The Relationship Between Optic Disc-Foveal Distance with Choroidal and Retinal Nerve Fiber Thickness

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Abstract

Purpose
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.

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 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.

Result
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. In addition, it was observed that the RNLF increased as the DFD distance increased, but this was not statistically significant.

Conclusion
This study demonstrated that the optic disc-foveal distance, an anatomical measure of the fundus, does not affect RNLF in young and healthy subjects, but choroidal thickness does.

Introduction
The optic disc-to-foveal distance (DFD) is very important as it is an anatomical measure of the fundus \([12, 19]\). 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 \([7, 10, 12, 14, 19]\). This association may be linked to some ocular abnormalities and ocular disorders \([10, 15]\). In eyes with increased DFD, there may be variability in retinal and choroidal thickness due to stretching of the fundus \([15]\).

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 [6]. 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 [21].

Optical coherence tomography (OCT) is a non-invasive method for visualizing cross-sections of the anterior and posterior parts of the eye [17]. 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 optic disc-foveal distance and choroidal and retinal nerve fiber thickness using data obtained from healthy eyes. This is a relatively new topic in the literature, and this is only the second paper to specifically address the relationship with the choroid.

**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. The study included healthy subjects aged 20–40 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.

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.
To correct the magnification at the fundus camera imaging stage, the Littmann formula \( t = p \times q \times s \) was applied as modified by Bennett. 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 [2, 13].

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.

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Min.</th>
<th>Max.</th>
<th>Mean</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>72</td>
<td>20</td>
<td>36</td>
<td>25,75</td>
<td>4,47</td>
</tr>
<tr>
<td>DFD (mm)(Right)</td>
<td>72</td>
<td>5,33</td>
<td>7,18</td>
<td>6,37</td>
<td>.44</td>
</tr>
<tr>
<td>DFD (mm)(Left)</td>
<td>72</td>
<td>5,90</td>
<td>7,16</td>
<td>6,45</td>
<td>.36</td>
</tr>
<tr>
<td>Right Nasal Choroid</td>
<td>72</td>
<td>141</td>
<td>373</td>
<td>247,46</td>
<td>52,56</td>
</tr>
<tr>
<td>Right Subfoveal Choroid</td>
<td>72</td>
<td>213</td>
<td>392</td>
<td>307,75</td>
<td>39,07</td>
</tr>
<tr>
<td>Right Temporal Choroid</td>
<td>72</td>
<td>128</td>
<td>356</td>
<td>269,79</td>
<td>54,21</td>
</tr>
<tr>
<td>Right RNLF</td>
<td>72</td>
<td>71</td>
<td>103</td>
<td>91,17</td>
<td>7,93</td>
</tr>
<tr>
<td>Left Nasal Choroid</td>
<td>72</td>
<td>170</td>
<td>365</td>
<td>264,54</td>
<td>54,81</td>
</tr>
<tr>
<td>Left Subfoveal Choroid</td>
<td>72</td>
<td>200</td>
<td>392</td>
<td>309,33</td>
<td>51,54</td>
</tr>
<tr>
<td>Left Temporal Choroid</td>
<td>72</td>
<td>208</td>
<td>404</td>
<td>283,29</td>
<td>51,37</td>
</tr>
<tr>
<td>Left RNLF</td>
<td>72</td>
<td>71</td>
<td>106</td>
<td>91,71</td>
<td>8,05</td>
</tr>
</tbody>
</table>

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.
Table 2
Correlation between DFD with Choroid and RNLF

<table>
<thead>
<tr>
<th></th>
<th>Nasal Choroid</th>
<th>Subfoveal Choroid</th>
<th>Temporal Choroid</th>
<th>RNLF</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DFD (mm)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Right) Pearson</td>
<td>-0.326*</td>
<td>-0.336*</td>
<td>-0.386*</td>
<td>0.203</td>
</tr>
<tr>
<td>Correlation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sig.</td>
<td>0.005</td>
<td>0.004</td>
<td>0.001</td>
<td>0.086</td>
</tr>
<tr>
<td>N</td>
<td>72</td>
<td>72</td>
<td>72</td>
<td>72</td>
</tr>
<tr>
<td>(Left) Pearson</td>
<td>-0.324*</td>
<td>-0.462*</td>
<td>-0.374*</td>
<td>0.192</td>
</tr>
<tr>
<td>Correlation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sig.</td>
<td>0.006</td>
<td>0.000</td>
<td>0.001</td>
<td>0.107</td>
</tr>
<tr>
<td>N</td>
<td>72</td>
<td>72</td>
<td>72</td>
<td>72</td>
</tr>
</tbody>
</table>

*Correlation is significant at the 0.01 level.

Discussion

In this study, the relationship between DFD with Choroidal and RNLF was revealed. In both right and left eyes, the thickness of the choroidal layer decreased significantly while 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 [18]. Previous studies have shown that choroidal thickness is affected by age, refractive error, axial length, circadian rhythm, uveitis and age-related macular degeneration [3]. 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.

Jonas et al. [11] 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 [15]. 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. [11] and Qiu et al. [15]. Choi et al. [4] 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 [4]. 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. [9] 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 [3]. 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 [16].

The relationship between choroidal thickness and AL has been demonstrated in previous studies [20]. Xie et al. [20] 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 [5, 8]. Choi et al. [4] 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. [3]. 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 [3]. 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.

In conclusion, this study demonstrated that the optic disc-foveal distance, an anatomical measure of the fundus, does not affect RNLF but choroidal thickness in young and healthy subjects.

**Declarations**

**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 conflicts of interest to declare.

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


Figures
Figure 1

Fundus photograph; A: Optic disc, B: Fovea, Distance between A-B: Optic disc-fovea distance