Comparison of Structural and Vascular Characteristics of the Macula in Dominant and Non-dominant Eyes

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ABSTRACT

Purpose: This study aimed to compare dominant and non-dominant eyes of healthy individuals with swept-source optical coherence tomography angiography (SS-OCTA) to evaluate the effect of ocular dominance on macular and choroidal microcirculation.

Materials and Methods: Eighty eyes of 40 healthy participants were included in the study. Ocular dominance was determined with the hole in the card test. Participants' handedness was also noted. Superficial foveal avascular zone, deep foveal avascular zone, superficial capillary plexus density, deep capillary plexus density, choriocapillaris vascular complex density were measured with SS-OCTA. Central macular thickness (CMT) and subfoveal choroidal thickness (SFCT) values were recorded.

Results: The mean age of the participants was 23.95±3.39 years. It was determined that 65.5% (n=26) of the patients had a right eye dominance and 35.0% (n=14) had a left eye dominance. Thirty-six (90%) individuals were right-handed and 4 (10%) were left-handed. There was no significant difference in OCTA parameters and CMT, SFCT measurements between dominant and non-dominant eyes of the participants (p>0.05). Likewise, there was no difference between right and left eyes (p>0.05).

Conclusion: Ocular dominance was found to be mostly in the right eye. There was no significant difference in the structural and vascular characteristics of the macula between dominant and non-dominant eyes with the use of SS-OCTA.

Keywords: Dominant eye, Handedness, Macular perfusion, Optical coherence tomography angiography

INTRODUCTION

Ocular dominance is the tendency to prefer visual stimulation from one eye to stimulation from the other eye.[1] The concept of ocular dominance, first introduced in the 1500s, remains important in ophthalmology and neurology practice today.[2] Images are perceived as clearer, more stabilized and larger by the dominant eye.[3] The human retina exhibits half-crossing. Most visual stimulus from one eye is crossed and processed in the contralateral cerebral hemisphere. Functionally, stimulation of the dominant eye leads to a larger response in the primary visual cortex than in the non-dominant eye.[4] In approximately two-thirds of the population, the right eye is the dominant eye, and in approximately one-third, the left eye is the dominant eye.[5] Indications for determining ocular dominance in ophthalmology practice include monovision applications, laser refractive surgery, cataract surgery, contact lens application.[6,7] Different methods have been proposed to determine ocular dominance. The hole-in-the-card test and the sighting test are the most frequently used methods. The association of ocular dominance with ocular or neurologic morphologic differences or with higher cortical function has not been conclusively established. Studies on ocular dominance are mostly related to neuroimaging and studies on ocular morphologic structures are limited. The effects of stimulation to the dominant eye have been demonstrated

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in the primary visual cortex, but there is limited data on whether it causes changes in the human retina and choroidal vascular structures. It is not known whether the macula affects ocular dominance or whether the macula is affected by ocular dominance.

Swept source-optical coherence tomography angiography (SS-OCTA) device is a new generation imaging tool that provides noninvasive evaluation of retinal and choroidal vascular structures.[8] It can provide detailed images of the retinal vascular circulation using sequential optical coherence scans of a specific retinal region based on the motion contrast of erythrocytes in vascular structures. Allows quantitative measurement of both superficial and deep retinal vessels to evaluate macular perfusion and vascular structure.[9]

Ophthalmologic studies often use data obtained by randomly selecting right or left eyes of all participants, but it is not known whether there is a difference due to retinal blood flow and therefore whether it affects the results. There are limited studies in the literature evaluating macular perfusion in dominant and non-dominant eyes. Therefore, the aim of our study was to compare the microvascular properties of the retina and choroid between dominant and non-dominant eyes using SS-OCTA.

MATERIALS AND METHODS

This study was performed in a tertiary ophthalmology clinic with healthy participants. The protocol was approved by a clinical research ethics committee (Selçuk University Medical Faculty, 2022/296) and followed the tenets of the 1964 Helsinki Declaration. Informed consent was obtained from each participant. Two eyes of healthy, emmetropic patients between the ages of 18 and 30, with no ocular pathology, a body mass index between 18.5 and 24.9, no chronic systemic or topical drug use, and no ocular or systemic surgery were included in the study. Autorefractometer (Tonoref III, Nidec Co. Ltd, Aichi, Japan) measurements and intraocular pressure measurements with an air-puff tonometer (Topcon CT-800, Tokyo, Japan) were performed. Best corrected visual acuities were recorded using the LogMAR chart.

