.551	0.631	0.572	0.558	0.622	0.571	0.275	0.078	0.216	0.449	0.396	0.395
Cup volume	**r**	0.162	0.135	0.154	-0.002	-0.010	-0.006	0.059	-0.062	0.003	-0.119	-0.125	-0.125
	p	0.247	0.336	0.272	0.987	0.943	0.965	0.676	0.658	0.986	0.396	0.373	0.371
Rim volume	**r**	0.204	0.178	0.200	0.149	0.167	0.168	0.242	**0.298**	**0.288**	0.301	**0.321**	**0.329**
	p	0.144	0.203	0.151	0.286	0.232	0.229	0.081	**0.030**	**0.037**	0.029	**0.019**	**0.016**
Mean cup depth	**r**	0.126	0.081	0.109	0.051	0.036	0.045	-0.140	-0.012	0.064	0.133	0.095	0.120
	p	0.367	0.564	0.437	0.719	0.801	0.748	0.319	0.931	0.648	0.342	0.497	0.391
Maximum cup depth	**r**	0.153	0.081	0.135	0.213	0.127	0.134	0.121	0.092	**-0.290**	-0.248	-0.138	-0.226
	p	0.273	0.566	0.335	0.125	0.363	0.338	0.390	0.511	**0.035**	0.073	0.323	0.103
RNFL cross-sectional area	**r**	0.136	0.173	0.177	0.185	0.182	0.208	0.234	**0.304**	**0.308**	0.241	**0.282**	**0.309**
	p	0.330	0.215	0.205	0.186	0.192	0.135	0.092	**0.027**	**0.025**	0.082	**0.041**	**0.025**
Mean RNFL thickness	**r**	0.141	0.192	0.163	0.188	0.205	0.191	0.242	**0.337**	**0.283**	0.258	**0.324**	**0.274**
	p	0.313	0.169	0.245	0.178	0.140	0.171	0.080	**0.014**	**0.040**	0.062	**0.018**	**0.047**

ST = Superotemporal HRT II sector; SN = Superonasal HRT II sector; SUP = Summation of parameters for ST and SN; r = Pearson's correlation coefficient; p = p value; DN-S = Superior deviation from normal; SR = Superior ratio; S/N = Superior/nasal; SA = Superior average; r = Pearsons' correlation coefficient; p = p value; RNFL = Retinal nerve fiber layer of the HRT II, we found a non-significant increase in the former and a non-significant decrease in the latter (Tab. IV). In the superonasal sub-sector, the S/N ratio on the GDx was significantly lower when the Moorfields regression analysis was ONL compared to WNL and BL. There was a closer correlation in the inferior quadrant between the GDx parameters, showing a significant progressive change with abnormality of the result of the HRT-II according to the Moorfields regression analysis. In the inferotemporal sub-sector, the inferior average showed a significant progressive decrease with increasing abnormality of the HRT-II. In the inferonasal sub-sector, all the GDx parameters were significantly correlated with progressive abnormality on the HRT-II results.

The clinical output on Moorfields regression analysis on HRT-II and GDx advanced analysis parameters is based on comparison with a normative database for age, sex and race. The agreement between the diagnostic labels of ‘WNL’, ‘BL’ or ‘ONL’ on Moorfields regression analysis and on any of the GDx advanced analysis parameters showed a kappa range of 0.086 to 0.255 (Tab. V). The coefficient of variance of HRT-II parameters is detailed in Table VI. The HRT and GDx parameters were also evaluated for their correlation with visual field indices (Tabs. VI-VII). Linear correlation was studied using Pearson’s correlation coefficient. A correlation was considered significant if the p value was less than 0.05. A larger proportion of HRT parameters had a significant correlation with visual field indices than GDx parameters.

