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ORIGINAL ARTICLE

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The relationship between optic disc-foveal distance with choroidal and retinal nerve fiber thickness

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ABSTRACT

Background: The optic disc-foveal distance is very important as it is an anatomical measure of the fundus. As this distance increases and the fundus tension, there may be variability in retinal and choroidal thickness. The aim of this study was to determine the relationship between optic disc-foveal distance and choroidal and retinal nerve fiber thickness in healthy subjects.

Materials and methods: A total of 72 people between the ages of 20–36 participated in the study. Optic disc-foveal distance was measured with a fundus camera and choroidal and retinal nerve fiber thicknesses were measured with an OCT (optical coherence tomography) device. Littmann's formula ($t = p \times q \times s$) as modified by Bennett was applied to correct the magnification at the fundus camera imaging stage.

Results: The thickness of the nasal choroid ($p=0.005$; $p=0.006$), subfoveal choroid ($p = 0.004$; $p < 0.001$) and temporal choroid ($p = 0.001$; $p = 0.001$) layers decreased as the DFD (Optic disc-to-foveal distance) increased in both right and left eyes of the individuals participating in the study, which was statistically significant. In addition, it was observed that the RNLF (Retinal nerve fiber layer) increased as the DFD distance increased, but this was not statistically significant.

Conclusions: This study demonstrated that the optic disc-foveal distance, an anatomical measure of the fundus, does not affect RNLF in healthy subjects, but choroidal thickness does.
Keywords: optic disc-foveal distance, choroid, retinal nerve fiber thickness, fundus

INTRODUCTION

The optic disc-to-foveal distance (DFD) is very important as it is an anatomical measure of the fundus [15, 28]. It has been reported that this distance may be related to the size of the structures in the posterior part of the ocular segment, optic disc diameter, axial length, anatomical structures such as macula, retina and choroid [8, 13, 15, 18, 28]. This association may be linked to some ocular abnormalities and ocular disorders [13, 21]. In eyes with increased DFD, there may be variability in retinal and choroidal thickness (CT) due to stretching of the fundus [21]. Optic disc-foveal distance was initially used to estimate the diameter of the optic disc and the size of the structures in the posterior ocular segment. The increased optic disc-foveal distance after birth may have a direct effect on the stretching of the posterior fundus and thus on visual acuity, which is related to the increased distance between photoreceptors. The disc-foveal distance can be determined ophthalmoscopically without advanced imaging instruments. It is possible to do this with the daily routine examination of patients. The number of studies investigating the disc foveal distance systemically and determining its relationship with ocular anatomical structures is limited [13].

On the surface of the retina facing the corpus vitreum, the retinal nerve fiber layer (RNLF) is composed of bipolar and multipolar ganglion cell axons and their extensions and bipolar and cone cells that collect visual impulses. The RNLF is a delicate structure that can be affected by many causes such as high intraocular pressure, inflammation and vascular causes, resulting in fiber loss and atrophy of the optic nerve [7]. The choroid is a thin, vascular-rich layer inside the sclera, which forms most of the back of the eyeball and supplies blood to the retina, retinal pigment epithelium and optic nerve. The choroidal layer has a very good blood supply in proportion to its tissue size compared to other body tissues. A choroidal defect or impaired choroidal blood flow can cause degenerative changes and neovascularization that can lead to severe vision loss [30].

Optical coherence tomography (OCT) is a non-invasive method for visualizing cross-sections of the anterior and posterior parts of the eye [24]. OCT is widely used to diagnose many diseases by visualizing the macula, optic nerve, retinal nerve fiber and choroidal layers [1].

The aim of this study was to determine the relationship between the optic disc-foveal distance, which can be calculated without advanced imaging tools, and the retinal nerve fibre layer (RNLF), which collects visual impulses, and the choroidal layers, which supply blood to the retina and optic nerve. Relatively new topic in the literature, and this is only the second paper [4] to specifically address the relationship with the choroid.

A second aim of the research is to investigate whether it is possible to provide information about how the anatomical regions that play an important role in vision change depending on the increase or decrease of DFD and thus whether some diseases can be diagnosed from simply measured distance.