The dominant eyes of the participants were determined by performing the hole-in-the-card test. First, each participant was given a 12 × 15 cm card with a 3 cm diameter circular hole in the center and asked to hold it approximately 40 cm away from their eyes. The participant was then asked to look at an object away from the hole with both eyes open. They were then told to close first one eye and then the other. When the non-dominant eye was closed, the dominant eye continued to focus on the object, but when the dominant eye was closed, the object was not visible through the hole. This process was applied 3 times for each participant, and participants with uncertain ocular dominance were excluded from the study.

Biomicroscopic examinations with a slit lamp and detailed fundus examinations with a +90D lens were performed after full dilatation with 0.1% tropicamide.

To evaluate the retinal and choroidal microvascular structures, swept-source OCTA images were obtained from all participants with a DRI Triton OCT (Topcon Corp., Tokyo, Japan) device. Images were taken under full dilatation with tropicamide and after half an hour of rest. During the scanning, a 6×6 mm area centered on the fovea was scanned and the scanned area was automatically segmented in en-face mode with OCTA software (IMAGEnet 6 V.1.14.8538). Superficial capillary plexus density (VDs), deep capillary plexus density (VDd), choriocapillaris vascular complex density (VDcc) were obtained from SS-OCTA images as automated numerical values in five quadrants: central, superior, temporal, inferior and nasal. Automatic segmentation of retinal layers was performed on B-mode images. The superficial capillary plexus layer extends from 2.6 µm below the inner limiting membrane to 15.6 µm below the interface of the inner plexiform layer and the inner nuclear layer (IPL/INL). The deep capillary plexus layer extends from 15.6 µm below the IPL/INL to 70.2 µm below the IPL/INL. The choriocapillaris vascular complex layer extends from Bruch's membrane to 10.4 µm below Bruch's membrane.[10]

GNU Image Manipulation Program (GIMP) 2.8.14 was used to quantitatively analyze the vascular densities (VD) for VDs, VDd, VDcc and the superficial foveal avascular zone (FAZs) and deep foveal avascular zone (FAZd). Each VD measurement was calculated as the percentage of vascularized tissue in the delineated area. Enhanced HD line scans provided measurements of central macular thickness (CMT) and subfoveal choroidal thickness (SFCT). The same experienced operator (A.E) completed all measurements of the eyes.Those with poor OCTA image quality were not included in the study. The participants' eyes were divided into two groups as dominant and non-dominant, and these parameters were compared between the two groups.

STATISTICAL ANALYSIS

The data obtained as a result of the research were analyzed in computer environment with SPSS (Statistical Package for Social Sciences) 18.0 package program. In descriptive analyses, frequency data were given using number (n) and percentage (%) and numerical data were given using mean±standard deviation (SD). Chi-square test was used to compare categorical data. the Kolmogorov-Smirnov test was used to verify whether numerical data were normally distributed. The distribution of normally distributed numerical data in two independent groups was evaluated by Independent Samples T test and the distribution of non-normally distributed numerical data was evaluated by Mann Whitney U test. The results were evaluated at a 95% confidence interval and significance was at p<0.05.

RESULTS

This study included 80 eyes of 40 healthy individuals. The mean age of the individuals was 23.95±3.39 years. 70% (n=28) of the participants were female and 30% (n=12) were male. It was determined that 65.5% (n=26) of the participants had a right eye dominance and 35.0% (n=14) had a left eye dominance. There was no significant difference in terms of gender and age between the two groups, right eye dominant and left eye dominant (p>0.05). Participants had visual acuity of 0 on the logMAR chart in both eyes.

Superficial foveal avascular zone and deep foveal avascular zone were similar when compared according to ocular dominance (p=0.995, p=0.899).

Superficial capillary plexus density and deep capillary plexus density did not show statistically significant differences between the two groups in the central, superior, temporal, inferior and nasal quadrants (p>0.05). There is no difference in choriocapillaris density in the central, superior, temporal, inferior and nasal quadrants (p>0.05). Central macular thickness and subfoveal choroidal thickness were similar in the two groups (p>0.05). There was no statistically significant difference in SS-OCTA parameters in the dominant and non-dominant eyes of the participants included in the study (p>0,05) (Table 1).

