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ORIGINAL ARTICLE

Macular asymmetry analysis in sighting ocular dominance

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Abstract Sighting ocular dominance is the preference of one eye over the other in terms of sighting. In this study, our aim was to examine differences in interocular and intraocular macular thickness, interocular fovea-optic disc angle, and foveal blood vessel asymmetries associated with sighting ocular dominance. Ninety eyes of 45 healthy young adults were included in this prospective, cross-sectional, and comparative study. Sighting ocular dominance was determined by a hole-in-the-card test. Macular thickness measurements were taken and posterior pole asymmetry analysis conducted with spectral domain optical coherence tomography. The optic disc–fovea angle and visible foveal blood vessel counts were calculated by using the posterior pole retinal images of optical coherence tomography. The mean age of the participants was 27.3 (standard deviation [SD] 6.6) years. There were 20 males and 25 females. The mean total macular area thickness, and mean macular thickness of the superior and inferior hemispheres of the dominant and nondominant eyes were similar ($p > 0.05$). Macular asymmetry analysis revealed no statistically significant interocular difference ($p > 0.05$). In the dominant eyes, the mean optic disc–fovea angle was 5.24° (SD 1.77), whereas it was 5.49° (SD 2.58) in the nondominant eyes ($p = 0.51$). The number of visible blood vessels passing through the fovea was similar in the dominant and nondominant eyes ($p > 0.05$). These results suggested that interocular and intraocular macular thickness differences, interocular fovea–optic disc angle differences, and number of visible foveal blood vessels are not associated with sighting ocular dominance.
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Conflicts of interest: All authors declare no conflicts of interest.

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Introduction

Posterior pole asymmetry analysis (PPAA) is a novel retinal imaging technique of the Spectralis optical coherence tomography (OCT) device that at once maps the posterior pole retinal thickness and performs asymmetry analysis between the eyes and between the hemispheres of each eye. It compares the thicknesses of 64 cells obtained from the macular areas of both eyes equivalent to a central 20° visual field [1—3]. Posterior pole images can also be used for optic disc—fovea angle measurements and retinal blood vessel examinations.

Ocular dominance is the superiority or preference of one eye over the other for sighting, sensory, and oculomotor tasks [4,5]. Although the importance of eye dominancy in daily life is not fully understood, it is clinically important in sports vision, vision therapy, and monovision treatments [6]. It has been reported that eye dominance might be related to cortical hemispheric specialization for visual attention [7]. People's dominant eye is frequently on the same side as the master hand, but the opposite is not rare.

Although ocular dominance has been studied for centuries, it continues to be a poorly understood phenomenon. The role of the brain in ocular dominance has some support, such as a finding that lesions of various cortical and subcortical tissues can cause unilateral spatial neglect [8]. Also, the first neurons of the visual pathway that encode binocular disparities are located in the visual cortex [9]. Higher-order centers of the brain beyond the visual cortex probably also exert some influence. It seems, however, that there are multiple determinants for sighting ocular dominance.

This study was motivated by recent reports revealing interocular quadrant macular thickness, refractive error, and axial length differences in sighting ocular dominance [10,11]. Because the macula is the retinal area concerned with central vision and is the primary determinant of visual output to the visual cortex, we hypothesized that it might complement the brain's primary role in the mechanism of ocular dominance. One of the aims of this study was to investigate the differences in interocular macular thickness, as well as the hemispheric differences of each eye in terms of sighting ocular dominance. In addition to this, we compared the optic disc—fovea angle of the dominant and nondominant eyes. We also examined interocular visible foveal blood vessel count differences.

Materials and methods

Ninety eyes of 45 healthy young adults were included in this prospective cross-sectional comparative study. The study was conducted in accordance with the ethical standards of the Declaration of Helsinki and was approved by the Institutional Ethical Committee.