MATERIALS AND METHODS

The study included 72 volunteers (42 males, 30 females) who came to Niğde Ömer Halisdemir University Training and Research Hospital Eye Polyclinic for routine controls. Selections were made by systematic random sampling method. The study included healthy subjects aged 20–36 years with best-corrected visual acuity of 20/20 according to Snellen's threshold and intraocular pressure (IOP) between 10–21 mmHg. Subjects with intraocular pressure greater than 21 mmHg, ocular and systemic diseases such as refractive errors, corneal disease, retinal disease, uveitis, glaucoma, tumor/trauma, history of ocular surgery were excluded. The measurements were performed at the same time of the day between 09:00 and 10:00. Measurements were made in both eyes. The measurements were analysed by two ophthalmologists and an anatomist. Each researcher performed the measurements independently of each other. The measurements were averaged.

Optic disc-to-foveal distance (Fig. 1) was calculated using ImageJ version 1.40 software (National Institutes of Health, Bethesda, Maryland; http://rsb.info.nih.gov/ij/index) after images were obtained from a Topcon TRC 50 DX (fundus camera base (TRC-50DX; Topcon Corporation, Tokyo, Japan) fundus camera imaging device 30 minutes after pupil dilation with 1% tropicamide.

Choroidal thickness was measured by OCT using Spectral Domain Cirrus OCT Model 400 (Carl Zeiss Meditec, Jena, Germany). HD 5 Line Raster protocol reduced to a single line. Measurements with signal quality below 6 were excluded. The choroid was evaluated on Cirrus HD-OCT using enhanced depth imaging (EDI) mode. The center of the fovea was the first measurement point. The retinal pigment epithelium (RPE) was considered as the starting point and the border formed at the choroido-scleral junction was considered as the end point. Measurements were taken in temporal and nasal directions. Similarly, RNFL thickness was measured using the Spectral Domain Cirrus OCT Model 400 device. It was obtained by scanning a 6×6 mm cubic optical disc from 200 A scans made for every 200 B scans. The instrument automatically determined the center of the disc and created a calculation circle with a diameter of 3.4 mm around the disc.

The Littmann formula ($t = p \times q \times s$) modified by Bennett was applied to correct the magnification and standardise the measurements at the fundus camera imaging stage. In the formula, t is the actual fundus size, s is the size measured in the fundus photograph, p is the magnification factor of the camera and q is the magnification of the eye [3, 17].

Statistical analysis

The normal distribution of the measured parameters was checked by Shapiro Wilk test. Descriptive statistics of the parameters are summarised as Mean ± SD and Min–Max. Pearson Correlation was used to examine the relationship between numerical variables. Statistical analyses were performed with IBM SPSS version 22 (SPSS, Inc., Chicago, IL, USA). $P < 0.05$ was accepted as statistical significance level. For the comparison between variables, it was found appropriate to include at least 61 patients in the study with 80% power and 5% type error with an effect size of 0.50 (moderate level). The calculation was performed in G*Power 3.1.9.7 programme.

RESULTS

72 volunteers, 42 men and 30 women, participated in the study. Age, optic disc-foveal distance, choroidal and RNLF values of all volunteers participating in the study are given in Table 1. According to Table 1, the mean age of the participants was 25.75 ± 4.47 years. The mean DFD in the right and left eyes were 6.37 ± 0.44 and 6.45 ± 0.36 mm, respectively (Table 1). Right nasal (mean 247.46 ± 52.56), subfoveal (mean 307.75 ± 39.07) and temporal choroid (mean 269.79 ± 54.21) were lower than left nasal (mean 264.54 ± 54.81), subfoveal (mean 309.33 ± 51.54) and temporal choroid (mean 283.29 ± 51.37) (Table 1). In terms of RNLF parameter, both right and left eye values (91.17 ± 7.93; 91.71 ± 8.05, respectively) were very close to each other (Table 1).

Table 2 shows the correlation between optic disc-foveal distance and nasal choroid, subfoveal choroid, temporal choroid and RNLF. According to the table, it was determined that the thickness of the nasal choroid ($p = 0.005$; $p = 0.006$), subfoveal choroid ($p = 0.004$; $p < 0.001$) and temporal choroid ($p = 0.001$; $p = 0.001$) layers decreased as the DFD increased in both right and left eyes of the individuals participating in the study, which was statistically significant (Table 2). In addition, it was observed that the RNLF increased as the DFD distance increased, but this was not statistically significant.

