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Assessment of cup-to-disc ratio with slit-lamp funduscopy, Heidelberg Retina Tomography II, and stereoscopic photos

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PURPOSE. *To compare optic disc measurements achieved by slit-lamp funduscopy, Heidelberg Retina Tomography II (HRT II), and stereoscopic optic nerve photos (SONP) in glaucomatous, ocular hypertensive, and normal eyes.*

METHODS. *A total of 176 eyes (glaucomatous [n=87], ocular hypertensive [n=40], and normal eyes [n=49]) of 90 participants were studied. Each participant underwent a full ophthalmic examination, including automated perimetry, slit-lamp funduscopy, HRT II, and SONP. To compare the three different methods being investigated, the following measurements were used: vertical cup to disc ratio (VCDR), horizontal cup to disc ratio (HCDR), and cup to disc area ratio (CDR). Slit-lamp funduscopy was evaluated only with respect to VCDR. HRT II and SONP were evaluated with all three measurements (VCDR, HCDR, and CDR).*

RESULTS. *CDR measurements in ocular hypertensive eyes did not differ significantly according to the measurement methods used (p=0.4). CDR in the other groups of participants, as well as VCDR and HCDR, all differed significantly within each group according to the method used (p<0.05 for all). Mean VCDR measured with funduscopy was smaller than mean VCDR measured with either HRT II or SONP in the glaucoma and ocular hypertension groups (p=0.0001). However, overall, the three methods showed a strong correlation in terms of VCDR, HCDR, and CDR measurements.*

CONCLUSIONS. *Despite the correlation among the three methods, the significant differences between their measurements of optic disc parameters may be too large for these methods to be used interchangeably in clinical situations. (Eur J Ophthalmol 2009; 19: 55-60)*

KEY WORDS. *Cup disc ratio, Funduscopy, Heidelberg Retinal Tomography II, Stereoscopic photographs*

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INTRODUCTION

Optic nerve head evaluation is important for the early detection, monitoring, and management of glaucoma (1). Changes in the structural appearance of the optic disc usually occur before visual field loss (2). Hence, cautious documentation of optic nerve morphometric parameters is essential. Precise and reproducible measurements of the optic disc are also critically important for evaluating the progression of the disease.

There are several different methods for determining optic disc parameters, including ophthalmoscopy, funduscopy, disc photography, and semiautomated methods (2). In the clinical assessment of optic nerve head morphologic parameters with direct or indirect ophthalmoscopy, interobserver variability has been reported (3). Optic nerve head photography (ONHP) is a technique frequently used in the assessment of cup to disc area ratio (CDR) for monitoring glaucoma. However, owing to high intra- and interobserver variability and the broad range of variations in normal

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optic disc formation, the usage of ONHP is limited (4). Semiautomated methods such as the Heidelberg Retinal Tomograph II (HRT II) have been developed to provide objective and reproducible analysis of the optic nerve head. These methods have higher reproducibility and less interobserver variability compared to traditional methods. Moreover, archiving and documentation of the morphometric parameters of the optic disc is easier with these methods (5).

Previous studies have compared different methods, e.g., funduscopy, semiautomated methods, or stereoscopic optic nerve photographs (SONP), in glaucomatous and/or normal eyes (4-10). Most of these reports compared methods with respect to only one disc parameter, such as vertical cup to disc ratio (VCDR) or CDR (2, 7-11). However, no studies have compared funduscopy, HRT II, and SONP in the assessment of VCDR, horizontal cup to disc ratio (HCDR), and CDR in glaucomatous, ocular hypertensive, and normal eyes. The aim of this study was therefore to make this comparison.

METHODS

The participants in this study were recruited from the glaucoma service at Fatih University Medical School in Ankara, Turkey. Eligible subjects had spherical and cylindrical refraction between ±4.0 and ±2.0 diopters (D), respectively. All participants were similar in ethnic background. Excluded from the study were any subjects with corneal disease, corneal scarring, or posterior segment pathology other than glaucoma. The study was carried out during the period October 2006–February 2007. The local university ethics committee approved the study and the tenets of the Declaration of Helsinki were observed.

All subjects underwent a full ophthalmic examination including the Snellen visual acuity test, intraocular pressure (IOP) measurement, standard 24-2 Swedish Interactive Thresholding Algorithm (SITA) automated perimetry (Humphrey Field Analyzer Model 750, Carl Zeiss Meditec, Dublin, CA), slit-lamp funduscopy under dilated pupils, HRT II (HRT II, Heidelberg Engineering GmBH, Dossenheim, Germany), and SONP (Topcon TRC-50IX retinal camera, Hasunuma-CHO, ITABASHI-KU, Tokyo, Japan).

Primary open-angle glaucoma (POAG) was defined as IOP >21 mmHg, open angle on gonioscopy, glaucomatous visual field defects, and glaucomatous cupping of the optic disc. Normotensive glaucoma (NTG) was defined as the existence of glaucomatous optic neuropathy, visual field defect, and IOP <21 mmHg. Ocular hypertension (OHT) was defined as IOP >21 mmHg on two or more measurements in the presence of a normal optic nerve head, normal visual field, and normal gonioscopy.

