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Scanning Laser Tomography to Evaluate Optic Discs of Normal Eyes

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Purpose: To investigate the effects of age, eye refraction, and disc area on topographic parameters of the optic nerve head in normal volunteers, using the Heidelberg Retina Tomograph.

Methods: Seventy-seven eyes of 77 normal volunteers were examined by scanning laser tomography. The topographic parameters analyzed were disc area, cup area, cup/disc area ratio, rim area, cup volume, rim volume, mean cup depth, maximum cup depth, cup shape measure, height variation contour, mean retinal nerve fiber layer thickness (MnRNFLT), and retinal nerve fiber layer (RNFL) cross-section area. The effect of age, refraction, and disc area on each parameter was analyzed by the multiple linear regression model.

Results: Significant declines in MnRNFLT and RNFL cross-section area were found with increasing age ($P < .05$). The mean cup depth and maximum cup depth were significantly deeper in myopic subjects ($P < .05$). Large discs had large cup area, cup/disc area ratio, rim area, cup volume, mean cup depth, cup shape measure ($P < .01$), and maximum cup depth ($P < .05$). The MnRNFLT was smaller in large discs ($P < .01$). Rim volume was unaffected by age, refraction, or disc area.

Conclusions: The age, refraction, and disc area were related to several optic disc parameters obtained by the Heidelberg Retina Tomograph. Because of these relationships, care should be taken to analyze the appearance of the optic disc on the basis of these parameters in patients with glaucoma or other diseases. Rim volume appears to be a good parameter for evaluating the optic disc without considering age, refraction, or disc area. **Jpn J Ophthalmol 1999;43:410–414**

Key Words: Age, multivariate statistical method, normal eye parameters, optic disc, scanning laser tomographic analysis.

Introduction

The ophthalmoscopic appearance of the optic disc provides the most reliable evidence of damage in glaucoma patients. Therefore, thorough examination of the optic disc is essential for diagnosis and follow-up of glaucoma. To provide a basis for evaluating glaucomatous discs, the appearance of normal discs should be analyzed. Numerous studies[1–15] have shown that individual differences, such as age, refractive error, and disc area, affect the size and shape of the optic disc in normal eyes. The results of these studies, however, have not always been in agreement.

Recently, the scanning laser ophthalmoscope has been developed for objective, three-dimensional assessments of ocular tissues, such as the retina and optic disc. The Heidelberg Retina Tomograph (HRT, v. 1.11; Heidelberg Engineering, Heidelberg, Germany) is a scanning laser ophthalmoscope with excellent spatial resolution. Various parameters, such as optic disc area, cup area, cup volume, rim area, and rim volume, can be measured accurately with this instrument. In this study, we examined normal optic discs with the HRT and analyzed the effect of age, refractive error, and disc area on disc shape parameters by means of a multivariate analysis.

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Materials and Methods

Seventy-seven volunteers (77 eyes) were included in this study. All subjects underwent eye examinations and were confirmed to have no ocular disease other than refractive errors and/or mild cataracts. After an informed consent was obtained from each subject by interview, the appearance of the optic disc was evaluated with the HRT. The participants were selected by the following criteria: best corrected visual acuity better than 0.8; refractive error between +5.0 and −5.0 diopters (D); intraocular pressure less than 21 mm Hg in both eyes, as measured with a Goldmann applanation tonometer; a disc area between 1.3 mm^2 and 4.1 mm^2, as measured with the HRT; and no family history of glaucoma (Table 1). Volunteers having tilted discs or discs with oblique insertion were excluded. Qualifying subjects included 24 men and 53 women. Their average age was 56 years (age range, 21–84 years), and the average refractive error was −0.18 D (−5.0 to +4.13 D). If both eyes of the subject met the above criteria, the left eye was selected because examination of the left eye tended to be better tolerated by most subjects, and the examination results were more satisfactory (Table 1).

Measurements with the HRT were performed by three skilled operators after laser stability was achieved. The HRT is a confocal imaging device that uses a diode laser at 670 nm as a light source. A series of 32 confocal images, each 256 × 256 pixels, is acquired within 1.6 seconds. The field size can vary between 10° × 10° of retina to 20° × 20° of retina in 5° increments. In our study, we used the smallest field that included the peripapillary atrophic region for the acquisition of disc images. Each measurement was repeated three times, and the average was calculated. The standard deviation (SD), which indicated the precision of the measurement process, was less than 40 μm. The disc contour line was determined by the same operator. The topographic parameters analyzed were disc area (DA), cup area (CA), cup/disc area ratio (C/D), rim area (RA), cup volume (CV), rim volume (RV), man cup depth (MnCD), maximum cup depth (MxCD), cup shape measure (CSM), height variation contour (HVC), mean retinal nerve fiber layer thickness (MnRNFLT), and retinal nerve fiber layer (RNFL) cross-section area (RCSA).