DISCUSSION

In this study, the relationship between DFD with Choroidal and RNLF was revealed. It was observed that the thickness of the choroidal layer decreased significantly while the DFD increased in both right and left eyes, and the RNLF increased, but this result was not significant. Many factors affecting RNLF have been identified, including advanced age, glaucoma, refractive error, migraine and diabetes [26]. Previous studies have shown that choroidal thickness is affected by age, refractive error, axial length, circadian rhythm, uveitis and age-related macular degeneration [4]. Therefore, our study population consisted of young participants aged 20–36 years without refractive error and without any ocular and systemic disease. Measurements were also performed between 9 and 10 am to eliminate the influence of circadian rhythm. Although there are many studies demonstrating the relationship between RNLF and axial length (AL), optic disc area and peripapillary gamma zone width, there are relatively fewer studies demonstrating and analyzing the relationship with optic disc-foveal distance.

DFD is an important anatomical measurement of the fundus. There are studies showing the association of DFD with myopia, situs inversus, diabetic retinopathy and ocular growth [8–10, 25]. Qiu et al. [22] calculated the mean DFD measured with OCT device as 4.90 ± 0.29 mm in 182 healthy eyes. Cevher et al. [4] found a mean DFD of 4634.29 ± 274.70 mm in 250 healthy eyes calculated with OCT device. In our study of 72 healthy subjects, we calculated DFD as 6.37 ± 0.44 mm in the right eye and 6.45 ± 0.36 mm in the left eye. It is assumed that the difference between the DFD values is due to the difference in sample size and measurement devices. In this study, measurements were calculated manually from the data obtained from fundus photographs. Jonas et al. [13], who made measurements from fundus photograph, calculated the DFD value in the range of 3.76–6.53 mm. The range of these data is consistent with our data.

Jonas et al. [14] found an inverse correlation between optic disc-foveal distance and RNLF in their study with 632 participants. They argued that a longer disc-to-foveal distance would lead to elongation and stretching of retinal nerve fibers, potentially leading to thinning or loss of nerve fibers. Similarly, another study with 182 healthy eyes showed that for every millimeter increase in disc-foveal distance, RNFL thickness decreased significantly ($p < 0.001$) by 6.78 μm [21]. In our study, mean RNLF thickness was positively correlated with optic disc-foveal distance, although not significantly. In this respect, we obtained different results from Jonas et al. [14] and Qiu et al. [21]. Choi et al. [5] looked at the relationship between axial length (AL) and RNLF and found that AL and optic disc foveal distance are positively correlated with each other. In this study, they reported that AL was negatively correlated with RNLF in the inferior quadrant and positively correlated with superior, temporal and mean RNLF [5]. They attributed this to the fact that eyes with larger retinal surface area (i.e. eyes with longer AL and optic disc-to-foveal distance) may have greater RNLF thickness than normal eyes. Jonas et al. [12] had previously attributed this claim to their histomorphometric study. There is a need for many more studies on this subject.

Between the sclera and retina is the choroid layer, which is rich in blood vessels. This layer regulates the temperature of the retinal layer and provides nutrients and oxygen to the photoreceptors and retinal layers in the retina [4]. The thickness of the choroidal layer in different regions (subfoveal, nasal and temporal) varies. In healthy individuals, the subfoveal part of the choroidal layer has a greater thickness than the nasal and temporal parts [23]. In this study, when the choroidal parts of both right and left eyes were analysed, it was determined that the subfoveal choroidal part was thicker than the nasal and temporal choroidal parts (Table 1). In addition, for the right and left eyes, the choroidal part was sorted as subfoveal, temporal and nasal from thicker to thinner (Table 1).