Similarly, there was no significant difference in OCTA parameters between the right and left eyes of the participants (p>0.05) (Table 2).

Participants' handedness was also examined. Of the participants, 90% (n=36) were right-handed and 10% (n=4) were left-handed. Of the 26 individuals whose dominant eye was right, 24 were right-handed and 2 were left-handed. Of the 14 individuals with left eye dominance, 12 were right-handed and 2 were left-handed. There was no association between ocular dominance and handedness (p>0.05) (Table 3).

DISCUSSION

The detection and understanding of the characteristics of the dominant and non-dominant eye remains important in many areas of ophthalmology practice. Cataract and refractive surgery, monovision applications, contact lens applications, presbyopia and amblyopia treatments are some of the areas where it is important to determine the dominant eye.[6,7] Neuroimaging and neurological tests on ocular dominance have revealed that ocular dominance may be related to cortical preference.[11] Ocular dominance may vary depending on visual acuity, previous surgeries, and various neurological conditions. A study has shown that the dominant eye can change after cataract surgery.[12] It is unknown whether the change in the dominant eye also affects retinal and choroidal microvascularity. Although there are studies on ocular morphological and functional parameters related to ocular dominance, meaningful results that can be reflected in clinical practice are still limited.

In this study compared optical coherence tomography angiography parameters between dominant and non-dominant eyes. In our study, the majority of dominant eyes were right eyes (65.5%). In the literature, there are data supporting our study, showing that the dominant eye is the right eye in most of the population.[13-15]

In our study, there was no significant difference in retinal and choroidal microvascular properties between dominant and nondominant eyes. Similarly, no statistically significant differences were found in central macular thickness and

Table 1. *Comparison of OCTA parameters of dominant and non-dominant eyes*

	Dominant eye (n=40) Mean±SD	Nondominant eye (n=40) Mean±SD	p
FAZs (µm²)	256,81±68.42	256,91±71,29	0,995
FAZd (µm²)	240,63±64,48	238,83±62,46	0,899
VDs central (%)	20,88±4,02	20,75±4,39	0,894
VDs superior (%)	50,63±3,40	50,18±4,01	0,584
VDs temporal (%)	47,32±3,14	46,90±3,79	0,591
VDs inferior (%)	49,95±4,51	49,73±3,62	0,812
VDs nasal (%)	45,67±4,25	46,62±3,53	0,280
VDd central (%)	21,40±6,30	19,63±4,93	0,166
VDd süperior (%)	52,95±3,34	52,39±3,28	0,455
VDd temporal (%)	49,17±3,89	47,88±2,79	0,095
VDd inferior (%)	53,12±3,98	51,69±4,16	0,121
VDd nasal (%)	50,07±3,88	50,88±3,20	0,310
VDcc central (%)	49,51±4,45	49,41±5,14	0,927
VDcc süperior (%)	53,62±2,66	53,99±3,16	0,572
VDcc temporal (%)	53,29±3,28	52,84±3,72	0,565
VDcc inferior (%)	55,86±4,35	55,46±3,95	0,664
VDcc nasal (%)	52,20±3,60	52,67±3,99	0,585
CMT (µm)	233,35±29,48	224,20±24,73	0,137
SFCT (µm)	322,47±56,53	315,52±44,91	0,545

SD: standart deviation; FAZs: superficial foveal avascular zone; FAZd: deep foveal avascular zone; VDs: superficial vascular density; VDd: deep vascular density; VDcc: choriocapillaris vascular density; CMT: central macular thickness; SFCT: subfoveal choroidal thickness

