Evaluation of Diagnostic Ability of Optical Coherence Tomography and Confocal Scanning Laser Ophthalmoscopy Among Ocular Hypertension, Suspected Glaucoma and Glaucoma Patients

Optik Koherens Tomografi ve Konfokal Tarayıcı Lazer Oftalmoskopinin Tanısal Yeteneklerinin Oküler Hipertansif, Glokom Şüphesi ve Glokom Olgularında İncelenmesi

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ABSTARCT

Purpose: To compare the discriminating ability of the optic nerve head (ONH) and retinal nerve fiber layer (RNFL) parameters in ocular hypertension (OHT), glaucoma suspect (GS) and primary open angle glaucoma (POAG).

Materials and Methods: Two hundred and nine subjects (62 with OHT, 65 with GS, 82 POAG) were studied retrospectively. ONH configuration was analyzed by Heidelberg Retinal Tomograph III (HRTIII), RNFL was analyzed by Spectralis Optical Coherence Tomography (SD-OCT). Global and sectoral (temporal, superotemporal, superonasal, nasal, inferonasal, and inferotemporal) optic disc and RNFL parameters were evaluated. The areas under the receiver operator characteristic curve (AUC) were calculated for each HRTIII and SD-OCT parameter to compare the discriminating ability of each imaging method to differentiate between OHT, GS, POAG eyes. Agreement between Moorfields regression analysis (MRA) of HRT and global RNFL categorical classification of SD-OCT was also investigated.

Results: The global rim area (AUC:0.725) and the inferotemporal RNFL thickness (AUC:0.700) demonstrated the best diagnostic performance to discriminate OHT from POAG patients for the HRTIII and SD-OCT respectively. Regarding AUCs distinguishing GS from POAG eyes, both HRT III and SD-OCT parameters had a suboptimal performance. No agreement was found between the MRA classification of HRTIII and global classification of SD-OCT RNFL analysis.

Conclusions: This study demonstrated fairly good performance of the SD-OCT and HRTIII in discriminating eyes with OHT and glaucoma. Although the performance of the RNFL assessment seems to be better than the optic disc assessment, however, both methods performed less well for discriminating the glaucoma from suspected glaucoma.

Key Words: Glaucoma, ocular hypertension, glaucoma suspect, optic disc, retinal nerve fiber layer.

ÖZ

Amaç: Optik sinir başı (OSB) ve retina sinir lifi tabakasına (RSLT) ait parametrelerin, oküler hipertansif (OHT), glokom şüphesi (GŞ) ve primer açık açılı glokom (PAAG) olgularını ayırt edebilme yeteneklerinin karşılaştırılması.

Gereç ve Yöntem: İki yüz dokuz olguya ait kayıtlar (62'si OHT, 65'i GŞ ve 82'si PAAG) geriye dönük olarak incelendi. OSB özellikleri Heidelberg Retinal Tomografi III (HRT III) ile RSLT ise Spectralis Optik Koherens Tomografisi (SD-OKT) ile analiz edildi. OSB ve RSLT'na ait global ve sektörel (temporal, süperotemporal, süperonasal, nasal, inferonasal, ve inferotemporal) parametreler incelendi. Her iki görüntüleme yöntemine ait tüm parametreler için eğri altında kalan alan (AUC) hesaplanarak HRT III ve SD-OKT'nin OHT, GŞ, PAAG'lu gözleri ayırt edebilme yetenekleri araştırıldı. Ayrıca HRT'ye ait Moorfields regresyon analizi (MRA) ile SD-OKT'deki global RSLT kategorik sınıflamalarına ait tanıların birbirleri ile uyumları incelendi.

Bulgular: OHT'nu PAAG'dan ayırt etmede en iyi tanısal performansı HRT'de global rim alanının (AUC:0.725) ve SD-OKT'de inferotemporal RSLT kalınlığının (AUC:0.700) gösterdiği tespit edildi. GŞ'li olguların PAAG olgulardan ayırt edilmesinde hem HRT III'de hem de SD-OKT'nin performansı yetersiz bulundu. Ayrıca bu üç olgu grubunda SD-OKT'nin RSLT analizi ile HRT III'ün MRA arasında tanısal sınıflamalar açısından uyum olmadığı görüldü.

Sonuç: Bu çalışmada SD-OKT ve HRT III'ün OHT'nu PAAG'dan ayırt etmede iyi bir performans gösterdikleri görüldü. Ancak her iki analiz yöntemi glokom şüphesi olan olguları glokomdan ayırt etmekte başarılı bulunmadı.