Study population

Participants were aged from 19 to 41 years, and all had visual acuity of 20/20 or better for both eyes according to the Snellen chart examination. Exclusion criteria were any systemic diseases, a history of ocular surgery, ocular diseases (e.g., corneal opacity or irregularity, dry eye, amblyopia, anisometropia >0.50 diopters, glaucoma, and retinal abnormalities), on medications that might affect the eyes, and insufficient mental capacity to perform the tests. Participants exhibited refractive errors from −2.0 to +2.0 diopters spherical equivalent. Higher ametropies were excluded.

Ocular dominance detection

Sighting ocular dominance was determined by a hole-in-the-card test, in which each participant was given a card with a small hole in the center, instructed to hold it with both hands at a distance of approximately 40 cm from the eyes, and told to view a distant object through the hole with both eyes open. The researcher then alternates which eye is closed or the participant slowly draws the opening back to the head to determine which eye is viewing the object and is thus the dominant eye [6,12]. For each participant, the test was performed at least three times for confirmation. Participants with uncertain dominance were excluded. Fig. 1 shows the schematic representation of the visual process in sighting ocular dominance testing.

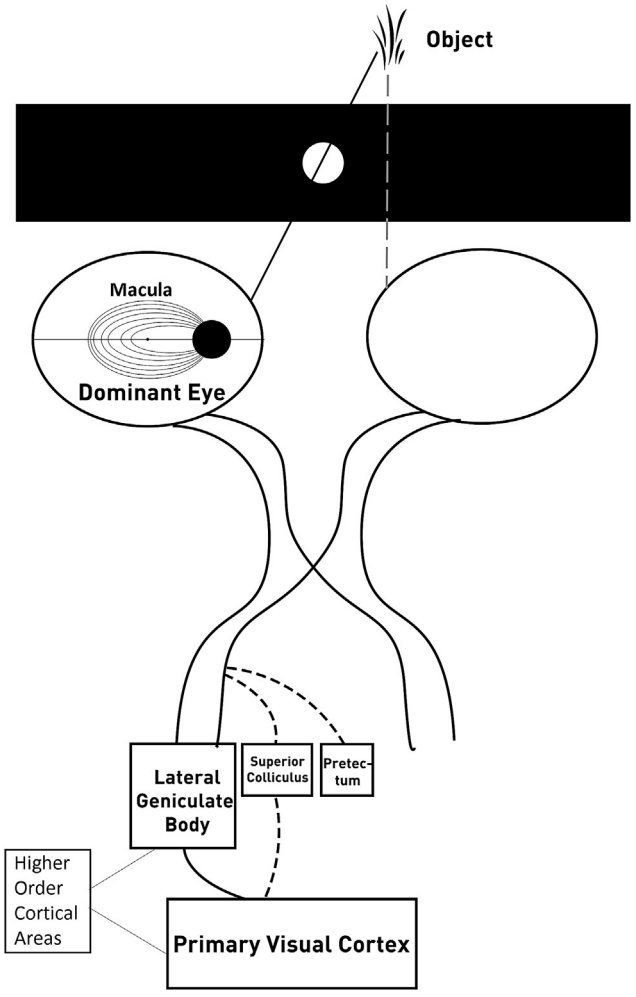

Figure 1. The schematic representation of the visual process in sighting ocular dominance testing.