The relationship between choroidal thickness and age-related macular degeneration, pachychoroidal disease, central serous chorioretinopathy, polypoidal choroidal vasculopathy, myopia, uveitis, Vogt-Koyanagi-Harada disease, COVID-19, Parkinson's disease and coronary artery disease has been shown in many studies [2, 16, 19, 20]. Increased choroidal thickness is involved in the direct etiology of age-related macular degeneration, pachychoroid disease, central serous chorioretinopathy, polypoidal choroidal vasculopathy, which are the most common causes of permanent visual loss [20]. Myopia, which has reached as high as 90% in the Far East, has become an important public health problem worldwide [27]. Many studies have been conducted on this subject, one of which is the study of Ulaganathan et al. [27] in 2019. Ulaganathan et al. [27] concluded that the choroid may play a potential role in eye growth. They also reported a negative correlation between AL and choroidal thickness. According to them, they claimed that factors that may affect CT, such as sunlight, may reduce AL and thus prevent the development of myopia [27]. In this study, we found a statistically significant negative correlation between DFD and CT. In practice, it will be possible to make comments about the choroid by calculating the DFD with ophthalmoscopic examination, even in clinics where there is no OCT device, which is an expensive and complicated device required for CT measurement. In this respect, DFD as a clinical anatomical parameter may find its use in the future.

The relationship between choroidal thickness and AL has been demonstrated in previous studies [29]. Xie et al. [29] found that AL was significantly negatively correlated with choroidal thickness in the central foveal, parafoveal and perifoveal areas, with the highest correlation in the central foveal area. Other studies have also reported a negative correlation between AL and choroid. Other studies have also reported a negative correlation between AL and choroid [6, 11]. Choi et al. [5] state that AL and DFD are positively correlated with each other. In the literature review, the relationship between the choroid and DFD was first revealed by Cevher et al. [4]. In their study, they found a negative correlation with DFD in the subfoveal and temporal choroidal parts and a positive correlation in the nasal part [4]. However, this relationship between DFD and choroid was found to be statistically insignificant. In our study, a significant negative correlation was observed between DFD and subfoveal, temporal and nasal choroidal parts (Table 2). This is explained by the positive correlation of DFD and AL and the negative correlation of AL and choroid.

This study has some limitations. The study sample is relatively small. Since the posterior fundus images obtained with fundus photography did not give the actual dimensions, they were manually calculated with the Litman formula. Our sample group includes health individuals between the ages of 20–36 and does not reveal any relationship with any disease.

In conclusion, this study demonstrated the relationship between optic disc-foveal distance, an anatomical measure of the fundus, and choroid and RNLF. Our study shows that the change in DFD negatively affects the choroidal layer but not the RNLF. The DFD can be taken into account for information about the vascular layer of the eye and for the early diagnosis of certain diseases affecting the vascular layer of the eye. In the future, the relationships between DFD distance and choroidal diseases can be addressed.

Article information and declarations

Data availability statement

The study included 72 volunteers (42 males, 30 females) who came to Niğde Ömer Halisdemir University Training and Research Hospital Eye Polyclinic for routine controls. More detailed inquiries can be directed to the corresponding author.

Ethics statement

Ethical approval was obtained for the study by Niğde Ömer Halisdemir University Non-Interventional Clinical Research Ethics Committee (Protocol No: 2023/32).

Author contributions

HK project development, data management, data analysis, manuscript writing/editing. KRZ project development, data collection, manuscript writing. EK data collection, data analysis. GYB data collection, data analysis. FÇ data analysis, manuscript writing/editing. FGC data analysis, manuscript writing/editing.

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Conflict of interest

The authors have no conflict of interest to declare.

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Table 1. Descriptive characteristics of the whole study group

	N	Mean ± SD	Min–Max

Age	72	25.75±4.47	20.00-36.00
DFD (mm)(Right)	72	6.37±0.44	5.33-7.18
DFD (mm)(Left)	72	6.45±0.36	5.90-7.16
Right Nasal Choroid	72	247.46±52.56	141.00-373.00
Right Subfoveal Choroid	72	307.75±39.07	213.00-392.00
Right Temporal Choroid	72	269.79±54.21	128.00-356.00
Right RNLF	72	91.17±7.93	71.00-103.00
Left Nasal Choroid	72	264.54±54.81	170.00-365.00
Left Subfoveal Choroid	72	309.33±51.54	200.00-392.00
Left Temporal Choroid	72	283.29±51.37	208.00-404.00
Left RNLF	72	91.71±8.05	71.00-106.00

N — number of participants; SD — standard deviation; Min — minimum; Max — maximum

Table 2. Correlation between DFD with Choroid and RNLF

		Nasal Choroid	Subfoveal Choroid	Temporal Choroid	RNLF
DFD (mm)	r	–0.326*	–0.336*	–0.386*	0.203
	p	0.005	0.004	0.001	0.086
(Right)	N	72	72	72	72
DFD (mm) (Left)	r	–0.324*	–0.462*	–0.374*	0.192
	p	0.006	< 0.001	0.001	0.107
	N	72	72	72	72

*Correlation is significant at the 0.01 level.