Anahtar Kelimeler: Glokom, oküler hipertansiyon, glokom şüphesi, optik disk, retina sinir lifi tabakası.

Anahtar Kelimeler: Pediatrik katarakt cerrahisi, sekonder glokom.

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Geliş Tarihi - Received: 12.12.2011
Kabul Tarihi - Accepted: 29.01.2012
Glo-Kat 2012;7:31-37

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INTRODUCTION

The detection of early glaucomatous damage is one of the most important aspect of glaucoma management. Newer versions of imaging devices for the optic nerve head (ONH) and retinal nerve fiber layer (RNFL) are introduced with the expectation that higher resolution would lead to more reproducible measurements, better clinical performance and diagnosis of preprerimetric glaucoma.[1-4] As glaucomatous structural damage is widely accepted to precede functional damage.[1,5,6] Hence currently available imaging techniques used for detection of glaucoma including confocal scanning laser ophthalmoscopy (CSLO), optical coherence tomography (OCT), and scanning laser polarimetry (SLP) have gained much clinical interest. It is uncertain whether the RNFL or the neuroretinal rim represents a more sensitive surrogate for detecting glaucomatous change.

Moreover, since these techniques use different methods to measure different aspects of the eye, it is possible to expect that their measurements have different associations with glaucoma diagnosis.

The aim of the current study could be divided into two aspects; the first comparison of the parameters generated by the latest versions of OCT, Spectralis OCT (SD-OCT), (Heidelberg Engineering, GmbH, Dossenheim, Germany), and Heidelberg Retinal Tomograph III (HRT III; software version 3.1; Heidelberg Engineering) among the patients with ocular hypertension (OHT), glaucoma suspect (GS), and POAG; the second consisting of a comparison of the ability of each instrument to detect glaucomatous damage.

MATERIALS AND METHODS

This study involved a retrospective comparison analysis of HRT III, SD-OCT variables of the eyes diagnosed with OHT, GS or POAG. We reviewed the medical records of the patients who underwent imaging of the RNFL with SD-OCT and the ONH with HRT III from March 2009 to January 2011 at the Glaucoma Division, Ulucanlar Eye Research Hospital. Only one eye per subject was randomly selected if both were eligible. All methods adhered to the Declaration of Helsinki for Research involving human subjects.

Data of 209 eyes from 209 patients were recruited and classified into three groups. In the first group sixty two of the eyes were followed as OHT, where OHT was defined as intraocular pressure (IOP) above 21 mm Hg on presentation, without alterations of the ONH and with normal VF. Twenty three ocular hypertensive eyes were treated with topical medications. Second group contained 65 eyes and was followed as suspected glaucoma. GS was defined as suspicious appearance of the ONH ie, the presence of one of the following: notching, hemorrhage, and suspicious cup:disc (C/D) ratio 0.5 considering disc size, with normal or borderline VF. Eleven eyes with suspected glaucoma were treated with topical medications. POAG group contained 80 eyes, in which POAG was defined as IOP above 21 mm Hg in three separate measurements, structural alterations of the ONH, and glaucomatous changes in the VF according to Anderson's classification.

All patients had a complete medical history and ocular examination review, including best corrected visual acuity, slit-lamp examination, gonioscopy, applanation tonometry, fundus examination, stereoscopic ophthalmoscopy of the ONH. Patients were included in the study according to the following inclusion criteria: age older than 40 years, best corrected visual acuity on the Snellen Chart better than 0.5, refractive error within 4 spherical diopter range, with less than 2 cylinder diopters and at least three reliable VF tests and good quality OCT and CSLO scans. Patients were included if they had standard automated perimetry (SAP), HRT III and SD-OCT testing within 3 months of each other. Exclusion criteria were the presence of any retinal and/or neurologic diseases affecting the optic disc or visual field, secondary causes of increased IOP, and a history of any surgical or laser procedures. Patients with tilted discs, nonglaucomatous optic disc atrophy or any significant media opacity in which the fundus was not visible were also excluded. Nine hundred and eighty subjects were excluded due to these criteria.

All subjects' VF were assessed by a Humphrey field analyser 750i (Carl Zeiss Meditec, Dublin, CA, USA), program 24-2 using Swedish Interactive Thresholding Algorithm. Only the last perimetric examination was considered for statistical analysis. The VF reliability criteria included <20% fixation loss and <20% false negative and false positive rates.