Macular asymmetry analysis

We performed three techniques for interocular macular asymmetry analysis: macular thickness, fovea—optic disc angle, and foveal blood vessel counts. Macular thickness measurements were taken and PPAA performed with the spectral domain OCT (Spectralis OCT, Heidelberg, Germany). Macular thickness was defined as the vertical distance between the vitreoretinal interface and the outer border of the retinal pigment epithelium. Only images of good quality were accepted. Such images were appropriately focused, evenly illuminated, and centered on the macula. On the PPAA screen, the macular thickness map is divided into 64 sectors centered on the fovea (8 × 8 grid). PPAA provides data derived from the cell-to-cell comparison between corresponding cells across the hemisphere within each eye (i.e., the superior hemisphere vs. the inferior hemisphere) and between both eyes (i.e., the dominant eye vs. the nondominant eye). The superior and inferior hemispheres were determined by a line passing through the center of the fovea and optic nerve head. In this study, we arbitrarily divided the whole macular area into two zones: the central macular zone (Zone 1), which included 16 sectors, and the peripheral macular zone (Zone 2), which included 48 sectors. This division was implemented to compare the reciprocal zones from both the dominant and nondominant eyes (Fig. 2). We calculated the mean thickness values of Zones 1 and 2. We also compared the mean macular thickness values between the right and left (nasal and temporal, according to the fovea) hemispheres of each eye, and their relationship with ocular dominance.

In order to detect prominent thickness differences, black cells and dark grey cells were included for interocular zonal comparison. Black cells indicate a mean thickness difference of >30 μm, whereas dark grey cells indicate a mean thickness difference of between 20 μm and 30 μm. Because clearly centering the posterior pole retinal thickness map is critical to obtain valid results, we only included participants whose asymmetry thickness maps were centered well on the fovea.

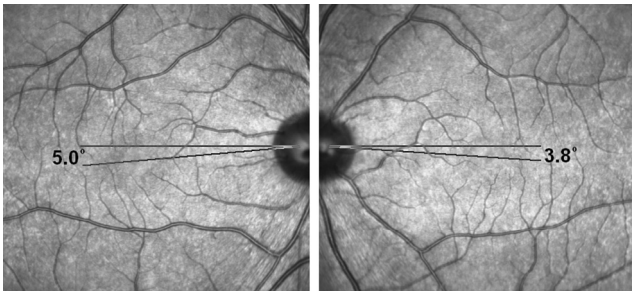

Figure 3. The optic disc—fovea angles of the dominant and nondominant eyes of one of the participants.

The optic disc center—fovea center angle (ocular torsion) was measured on posterior pole retinal images by using screen protractor software (Fig. 3). We drew a horizontal line passing through the center of the optic disc and another line passing through the center of fovea and optic disc. The angle between these two lines was accepted as the optic disc—fovea angle. In order to calculate the number of visible retinal blood vessels passing through the fovea, we drew a circle of 1.5 mm diameter corresponding to the fovea, and then counted the number of blood vessels in that circle (Fig. 4).

Statistical analysis

For statistical analysis, SPSS 17.0 software for Windows (SPSS Inc., Chicago, IL, USA) was used. The paired samples