N — number of participants; r — pearson correlation coefficients

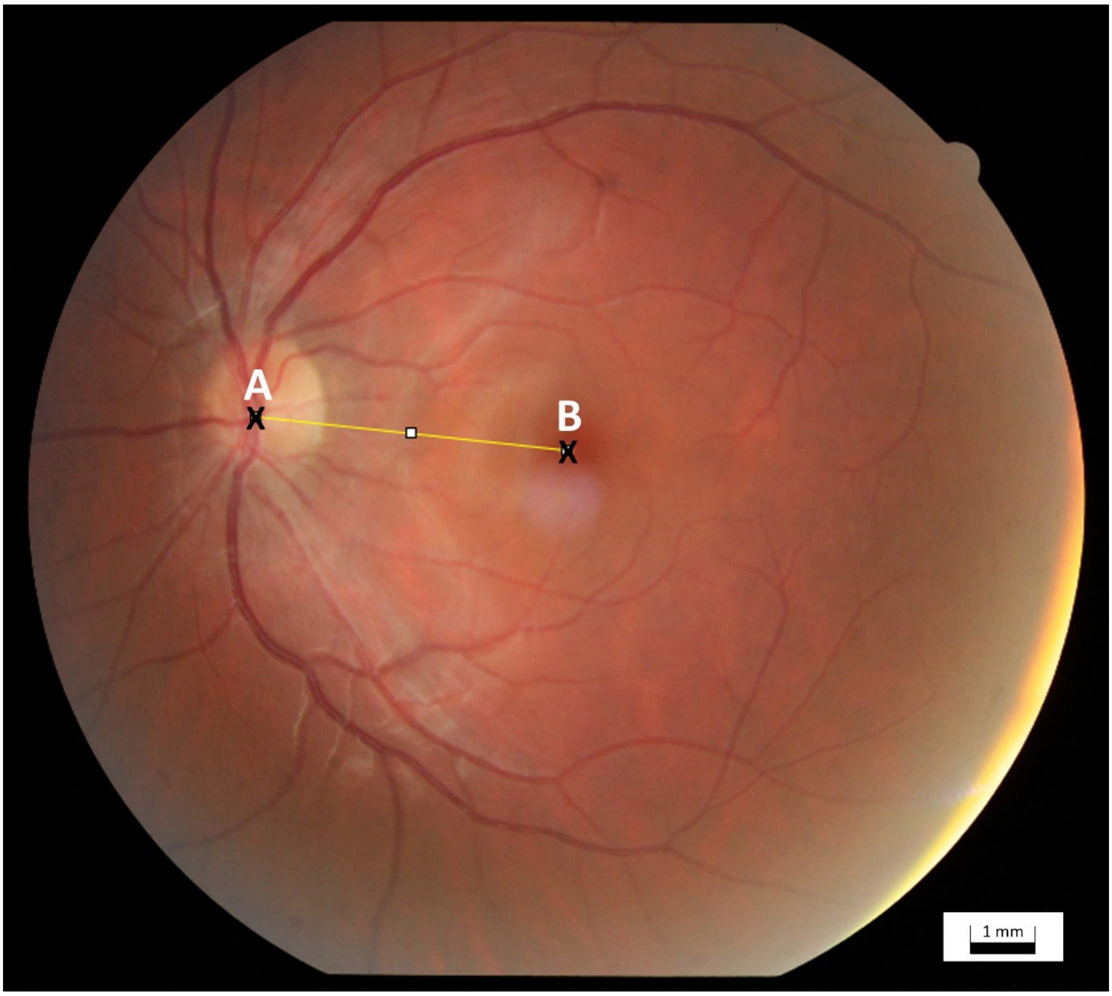

Figure 1