All CSLO scans were performed with the HRT III. The principles of CSLO have been described elsewhere.[7] Fifteen degree angle view was used under the same intensity of dim room light. Subjective refraction results were used to set the initial scan focus. Three scans centered on the optic disc were automatically obtained for each test eye, and a mean topography was created.

The disc margin was outlined on the mean topography image by the experienced technician while he viewed simultaneous stereoscopic photographs of the optic disc. The accuracy in defining ONH circumference was performed by using minimum 6 points for drawing the contour line. Keratometry values were used for the correction of the magnification errors. Subjects with standard deviation more than 30 μm were excluded in the study.

Table 1: Baseline Characteristics of the Study Population.

	OHT[a]	GS[b]	POAG[c]	P[1]	P[2]
Age (years)	54.7±7.9	55.3±9.8	59.7±10.9	0.03*	0.02*
Gender (N) Male	26	26	40		
Female	36	39	42	0.53	
Patients treated Yes	23	11	82		
No	39	54	0	<0.001*	
Follow-up time (years)	2.7±1.6	3.1±1.9	7.8±3.4	0.001*	0.001*
Intraocular pressure (mm Hg)	24.7±3.2	20.3±3.8	18.9±5.1	<0.001*	0.07
Pachymetry (µm)	554.1±23.4	548.0±31.5	545.5±34.1	0.09	0.64
Visual Field Index	98.5±1.0	97.9±1.7	87.3±9.9	<0.001*	<0.001*
Mean Deviation (dB)	-1.43±0.98	-1.88±1.20	-6.51±3.72	<0.001*	<0.001*
Pattern Standart Deviation (dB)	1.64±0.36	1.77±0.47	5.02±2.48	<0.001*	<0.001*
Glaucoma hemifield test					
Within Normal Limits	45	39	0		
Borderline	17	26	3	<0.001*	
Outside Normal Limits	0	0	79		

***: Statistically significant, a:** *Ocular Hypertension,* **b:** *Glaucoma suspect,* **c:** *Primary open angle glaucoma,* **P[1]:** *OHT vs POAG,* **P[2]:** *GS vs POAG.*

Disc area (mm^2), rim area (mm^2), rim volume (mm^3), linear C/D ratio, mean RNFL thickness (mm), Moorfields regression analysis (MRA) were evaluated from global data. We have selected the rim area, rim volume and the linear C/D ratio for the analyses since they directly reflect the structural integrity of the neuroretinal rim. The optic disc sectors used in this study were classified as follows: temporal, superotemporal, superonasal, nasal, inferonasal, and inferotemporal.

The SD-OCT was used to image the peripapillary RNFL. Details of this technique have been described elsewhere.[8] During OCT imaging, a scan circle with a diameter of 3.45 mm was manually positioned at the center of the optic disc while the eye-tracking system was activated. Only good quality OCT data (signal quality more than 20 dB.) were used for further analysis.

The global and regional RNFL thickness parameters calculated by the SD-OCT software were evaluated in this study. The RNFL thickness around the optic disc is divided into six sectors (temporal, superotemporal, superonasal, nasal, inferonasal, and inferotemporal) corresponding to the sectors generated by HRT MRA. In the analysis printout, global RNFL measurement was indicated by a categorical classification as “within the normal limits” (WNL) (within 95% normal distribution), “borderline”(BL) (between the lower 95.0% and the lower 99% of normal distribution) or ONL (below the lower 99% of normal distribution).

Statistical Analyses: Statistical analysis were performed on computer (SPSS for Windows ver. 15; SPSS, Chicago, IL, USA). Results were expressed as mean±SD. Student’s *t*-test, Tukey-HSD test, the Analysis of Variance (ANOVA) were used for the statistical analysis of the study. Categorical data was analysed with the chi-squared test. A P value of less than 0.05 was accepted as statistically significant. The areas under the receiver operator characteristic curve (AUC) were calculated for each single HRT III and SD-OCT parameter to compare the discriminating ability of each imaging method to differentiate between ocular hypertensive, suspected glaucoma and glaucomatous eyes. A perfect test would have an AUC of 1 (100% sensitivity and 100% specificity at the appropriate cut-off value), whereas a test with no diagnostic value would have an AUC of 0.5.

RESULTS

Table 1 shows the demographics of the subjects. With regard to sex and central corneal thickness there were no significant differences between the OHT, GS and POAG groups. Glaucomatous patients were significantly in older age than the OHT and GS patients ($p<0.05$ for both).