TABLE IV - CORRELATION OF MOORFIELDS REGRESSION ANALYSIS WITH GDX PARAMETERS

GDx parameters	**Moorfields regression analysis result (global)**			
(global)	**WNL (23)**	**BL (14)**	**ONL (16)**	**p**
The number	50.69 ± 29.01	75.31 ± 22.00	79.93 ± 19.86	0.091
Average thickness	50.96 ± 6.73	47.57 ± 3.94	48.31 ± 8.25	0.273
GDx parameters	**Moorfields regression analysis result (superotemporal)**			
(superior)	**WNL (35)**	**BL (16)**	**ONL (2)**	
DN-S	-17.00 ± 2.83	-22.88 ± 14.11	-27.34 ± 12.59	0.337
SA	2.01 ± 0.60	2.04 ± 0.51	1.75 ± 0.26	0.790
S/N	1.82 ± 0.37	1.82 ± 0.36	1.53 ± 0.37	0.562
SR	64.00 ± 7.07	59.31 ± 11.79	56.83 ± 10.48	0.540
	Moorfields regression analysis result (superonasal)			
	WNL (32)	**BL (8)**	**ONL (13)**	
DN-S	-24.78 ± 15.39	-26.47 ± 11.02	-26.44 ± 8.83	0.898
SA	2.05 ± 0.64	2.09 ± 0.46	1.71 ± 0.41	0.206
S/N	1.86 ± 0.41	1.87 ± 0.30	1.52 ± 0.18	**0.032**
SR	59.26 ± 11.84	56.12 ± 10.23	56.89 ± 8.57	0.623
GDx parameters	**Moorfields regression analysis result (inferotemporal)**			
(inferior)	**WNL (27)**	**BL (17)**	**ONL (9)**	
DN-I	-31.88 ± 10.28	-35.38 ± 11.46	-37.31 ± 8.72	0.242
IA	1.76 ± 0.43	1.60 ± 0.51	1.39 ± 0.29	**0.034**
IR	53.88 ± 9.60	49.75 ± 9.85	47.92 ± 8.06	0.130
	Moorfields regression analysis result (inferonasal)			
	WNL (27)	**BL (8)**	**ONL (18)**	
DN-I	-30.44 ± 9.63	-36.06 ± 9.35	-39.63 ± 10.97	**0.037**
IA	1.82 ± 0.42	1.47 ± 0.41	1.46 ± 0.39	**0.009**
IR	55.37 ± 9.20	49.06 ± 8.67	45.88 ± 7.97	**0.012**

DN-S = Superior deviation from normal; SR = Superior ratio; S/N = Superior/nasal; SA = Superior average; DN-I = Inferior deviation from normal; IR = Inferior ratio; IA = Inferior average; WNL = Within normal limits; BL = Borderline; ONL = Outside normal limits; p = p value on analysis of variance (ANOVA)

DISCUSSION

The emphasis of glaucoma diagnosis is beginning to shift from overwhelming reliance on unambiguous features such as intraocular pressure and visual fields to early diagnosis of so-called pre-perimetric glaucoma. Objective imaging techniques such as the HRT, scanning laser polarimetry by the nerve fiber layer analyzer GDx, and optical coherence tomography, (OCT), now allow comparison of optic nerve head and nerve fiber layer measurements in individuals and age -matched normal populations (5-10).

The two machines use different principles to document structural changes in the optic nerve head and RNFL, that are thought to precede visual field defects. They both measure RNFL thickness, and the HRT-II also records the topography of the optic nerve head. RNFL measurements on the scanning laser ophthalmoscope are as accurate as histomorphometric studies (11) and similarly, scanning laser polarimetry has

TABLE V - AGREEMENT BETWEEN SECTORIAL MOORFIELDS REGRESSION ANALYSIS (WNL, BL OR ONL) WITH GDX ADVANCED ANALYSIS PARAMETERS' DIAGNOSTIC LABEL (WNL, BL OR ONL)

GDx Parameters		Superotemporal MRA WNL	BL	ONL	Agreement	Superonasal MRA WNL	BL	ONL	Agreement
DN-S	WNL	8	4	1		9	3	1	
	BL	10	7	1		6	7	5	
	ONL	17	5	0		12	7	3	
					K = -0.053				K =0.065
SR	WNL	24	12	2		17	14	7	
	BL	2	2	0		2	2	0	
	ONL	9	2	0		7	2	2	
					K = -0.086				K = -0.070
SN	WNL	21	10	1		17	12	3	
	BL	4	2	0		3	2	1	
	ONL	10	4	1		7	3	5	
					K = 0.015				K = 0.139
SA	WNL	11	6	2		11	4	4	
	BL	5	3	0		3	3	2	
	ONL	19	7	0		13	10	3	
					K = -0.092				K = -0.004
GDx parameters		**Inferotemporal MRA WNL**	**BL**	**ONL**		**Inferonasal MRA WNL**	**BL**	**ONL**	
DN-I	WNL	0	0	1		1	0	0	
	BL	14	3	3		12	3	5	
	ONL	17	5	10		14	5	13	
					K = 0.032				K = 0.095
IR	WNL	20	5	4		19	3	7	
	BL	2	1	0		2	0	1	
	ONL	10	2	9		6	5	10	
					K = 0.255				K = 0.227
IA	WNL	8	2	1		8	1	2	
	BL	4	0	0		4	0	0	
	ONL	20	6	12		15	7	16	
					K = 0.130				K = 0.193