Table 2: *Comparison of OCTA parameters of right and left eyes*

	Right eye (n=40) Mean±SD	Left eye (n=40) Mean±SD	p
FAZs (µm²)	260.27±69.32	254,59±70,24	0,454
FAZd (µm²)	247,21±65,52	237,26±61,53	0,320
VDs central (%)	20.61±5,24	21,25±4,92	0,669
VDs superior (%)	50,37±3,62	50,83±4,17	0,595
VDs temporal (%)	48,56±3,57	46,04±3,38	0,399
VDs inferior (%)	49,86±3,69	49,89±3,98	0,928
VDs nasal (%)	45,96±4,38	46,19±4,71	0,745
VDd central (%)	20,54±5,56	20,48±4,33	0,665
VDd superior (%)	52,65±3,19	52,53±3,46	0,852
VDd temporal (%)	48,29±3,24	48,27±3,54	0,885
VDd inferior (%)	52,15±3,38	51,95±4,72	0,648
VDd nasal (%)	50,72±3,72	50,56±3,34	0,865
VDcc central (%)	49,62±4,47	49,16±4,77	0,468
VDcc superior (%)	53,83±3,47	53,79±3,02	0,663
VDcc temporal (%)	52,85±3,38	53,17±3,84	0,759
VDcc inferior (%)	55,96±3,91	55,38±3,73	0,467
VDcc nasal (%)	52,34±3,79	52,48±3,78	0,350
CMT (µm)	227,4±27,84	230,15±26,45	0,758
SFCT (µm)	323,62±56,76	314,37±44,23	0,354

SD: standart deviation; FAZs: superficial foveal avascular zone; FAZd: deep foveal avascular zone; VDs: superficial vascular density; VDd: deep vascular density; VDcc: choriocapillaris vascular density; CMT: central macular thickness; SFCT: subfoveal choroidal thickness

Table 3: *Participants' handedness and ocular dominance*			
	Right eye dominant (n=26)	**Left eye dominant (n=14)**	**p**
Right-handed	24 (%92.3)	12 (%85.7)	0.507
Left-handed	2 (%7.7)	2 (%14.3)	0.507

subfoveal choroidal thickness measurements. These findings support that the dominant eye does not affect retinal microvascular structures and is not affected by retinal micravascular structures.

There are several studies in the literature comparing retinal images and morphologic parameters of the eye in dominant and non-dominant eyes. In a study, the relationship between central corneal thickness and dominant and non-dominant eyes was investigated, and no statistically significant difference was found between the groups.[16] Samarawickrama et al.[14] found that dominant eyes had higher axial length and myopic refraction than non-dominant eyes, but no significant difference was found between central macular thickness and retinal nerve fiber layer thickness. In our study, there was no difference in refraction because all participants were emmetropic. Further studies in more heterogeneous groups will be useful in terms of generalizability to the population.

Kim et al.[13] compared CMT, peripapillary retinal nerve fiber layer thickness, FAZ between dominant and non-dominant eyes of healthy individuals and showed no significant difference. Similarly, we found no difference in FAZ measurements in our study. In the study by Song et al.[17] dominant and non-dominant eyes were compared in healthy individuals and CMT, peripapillary retinal nerve fiber layer, and macular ganglion cell layer thicknesses were examined with optical coherence tomography (OCT) and no difference was found between dominant and non-dominant eyes. In another study, choroidal thicknesses of dominant and non-dominant eyes were compared and no difference was observed, as in our study.[18] Hagar et al.[19] compared OCT parameters such as CMT, peripapillary retinal nerve fiber layer and inner retinal layers and found no difference between dominant and non-dominant eyes. In a similar study comparing dominant and non-dominant eyes, it was observed that most of the participants were right eye dominant as in our study; no difference was reported in CMT and peripapillary retinal nerve fiber layer thickness measurements.[20] Khan et al.[15] found in their study that 97% of the participants were right-handed and 79% were right-eye dominant. These results are similar to our study, where we also found 90% right handedness and 65.5% right eye dominance. As in our study, no relationship was found between handedness and ocular dominance. In the same study, CMT and peripapillary retinal nerve fiber layer thickness were compared between dominant and non-dominant eyes and no difference was reported. Karakucuk et al.[21] reported that there was no difference between the OCTA parameters of dominant and non-dominant eyes as in our study.

There were several limitations of our study. These limitations include the small sample size, inability to evaluate different age groups and ethnic groups, and the inclusion of only individuals without refractive errors in the study. Future studies with larger patient groups and with different ethnic groups may clarify the possible retinal and choroidal vascular differences between dominant and non-dominant eyes.

In conclusion, in our study, there was no significant difference in retinal and choroidal microvascular characteristics between dominant and non-dominant eyes. It is still unclear whether there is a difference in random eye selection for data analysis in ophthalmological studies due to retinal blood flow and whether it affects the results, and the result of our study supports the use of randomized ocular data in scientific research regardless of which eye is dominant.

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