Table 2: *Comparison of Results of HRT III ONH Parameters.*

	OHT[a]	GS[b]	POAG[c]	P[1]	P[2]
Disc Area (mm^2)	2.27±0.38	2.3±0.43	2.32±0.51	0.59	0.91
Rim Area (mm^2)	1.65±0.26	1.36±0.24	1.39±0.38	<0.001*	0.55
Rim Volume (mm^3)	0.45±0.15	0.33±0.12	0.35±0.18	<0.001*	0.48
Linear Cup to Disc ratio	0.49±0.15	0.61±0.13	0.60±0.16	<0.001*	0.87
Mean RNFL[d] Thickness	0.26±0.07	0.22±0.07	0.22±0.09	0.002*	0.82
Rim Area Superonasal (mm^2)	0.24±0.05	0.19±0.05	0.21±0.07	0.009*	0.13
Rim Area Superotemporal (mm^2)	0.20±0.04	0.16±0.04	0.17±0.07	0.005*	0.075
Rim Area Temporal (mm^2)	0.27±0.07	0.21±0.07	0.22±0.10	0.001*	0.29
Rim Area Inferotemporal (mm^2)	0.22±0.05	0.18±0.04	0.17±0.07	<0.001*	0.40
Rim Area Inferonasal (mm^2)	0.25±0.04	0.21±0.06	0.22±0.07	0.01*	0.28
Rim Area Nasal (mm^2)	0.46±0.08	0.41±0.09	0.41±0.13	0.008*	0.74
Moorfields Regression Analysis					
Within Normal Limits	44	9	22		
Borderline	12	25	17	<0.001*	
Outside Normal Limits	6	31	43		

:** *Statistically significant,* ***a: *Ocular Hypertension,* ***b:*** *Glaucoma suspect,* ***c:*** *Primary open angle glaucoma,* ***P[1]:*** *OHT vs POAG,* ***P[2]:*** *GS vs POAG.*

As expected, mean deviation and visual field index values were significantly lower and pattern standard deviation values were significantly higher in the glaucoma group ($p<0.001$). Since most of the ocular hypertensive patients were not taking antiglaucomatous treatment, therefore the OHT group had significantly higher IOP than those of GS and POAG groups.

Comparisons of HRT III measurements among the OHT, GS, and POAG eyes were given in table 2. No differences were found in the optic disc area between the study groups. Significant differences were observed in the global and regional neuroretinal rim and RNFL measurements between the OHT group and POAG group.

Table 3: *Comparison of Results of HRT III ONH Parameters. Comparison of Results of SD-OCT RNFL Parameters.*

	OHT[a]	GS[b]	POAG[c]	P[1]	P[2]
Superonasal RNFLT (µm)	101.4±25.4	102.3±23.8	90.4±27.2	0.045*	0.01*
Superotemporal RNFLT (µm)	125.5±16.3	114.8±20.5	107.0±28.9	<0.001*	0.07
Temporal RNFLT (µm)	69.2±10.1	66.6±10.7	64.2±13.9	0.018*	0.27
Inferotemporal RNFLT (µm)	140.7±17.9	134.3±20.6	120.6±33.7	<0.001*	0.005*
Inferonasal RNFLT (µm)	106.5±22.4	101.3±22.9	99.2±26.3	0.082	0.62
Nasal RNFLT (µm)	72.5±11.0	71.0±10.8	65.5±16.9	0.005*	0.023*
Global RNFLT (µm)	94.7±8.6	91.3±9.5	84.8±15.9	0.00*	0.004*
Classification					
Within Normal Limits	45	36	26		
Borderline	17	13	20	<0.001*	
Outside Normal Limits	0	16	36		

:** *Statistically significant,* ***a: *Ocular Hypertension,* ***b:*** *Glaucoma suspect,* ***c:*** *Primary open angle glaucoma,* ***P[1]:*** *OHT vs POAG,* ***P[2]:*** *GS vs POAG.*

Table 4: *Comparison of HRT III and SD-OCT parameters areas under the Receiver Operator Characteristic curves in ocular hypertensive (OHT) vs glaucomatous (POAG) and glaucoma suspect (GS) vs POAG eyes.*