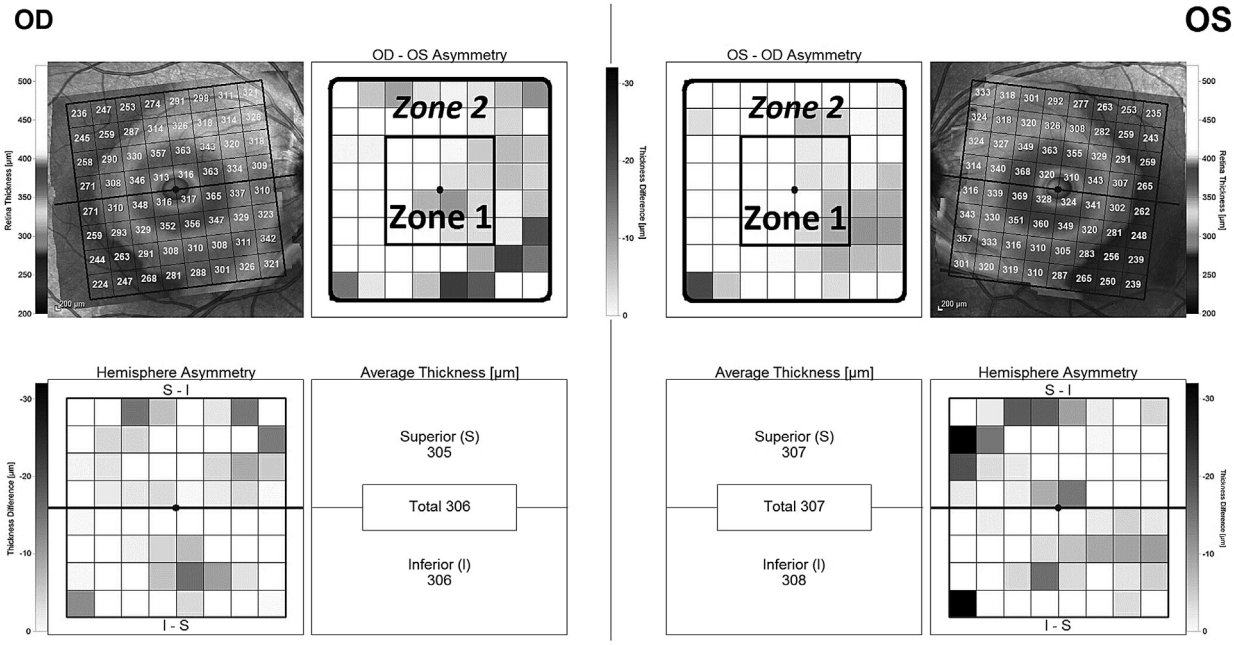

Figure 2. Posterior pole retinal thickness map showing the 64 cells used in spectral domain optical coherence tomography and the two zones (central and peripheral) used for the assessment of asymmetry.

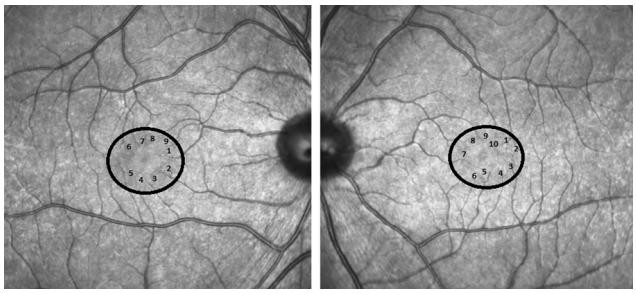

Figure 4. Visible foveal blood vessel counts of the dominant and nondominant eyes of one of the participants.

t-test was used to compare mean macular thickness values, optic disc–fovea angle values, foveal blood vessel counts, and interocular zonal black and dark grey cell numbers for the sample. In this study, p values <0.05 were considered to be statistically significant.

Results

The mean age of the participants was 27.3 (standard deviation [SD] 6.6) years. There were 25 females (56%) and 20 males (44%) in the study. Forty-one participants (91%) were right-handed. Thirty participants (67%) had their right eyes as the dominant eye. In sum, 32 participants (71%) had their dominant eye on the same side as their master hand. The mean refractive error was −0.26 diopters (SD 0.53) in the dominant eyes and −0.21 diopters (SD 0.50) in the nondominant eyes ($p = 0.29$).

Table 1 shows the mean macular thickness values for the dominant and nondominant eyes. Both eyes had similar total and hemispheric macular thickness values. There were no statistically significant differences in superior *versus* inferior hemispheres within the same eye ($p = 0.06$ for dominant eyes, and $p = 0.24$ for nondominant eyes).

We performed a further analysis of superior and inferior hemisphere asymmetry for Zone 1. The superior hemisphere mean macular thicknesses for Zone 1 were as follows; 331.3 μm (SD 13.4) for the dominant eyes, and 332.4 μm (SD 14.0) for the nondominant eyes ($p = 0.09$). Zone 1 inferior hemisphere thickness values were 331.6 μm (SD 13.5) for the dominant eyes, and 331.5 μm (SD 13.4) for the nondominant eyes ($p = 0.81$).