DN-S = Superior deviation from normal; SR = Superior ratio; S/N = Superior/nasal; SA = Superior average; DN-I = Inferior deviation from normal; IR = Inferior ratio; IA = Inferior average; WNL = Within normal limits; BL = Borderline; ONL = Outside normal limits; MRA = Moorfields regression analysis; K = Kappa been found to corroborate histological analysis (12). Measurement of the RNFL by OCT corresponds to optic disc topographic parameters on the HRT (13).

This study was designed to see if the data output of the HRT-II and the nerve fiber layer analyser, GDx, two machines commonly used in glaucoma practice, was interchangeable, and if there was agreement as to clinical analysis on their printouts. Global values on the HRT-II and the GDx represent the overall structure of the optic nerve head and nerve fiber layer of

TABLE VI - AVERAGE COEFFICIENT OF VARIANCE OF STEREOMETRIC PARAMETERS IN INDIVIDUAL HRT-II SECTORS

Parameter	tmp	Tmp/sup	Tmp/inf	Nasal	Nsl/sup	Nsl/inf
Disc area	0.0	0.0	0.0	0.0	0.0	0.0
Cup area	9.1	12.0	14.3	24.7	21.3	21.0
Rim area	14.8	11.6	10.1	8.0	7.9	6.2
Cup: disc area ratio	9.1	12.0	14.4	29.1	20.8	20.2
Rim: disc area ratio	14.8	11.7	10.1	8.0	7.9	6.2
Cup volume	15.9	19.2	21.7	21.6	25.1	25.4
Rim volume	25.3	21.8	19.8	19.4	18.7	16.2
Mean cup depth	8.0	9.0	9.9	10.9	9.5	11.4
Maximum cup depth	6.7	9.3	8.8	10.5	10.7	10.1
Height variation contour	23.4	17.8	18.1	20.6	32.9	32.8
Cup shape measure	5.3	40.4	0.6	2.0	21.6	2.3
Mean RNFL thickness	18.7	19.3	15.5	33.2	31.4	21.0
RNFL cross- sectional area	18.7	19.3	15.5	33.0	31.7	21.0

TABLE VII - LINEAR CORRELATION OF HRT AND GDX PARAMETERS WITH VISUAL FIELD INDICES. (Bold type indicates statistically significant correlations ($p<0.05$))

	Visual field indices			
HRT Parameters	Mean Deviation		CPSD	
Cup area [mm^2]	-0.218	0.118	0.257	0.063
Rim area [mm^2]	**0.442**	**0.001**	**-0.454**	**0.001**
Cup: disc area ratio	**-0.354**	**0.009**	**0.443**	**0.001**
Rim: disc area ratio	**0.354**	**0.009**	**-0.443**	**0.001**
Cup volume [mm^3]	-0.224	0.108	0.169	0.225
Rim volume [mm^3]	**0.436**	**0.001**	**-0.365**	**0.007**
Mean cup depth [mm]	-0.119	0.397	0.140	0.319
Maximum cup depth [mm]	-0.003	0.985	0.046	0.744
Mean RNFL thickness [mm]	**0.497**	**0.000**	**-0.388**	**0.004**
RNFL cross-sectional area [mm^2]	**0.528**	**0.000**	**-0.381**	**0.005**
GDx Parameters				
Deviation from normal - superior	-0.145	0.302	0.004	0.977
Superior ratio	0.058	0.680	-0.089	0.527
Superior/nasal	0.215	0.123	-0.199	0.153
Superior average	-0.037	0.792	-0.047	0.738
Deviation from normal - inferior	**0.280**	**0.043**	**-0.304**	**0.027**
Inferior ratio	**0.316**	**0.021**	**-0.285**	**0.038**
Inferior average	0.187	0.179	-0.192	0.167
Average thickness	-0.108	0.441	-0.016	0.907
The number	-0.150	0.285	0.153	0.275