	OHT[a] vs POAG[c]	GS[b] vs POAG
HRT III Rim Area	0.725	0.504
Rim Volume	0.694	0.479
Linear c/d	0.716	0.509
Mean RNFL Thickness	0.646	0.511
Superonasal Rim Area	0.648	0.438
Superotemporal Rim Area	0.648	0.401
Temporal Rim Area	0.696	0.463
Inferotemporal Rim Area	0.709	0.547
Inferonasal Rim Area	0.661	0.461
Nasal Rim Area	0.628	0.488
SD-OCT Superonasal RNFL Thickness	0.592	0.624
Superotemporal RNFL Thickness	0.698	0.564
Temporal RNFL Thickness	0.608	0.542
Inferotemporal RNFL Thickness	0.700	0.628
Inferonasal RNFL Thickness	0.600	0.539
Nasal RNFL Thickness	0.643	0.610
Global RNFL Thickness	0.689	0.615

***a:** Ocular Hypertension, **b:** Glaucoma suspect, **c:** Primary open angle glaucoma.*

On the other hand none of the HRT III parameters in the GS group eyes were significantly different than those of the POAG group. Table 2 also presented the proportion of the eyes, which were classified as WNL, BL, or ONL according to the MRA. Significantly higher proportions of eyes of POAG group subjects were identified as ONL and BL in this study ($p<0.001$). RNFL thickness measurements in sectors between OHT, GS and POAG eyes and the frequency distribution of global RNFL categorical classification of SD-OCT was shown in table 3. Proportions of the POAG group eyes identified as ONL and BL were significantly higher ($p<0.001$). To assess the diagnostic ability of HRT III and SD-OCT, the AUCs were used to describe the ability of each parameter to differentiate the glaucoma from OHT and GS eyes. Table 4 showed the values of AUC of the global and sectoral neuroretinal rim areas and RNFL thickness measurements. The AUC of SD-OCT measurements in our study varied from 0.592 to 0.700 in the OHT versus the POAG group and 0.539 to 0.628 in the GS versus the POAG. The AUC of HRT III parameters varied from 0.628 to 0.725 in the OHT versus the POAG group and 0.401 to 0.547 in the GS versus the POAG group. The global rim area (AUC: 0.725) and the inferotemporal RNFL thickness (AUC: 0.700) demonstrated the best diagnostic performance to make a discrimination between the ocular hypertensives and glaucomatous persons for their HRT III and SD-OCT parameters, respectively.

Table 5: *Agreement between diagnostic probability codes of Heidelberg Retinal Tomograph and Spectralis Optical Coherence Tomograph.*

		SD-OCT Global Classification		
		WNL[a]	**BL[b]**	**ONL[c]**
Moorfields Regression Analysis				
	WNL	37	23	15
	BL	32	12	10
	ONL	38	15	27
Measure of agreement (κ) 0.035 (p=0.45)				

***a:** Within normal limits, **b:** Borderline, **c:** Outside normal limits.*

The widest AUC of SD-OCT parameters for differentiating the GS from POAG was found to be the inferotemporal RNFL thickness (AUC: 0.628). Regarding AUCs to distinguish the GS from POAG eyes, the HRT III parameters had a significantly lower AUC than SD-OCT. The frequency distribution of MRA categorical classification of HRT III and global RNFL categorical classification of SD-OCT was shown in Table 5. No agreement between HRT and SD-OCT was found in this final classification.

DISCUSSION

In recent years, high-resolution imaging of anatomic structures has become a standard examination procedure and are increasingly used in the clinical management of glaucoma patients.[3,4,10,11] Several studies have confirmed the role of RNFL and ONH measurements in the detection of glaucoma.[1,2,11-13] Although, the clinical assessment of optic discs is largely influenced by the examiner's experience it was reported that subjective assessment of the ONH provided the superior efficacy in the diagnosis of glaucoma than contemporary versions of the quantitative imaging techniques.[14,15]

The results of the present study have demonstrated that most parameters in both instruments are significantly different in glaucomatous eyes than that of OHT eyes. On the other hand, ONH and RNFL imaging techniques that we used, do not reveal a significant difference between the GS and POAG groups; except the RNFL thickness measured with SD-OCT in superonasal, nasal, inferotemporal sectors and globally. Zangwill and colleagues found that RNFL thickness measured by OCT was significantly different in patients with OHT, patients with GS, and glaucomatous patients.[6] Gyatsho et al.,[16] showed significantly thinner RNFL measurements in all RNFL parameters in glaucoma comparing with the patients with OHT. According to Kanomori et al.,[17] the only parameter between GS and early glaucoma that did show a significant difference was the RNFL thickness in the inferotemporal quadrant, which was in good agreement with our study. They also reported that except rim area, there was no significant difference in any of the ONH parameters between the glaucoma suspect and the early glaucoma eyes.