All participants underwent 24-2 full threshold automated visual field (SITA). Only reliable fields with a fixation loss rate ≤33% and false-positive and false-negative rates ≤20% were included. To be eligible, glaucoma patients were required to have a glaucomatous visual field defect, defined as the presence of a glaucoma hemifield test (GHT) result outside normal limits, and a pattern standard deviation (PSD) with $p<0.05$ in the glaucomatous eye and a normal GHT and PSD p value > 0.05 in the healthy control eye.

Slit-lamp biomicroscopic examination of the optic nerve head (ONH) was performed with a Volk 66 D fundus lens (Volk Optical, Cleveland, OH, USA) by an experienced glaucoma specialist (I.F.H.). The extent of cupping was evaluated according to contour and small blood vessel deflection, not on pallor. All IOP measurements were made with a Goldmann applanation tonometer, which is still considered the gold standard for IOP readings.

Normal eyes were defined with the following criteria: no family history of glaucoma, no history of intraocular surgery, a best-corrected visual acuity of 20/20, a normal appearing optic disc, and normal visual field tests.

The technical details of HRT II have been defined in detail elsewhere (12, 13). HRT II was conducted after each patient's manifest refraction and average keratometry readings were entered. Images were encompassed if standard deviation was <40 µm and sensitivity levels were under 90%. An experienced operator (R.K.) marked the optic disk contour within the scleral ring while viewing a stereoscopic optic disk photograph. The cup to disk area ratio was obtained directly from the standard printout. The vertical disk diameter, vertical cup diameter, horizontal disk diameter, and horizontal cup diameter measurements were calculated with the use of the interactive measurements option. The VCDR and HCDR (calculated by dividing the cup diameter by the disc diameter along a line through the center of the disc vertically or horizontally, respectively) were utilized in statistical analysis.

Simultaneous optic disc photos were taken with a Topcon retinal camera after pupillary dilatation. For each eye, we took an optic disc photograph when the optic disc was at the center of the camera. The second photograph was taken at a viewpoint of approximately 20º to the optic

disc. The pair of photographs was then projected onto the computer monitor side by side. The images on the monitor were viewed with a large hand-held stereo viewer by the same clinician who took the photographs, and the cup and disc margins of the optic disc were drawn with a computer mouse. The CDR was calculated by the Topcon software. The vertical disk diameter, vertical cup diameter, horizontal disk diameter, and horizontal cup diameter measurements were made via the interactive measurements option. VCDR and HCDR were used in statistical analysis.

Results of the measurements and calculations were expressed as mean ± standard deviation and were analyzed statistically by means of Student *t* test. We also conducted repeated measures analysis of variance (ANOVA) to analyze the overall mean VCDR of the three methods. The correlation of the three methods' parameters was evaluated in terms of Pearson correlation coefficient. P values of less than 0.05 were considered statistically significant.

RESULTS

From 90 participants in the study (48 female, 42 male), 176 eyes (87 glaucomatous, 40 ocular hypertensive, and 49 normal) were evaluated. The participants' mean age was 54.7±11.6 years (range 25 to 80 years). The groups of participants with glaucomatous, ocular hypertensive, or normal eyes did not differ significantly in terms of age or gender (p>0.05 for all). Demographic data and the distribution of eyes across the categories of glaucomatous, ocular hypertensive, or normal are shown in Table I.

CDR measurements in ocular hypertensive eyes did not differ significantly according to the measurement methods used; however, CDR in the other groups of participants, as well as VCDR and HCDR, all differed significantly within each group according to the method used (Tab. II). For VCDR within each group of participants, the repeated measures ANOVA test showed significant differences in

TABLE I - DEMOGRAPHIC DATA AND THE DISTRIBUTION OF EYES ACCORDING TO CONDITION

	Glaucoma	OHT	Normal	p value
No. of eyes (%)	87 (49.4)	40 (22.7)	49 (27.9)	
Gender (eyes)				0.472
Male, n (%)	42 (48.3)	15 (37.5)	24 (49)	
Female, n (%)	45 (51.7)	25 (62.5)	25 (51)	
Mean age, yr ± SD	56.54±12.37	53.08±9.00	52.61±11.65	0.101

According to Student t test.
OHT = ocular hypertension.

TABLE II - MEAN VALUES OF OPTIC DISC PARAMETERS OBTAINED BY EACH METHOD

	HRT II	SONP	Funduscopy	p value
Mean VCDR*				
Glaucoma	0.63	0.55	0.47	0.0001
OHT	0.53	0.46	0.33	0.0001
Normal	0.43	0.30	0.22	0.0001
Mean CDR†				
Glaucoma	0.40	0.38		0.03
OHT	0.28	0.27		0.4
Normal	0.20	0.14		0.0001
Mean HCDR†				
Glaucoma	0.64	0.55		0.0001
OHT	0.53	0.46		0.002
Normal	0.42	0.30		0.0001

*Repeated measures analysis of variance test used.
†Student t test used.
HRT II = Heidelberg retina tomography II; SONP = stereoscopic optic nerve photographs; VCDR = vertical cup to disc ratio; OHT = ocular hypertension; HDCR = horizontal cup to disc ratio.

the methods' measurements (p=0.0001, Tab. II). The mean values of VCDR, HCDR, and CDR measured with HRT II were higher than the same values measured with SONP in the glaucomatous, ocular hypertensive, and normal eyes. Mean VCDR measured with funduscopy was smaller than mean VCDR measured with either HRT II or SONP in the glaucoma and ocular hypertension groups (p=0.0001).