RNFL = Retinal nerve fiber layer; CPSD = Corrected pattern standard deviation a particular eye. The number is a composite indicator of nerve fiber loss as measured on scanning laser polarimetry. This was shown to correlate with all rim-based data and the cup: disc area ratio on the HRT II, but not with cup volume or depth. The data reaffirms that a loss of nerve fibers correlates with enlargement of the cup area and with a loss in the rim area and volume. This could be interpreted to suggest that nerve fiber loss may not be reflected as an increase in the depth of the cup. The correlation of 'The number' was significant with the vertical cup: disc ratio but not with the horizontal cup: disc ratio. This may reflect the selective localization of glaucomatous damage at the two poles of the disc.

The average thickness of the RNFL as measured by the GDx did not correspond to the mean thickness on the HRT-II. It could, however, be correlated to the RNFL area measured by the HRT-II, as well as its rim area and rim volume. These parameters on the HRT have the highest diagnostic value for glaucoma. A regression equation derived in this study allows the AT values of the RNFL on the GDx to be converted to RNFL on the HRT-II, and vice versa.

In our study, more numerical values of the HRT parameters from the inferior sectors correlated with the corresponding quadrantic NFL-GDx parameters, than in the superior sectors. A better correlation of inferior and superior RNFL field defects has already been reported, compared to superior RNFL characteristics (14).

Evaluating the values for each pole of the disc as recorded by HRT with the NFL parameters, we found a difference between the superior and inferior poles. In the inferior quadrant, both the inferonasal and inferotemporal sector parameters on the HRT II showed a high degree of correlation with the nerve fiber layer thickness on GDx. The inferonasal sector correlated better than the inferotemporal. This could imply that there is a greater tendency to glaucomatous damage in the inferonasal sector of the optic nerve head. In the superior quadrant, the overall superior sector on the HRT-II correlated better with the parameters on GDx-NFA than any of the sub sectors, suggesting a more uniform change in the disc features in both the superonasal and superotemporal quadrants with progressive glaucomatous damage.

Moorfields regression analysis on HRT-II is a regression line-based comparison of the rim area with a predicted value for the given disc size and age, obtained from a normative database. The output is a 'diagnostic' label of within or outside normal limits, or borderline. GDx advanced analysis parameters also have an attendant p value and a similar label for each of the parameters, based on comparison with a normative database for age, sex and race. The agreement between what is defined as within normal limits, borderline or outside normal limits on Moorfields regression analysis and what is similarly defined on any of the GDx advanced analysis parameters is at best poor (kappa range: -0.086 to 0.255). This might be because of differences in the normative database for the two machines or in the method applied to arrive at the interpretation of data.

On the other hand if we look at the numerical values of GDx parameters, they seem to worsen as the Moorfields regression analysis goes from within to outside normal limits. This was significant for more GDx parameters reflective of the inferior half of the disc. Thus though the numerical worsening of parameters on the two machines correlates well, the labels such as "within" or "outside" normal limits do not.

In view of the use of multiple tests of statistical significance a correction factor like Bonferroni's was considered. Although this correction may help reduce the alpha error, it significantly increases the chances of beta error. Its use in medical literature is still controversial: "Adjusting statistical significance for the number of tests that have been performed on study data – the Bonferroni method – creates more problems than it solves and simply describing what tests of significance have been performed, and why, is generally the best way of dealing with multiple comparisons" (15). The p value is mentioned on the charts and the Bonferroni correction is easily deducible by a simple multiplication. We feel it is best to leave the results as they come, with a description of the method used to arrive at them. However the alpha value may be higher than indicated became of the multiple measurements.

Although the place of these investigations in the diagnosis of glaucoma is yet to be established, our study has shown that the results with these two instruments are correlatable. The RNFL thickness on the GDx can be calculated from the HRT-II thickness by a regression equation. However, agreement between final clinical interpretations on the two machines was meager.

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