Interrelationships of these parameters to age and refraction were evaluated by calculating Pearson's correlation coefficients. The effect of age, refraction, and DA on each parameter other than DA was analyzed by a multiple linear regression model using age, refraction, and DA as the explanatory variables, and each parameter other than DA as the objective variable.

Results

The mean values of the parameters obtained by HRT are shown in Table 2, and Pearson's correlation coefficients between the parameters are shown in Table 3. There were 41 statistically significant correlations ($P < .01$) among the parameters in 61 relationships, which indicates that these parameters were strongly interrelated (Table 3).

Analysis by multiple linear regression revealed that MnRNFLT and RCSA decreased with age ($P < .05$), and that MnCD and MxCD were significantly deeper in myopic eyes ($P < .05$). Disc area had a strong effect on many parameters: large discs had large CA, C/D, RA, CV, MnCD, CSM ($P < .01$), and MxCD ($P < .05$) (Table 4).

Discussion

This study showed that several of the optic disc parameters obtained with the HRT were related to age, refraction, and optic disc area. MnRNFLT and RCSA decreased with increasing age; MnCD and MxCD were significantly deeper in myopic eyes; and CA, C/D,

Table 1. Summary of Inclusion Criteria

Inclusion Criteria
1. Best corrected visual acuity defined as better than 0.8
2. Refractive error between +5.0 and −5.0 diopters
3. Intraocular pressure measured with Goldmann applanation less than 21 mm Hg in both eyes
4. Normal open angle
5. No ocular disease other than refractive errors and mild cataract
6. Disc area measured with HRT between 1.3 mm^2 and 4.1 mm^2
7. Tilted discs and discs with oblique insertion excluded
8. No family history of glaucoma

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Table 2. Mean Value and Standard Deviation of Each Parameter Obtained by Heidelberg Retina Tomograph

Topographic Parameter	Mean Value	Standard Deviation
Disc area (mm^2)	2.147	0.500
Cup area (mm^2)	0.550	0.416
Cup/disc area ratio	0.238	0.142
Rim area (mm^2)	1.596	0.339
Cup volume (mm^3)	0.124	0.155
Rim volume (mm^3)	0.439	0.149
Mean cup depth (mm)	0.205	0.090
Maximum cup depth (mm)	0.585	0.207
Height variation contour (mm)	0.416	0.107
Cup shape measure	−0.199	0.067
Mean RNFL thickness (mm)	0.250	0.080
RNFL cross-section area (mm^2)	1.279	0.388

RNFL: retinal nerve fiber layer.

RA, CV, MnCD, CSM, and MCD values increased with the disc size.

There have been several reports in which the relationship between disc size and refraction,[1] axial length,[2] cupping area, rim area, cup/disc ratio,[1–3] and sex[2,4,5] were investigated. The influence of age on the cup area or nerve fiber layer thickness[1,2,4,6–11] has also been investigated previously, and differences in optic disc structure among races[12,13] have also been reported. However, most of the studies were based on traditional methodologies, such as histological analysis,[5,7,8] evaluation by slit-lamp,[4–6] and analysis of disc photographs.[2,9]

Since then, automated instruments that permit three-dimensional topographical analysis of the optic nerve and retina, such as the HRT, have been developed. The latest generation of these instruments can provide reproducible measurements of optic disc topography on a point-by-point basis, as well as reproducible calculations of a variety of disc parameters.[16,17] In the present study, we analyzed the three-dimensional structure of normal optic discs by multivariate analysis to evaluate simultaneously the effects of age, refraction, and disc area on the parameters obtained by HRT.

The appearance of the optic disc varies among individuals, and, hence, it is very difficult to define a "normal optic disc." Jonas and Naumann[18] reported a range of normal disc areas of 1.29 mm^2–4.09 mm^2, based on an analysis of 571 normal eyes. Chihara and Sawada[19] reported that optic discs with oblique insertion frequently had focal nerve fiber layer defects and suggested that there might be some focal abnormality in the structure of such optic discs. Based on these reports, we define a "normal disc" as

Table 3. Pearson's Correlation Coefficients Among Parameters

	CA	C/D	RA	CV	RV	MnCD	MxCD	CSM	HVC	MnRNFLT	RCSA
DA	0.736**	0.552**	0.559**	0.597**	0.059	0.464**	0.306*	0.480**	−0.043	−0.284*	0.065
CA		0.950**	−0.150	0.879**	−0.441**	0.809**	0.641**	0.652**	−0.016	−0.446**	−0.223
C/D			−0.358*	0.813**	−0.573**	0.841**	0.717**	0.601**	−0.039	−0.462**	−0.293*
CV				−0.206	0.626**	−0.314*	−0.339*	−0.097	−0.043	0.132	0.368**
RV					−0.396**	0.845**	0.690**	0.524**	0.058	−0.425**	−0.277
MnCD						−0.297*	−0.260	−0.160	0.494**	0.701**	0.764**
MxCD							0.930**	0.492**	0.228	−0.131	0.013
CSM								0.194	0.237	−0.032	0.072
HVC									0.129	−0.221	−0.073
MnRNFLT										0.654**	0.629**
RCSA											0.929**

CA: cup area. C/D: cup/disc area ratio. RA: rim area. CV: cup volume. RV: rim volume. MnCD: mean cup depth. MxCD: maximum cup depth. CSM: cup shape measure. HVC: height variation contour. MnRNFLT: mean retinal nerve fiber layer thickness. RCSA: RNFL cross-section area. DA: disc area.