In the present investigation, the diagnostic precision of the parameters was evaluated with AUCs. To distinguish the OHT from POAG we found SD-OCT RNFL thickness in the inferotemporal sector and for HRT III global rim area to have the largest AUC and the greatest sensitivities. On the other hand, according to our results both HRT III and SD-OCT seemed to be suboptimal for distinguishing GS from a POAG eye.

Moreover, the HRT III parameters were significantly lower than the corresponding AUC parameters from OCT in GS and POAG eyes, demonstrating that the ONH was even a less sensitive parameter for the detection of glaucomatous damage. Average RNFL thickness has been documented to have the best discriminating ability among all OCT based RNFL parameters in various studies,[14,18] nevertheless, this result was not reproduced in our study. On the other hand, in concordance with our study, it was reported that the largest AUC for peripapillary RNFL thickness measurement was at inferior sector.[14,15,19-21] Badala et al. found that the second largest AUC was RNFL thickness in the inferior quadrant.[14]

In a previous study investigating the diagnostic ability of the HRT, rim area was found to have the largest AUCs which could also confirm our findings.[22] In another HRT II study, however, C/D area ratio gave the largest AUC.[18] For HRT examination C/D area ratio and rim/disc area ratio were also reported as the best parameters (both with an AUC value of 0.91) for discriminating the healthy eyes from those with early glaucoma.[14] In our study, the second highest AUC among the ONH parameters was found to be the vertical C/D ratio, in differentiating OHT eyes from the glaucomatous eyes (AUC:0.716).

Medeiros et al.,[23] demonstrated that severe disease was associated with increased sensitivity of all imaging modalities. So the performance of the optic nerve and RNFL imaging devices depend on how advanced the glaucoma is in the sample that is under study. Because the manifest glaucoma is not difficult to differentiate from the normal ones; normal subjects and patients with advanced glaucoma were excluded, and then we analyzed the capability of the structural tests to discriminate the glaucoma and OHT and the glaucoma suspect rather than the normal subjects and glaucoma. This might be the cause of getting smaller AUCs in the present study than the most of the previous studies. Mahdavi and associates also demonstrated fairly poor performance of the Stratus OCT in eyes with early glaucomatous optic disc neuropathy.[24] In a similar group of eyes (ocular hypertensive eyes, glaucoma suspects, and early glaucoma patients) however Kanamori and associates reported the Stratus OCT's performance better than that found in the current study for the discrimination of the early glaucoma eyes.[17] The most probable explanation for the less accuracy than the desired discriminatory ability of the SD-OCT in our study might be the higher interindividual variability of the optic nerve structure and RNFL thickness in normal individuals and patients with early to moderate glaucoma. The frequency distribution of MRA categorical classification of HRT and global RNFL categorical classification of SD-OCT was significantly different.

SD-OCT attained a higher diagnostic sensitivity for glaucoma detection than optic disc assessment with HRT. Recently Leung et al.,[25] evaluated the agreement of the diagnostic classification and compared the sensitivity and specificity between HRT optic disc and SD-OCT RNFL measurements. Their study showed the agreement of diagnostic classification between HRT and SD-OCT was only fair to moderate in most optic disc sectors except global and inferotemporal sector measurements. The most important limitation of our study was its retrospective design. The comparisons are between two groups at risk for glaucoma and those with perimetric glaucoma. Both "at risk" groups have individuals who have glaucoma and/or will develop the disease. It can be argued that a better comparison group would be controls who have no predisposition to the disease. Nevertheless, demonstration of the diagnostic ability of the various ocular imaging instruments in making the distinction between early glaucomatous damage and ocular hypertension and glaucoma suspect, which is the most important clinical challenges in glaucoma, foremost aim of this study.

In conclusion, although newer versions of imaging devices for the ONH and RNFL are introduced with the expectation that higher resolution, in this study they performed less well for detection of glaucoma. Poor agreement and less well detection of early glaucoma suggest that the combination of structural and functional tests may improve the detection of glaucomatous eyes. Although measuring the RNFL thickness and ONH parameters can provide some invaluable information for the clinician regarding the extent of glaucomatous damage, subjective assessment of the ONH seems to be still a mainstay of glaucoma evaluation.

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