Table III summarizes the correlation of the three methods in terms of VCDR, CDR, and HCDR, within each group and overall. The parameters measured with the three methods showed moderate to strong correlation within the glaucoma, OHT, and normal groups. The overall correlations were more significant.

DISCUSSION

In the present study, we found that measurements of optic disc parameters generally differed significantly according to the method of measurement used. The only exception to this was noted in patients with OHT, where the measurement of CDR via HRT II did not differ significantly from the same measurement made via SONP. Additionally, we found that the three methods had moderate to strong correlation within the three groups of participants.

Precise evaluation of structural damage to the optic disc is crucial in the early recognition and longitudinal assessment of glaucomatous optic neuropathy (14). In different clinics, several different methods for evaluating optic disc parameters are currently in use (2). Measurements of these parameters, in terms of their reproducibility and agreement across the different methods used in making them, are important in the follow-up of patients with glaucoma.

Previous studies have reported significant differences between measurements of optic disc parameters according to the semiautomated or traditional methods used. These studies demonstrated that measurements of disc parameters as determined by different methods are not interchangeable (4, 5, 8, 15). Moreover, three recent studies have indicated that optic disc parameters measured with ophthalmoscopy are smaller than those obtained with other methods (5, 8, 15). Our results are consistent with these; we found that measurements of VCDR, HCDR, and CDR obtained via slit-lamp funduscopy, HRT II, and SONP differed significantly, independent of the disease state of the eyes except in patients with OHT, where CDR obtained by the HRT II and SONP were similar.

Another important finding of the present study is that in all groups of participants, VCDR measured funduscopically was smaller than VCDR measured with HRT II or SONP, and this is consistent with previous studies (5, 8, 15). A possible explanation for this finding might be the clinicians' bias caused by non-topographical cues such as disc pallor, which is sometimes used as an indicator of

TABLE III - PEARSON CORRELATION COEFFICIENTS FOR VCDR, CDR, AND HCDR MEASUREMENTS IN THE PARTICIPANT GROUPS

Group	Measure	HRT–SONP	HRT–Funduscopy	SONP–Funduscopy
Glaucoma	VCDR	0.68	0.65	0.68
	CDR	0.64		
	HCDR	0.62		
OHT	VCDR	0.73	0.63	0.75
	CDR	0.79		
	HCDR	0.62		
Normal	VCDR	0.71	0.63	0.65
	CDR	0.74		
	HCDR	0.71		
Overall	VCDR	0.82	0.77	0.80
	CDR	0.82		
	HCDR	0.78		

All correlations were significant, p<0.05 for all.

VCDR = vertical cup to disc ratio; HDCR = horizontal cup to disc ratio; HRT II = Heidelberg retina tomography II; SONP = stereoscopic optic nerve photographs; OHT = ocular hypertension.

the optic cup. The area of pallor is smaller than the area at which vessels begin to bend, so measurements based on the area of pallor give smaller values.

Previous studies have demonstrated poor to good agreement between different techniques for evaluating optic disc parameters (1, 2, 4, 5, 8, 9, 11, 15-19). We found a substantial correlation between HRT II and SONP in terms of CDR and HCDR measurements within each of the three groups. There was also a substantial correlation among HRT II, SONP, and funduscopy measurements of VCDR within the three groups. The three methods showed the strongest correlation when the optic disc parameters were analyzed across all participants, and this correlation is higher than that reported in the majority of previous studies (1, 4, 8, 9, 11, 16, 17).

Generally, different ophthalmology centers use different methods for measurement and documentation of optic disc parameters. Semiautomated devices such as HRT II are not commonly used. In the present study, although the different methods generally gave different results in measuring a single instance of a given parameter, the methods showed a strong correlation in series of measurements. Hence, if HRT II is not available, stereoscopic photography may be used in the follow-up of these patients.

In summary, in participants having glaucomatous, ocular hypertensive, or normal eyes, we found that slit-lamp funduscopy, HRT II, and SONP measurements in general differed significantly in the results they gave for CDR, VCDR, and HCDR. The three methods showed substantial correlation within the participant groups, and stronger correlation when the participants were evaluated in one overall group. Despite this correlation, the different results obtained with the three methods suggest that the methods are not interchangeable. Additional studies of these three methods are needed to evaluate the sources of variability, their level of significance, and correlation between various other methods of VCDR, HCDR, and CDR estimation, as these techniques continue to evolve.

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