*$P < .01$.

**$P < .001$.

Table 4. Effect of Age, Refraction, and Disc Area (DA) Analyzed With Multiple Linear Regression Model

Topographic Parameter	Explanatory Variables	Partial Regression Coefficient	Significance Probability
Cup area	Age	0.002141	.2900
	Refraction	−0.019009	.3837
	DA**	0.598847	<.0001
Cup/disc area ratio	Age	0.001044	.2186
	Refraction	−0.011453	.2114
	DA**	0.147501	<.0001
Rim area	Age	−0.002139	.2906
	Refraction	0.018977	.3846
	DA**	0.401052	<.0001
Cup volume	Age	0.000328	.7132
	Refraction	−0.008805	.3620
	DA**	0.179038	<.0001
Rim volume	Age	−0.001224	.2538
	Refraction	0.004177	.7171
	DA	0.023483	.5182
Mean cup depth	Age	0.000330	.5525
	Refraction*	−0.014061	.0210
	DA**	0.073354	.0002
Maximum cup depth	Age	0.000508	.7079
	Refraction*	−0.037007	.0133
	DA*	0.099738	.0331
Cup shape measure	Age	0.000708	.0907
	Refraction	0.000300	.9465
	DA**	0.063574	<.0001
Height variation contour	Age	−0.000299	.6970
	Refraction	−0.008376	.3136
	DA	−0.014566	.5769
Mean RNFL thickness	Age*	−0.001042	.0447
	Refraction	−0.006732	.2257
	DA**	−0.047738	.0075
RNFL cross-section area	Age*	−0.005230	.0499
	Refraction	−0.031241	.2738
	DA	0.099738	.6517

RNFL: retinal nerve fiber layer.
*$P < .05$.
**$P < .01$.

one having a disc area between 1.3 mm^2 and 4.1 mm^2, a refractive error within ±5.0 D, and a disc that is not tilted or obliquely inserted.

Age significantly affected only the MnRNFLT and RCSA. Other studies[1,4,6] have reported that CA or C/D increases with age, but that the correlation is very weak. Studies that used stereoscopic photographs[2] or image analyzing systems[12] reported no relationship between age and cup or cup/disc ratio, and our results are consistent with these conclusions. There was a report of a histological study that found a significant decline in nerve fiber count with age,[8] and some clinical studies have shown that the thickness of the nerve fiber layer decreases with age.[9–11] Our results are compatible with these reports. Calculations have shown that MnRNFLT decreases 1.0 μm each year (partial regression coefficient; −0.001042 in Table 4).

Refraction significantly affected MnCD and MxCD. Myopic eyes had deeper MnCD and MxCD. The HRT uses a reference plane and a curved surface for the measurement of these parameters. The curved surface is determined based on the contour line. Therefore, it is possible that tilted discs and oblique insertion, which are frequently observed in high myopia, may affect the curved surface. The result would then be that the calculated MnCD and MxCD would be smaller than their actual values. Because of this possibility, we excluded volunteers with high myopia and oblique insertion from the present study. Myopic eyes actually have deeper cupping than the emmetropic and hyperopic eyes. To our knowledge, there has been only one report on the relationship between refraction and cup depth.[13] Based on an examination of 180 normal subjects with the HRT, including 43 Black, 45 Asian, 48 Hispanic, and 44 White

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subjects, Tsai et al[13] reported the absence of any significant relationship between refraction and MxCD. The discrepancy between their findings and ours suggests that there may be some racial difference in the relationship, but further investigations are necessary.

The disc area was related to several parameters. Large discs had large CA, C/D, RA, CV, MnCD, CSM, and MxCD values, and this finding was consistent with those of many previous studies,[1–3] suggesting that disc area always should be considered in estimating these parameters.

Rim volume was the only parameter that was unaffected by age, refraction, and disc area. Caprioli and Miller[3] used a Rodenstock computerized image analysis system in their study and reported that RV was unaffected by disc area. They suggested that further analysis of the effect of age, race, and gender on RV is necessary.

All the subjects in our study were Japanese, and refraction was considered simultaneously in the analysis. Accordingly, RV is considered to be a good parameter for evaluating disc shape irrespective of age, refraction, or disc area.

In summary, age, refraction, and disc area were related to several optic disc parameters obtained by the HRT. Care should be taken to analyze the appearance of the optic disc on the basis of these parameters in patients with glaucoma or other diseases. RV appears to be a good parameter to evaluate the optic disc shape without considering age, refraction, or disc area.

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