The mean nasal and temporal hemispheres' macular thickness values for the dominant eyes were 316.6 μm (SD 14.2) and 282.3 μm (SD = 12.1), respectively ($p < 0.001$). The mean nasal and temporal hemispheres' macular thickness values of the nondominant eyes were 317.1 μm (SD 14.5) and 282.1 μm (SD 11.8), respectively ($p < 0.001$). The temporal hemispheres' mean macular thicknesses of the dominant and nondominant eyes were similar ($p = 0.62$), as were the nasal hemispheres ($p = 0.27$).

To reveal interocular zonal asymmetry, we conducted statistical analysis by considering the number of black cells and dark grey cells on the PPAA screen. In Zones 1 and 2, there were no statistically important differences between the dominant and nondominant eyes for black cells and dark grey cells (black cells: $p = 0.57$ for Zone 1, and $p = 0.84$ for Zone 2; dark grey cells: $p = 0.08$ for Zone 1, and $p = 0.23$ for Zone 2).

The mean optic disc–fovea angle was 5.24° (SD 1.77) in the dominant eyes and 5.49° (SD 2.58) in the nondominant eyes ($p = 0.51$). The mean number of visible blood vessels passing through the fovea was 6.5 (SD 2.0) in the dominant eyes, and 6.4 (SD 1.8) in the nondominant eyes ($p = 0.46$).

Table 1 The mean macular thickness values of the dominant and nondominant eyes.

	Dominant eyes (SD)	Nondominant eyes (SD)	*p*
TMT (μm)	299.4 (12.8)	299.6 (12.9)	0.65
SHMT (μm)	299.0 (12.9)	299.2 (13.0)	0.83
IHMT (μm)	300.2 (13.6)	299.9 (13.1)	0.57

IHMT = mean inferior hemisphere macular thickness; SHMT = mean superior hemisphere macular thickness; TMT = mean total macular area thickness; SD = standard deviation.

Discussion

Our results show that differences in interocular and intraocular macular thickness are not associated with sighting ocular dominance. We also found that interocular optic disc–fovea angle and foveal visible blood vessel count differences are not associated with ocular dominance. One might think that, since sighting ocular dominance requires the summation of visual output in the higher-order centers of the brain, it cannot be due to asymmetric macular thickness. Because the macula mostly generates this visual output, however, it is possible that the macula has indirect influence in the summation process. It is important to remember that most of the visual cortex is devoted to macular activity.

Eye dominance has different types, including sighting, sensory, and acuity dominance [13,14]. The sighting-dominant eye could be defined as the eye that can both move quickly to a target and remained fixed upon it [14,15]. There is also some concern about whether the dominant eye is the eye with better visual acuity. Pointer [16] reported no difference between the monocular acuity levels of the dominant and nondominant eyes. Furthermore, Eser et al. [17] found no statistically significant difference between the dominant and nondominant eyes in terms of refractive errors. By contrast, Ito et al. [11] reported that nondominant eyes had a greater myopic refractive error and longer axial length compared to dominant eyes, especially in cases of high amounts of anisometropia. In this study, 32 participants (71%) had their dominant eyes on the same side as the master hand, which concurs with the results of previous reports [11,16,18]. It was shown that under different viewing conditions, eye preference changes as a function of horizontal gaze angle; for this reason, we performed the hole-in-the-card test with the participants' gazes pointed straight ahead [19].

The literature addressing eye dominance has focused on the functional aspects of interocular differences, as previously it was not possible to investigate fine ocular structures. Given the development of spectral-domain OCT,

however, it is now possible to examine the morphological structure of the whole macula in detail. In their study related to the comparison of 'central' macular thickness values between the dominant and nondominant eyes in children, Samarawickrama et al. [20] found no statistically significant interocular difference. In our study, the mean thickness values of the 'whole' macular area were similar in the dominant and nondominant eyes. Unlike other studies, Oka et al. [10] reported that the dominant eyes of patients with strabismus who had developed abnormal binocular vision had thinner superior temporal quadrantal macular thickness values.

Apart from specific macular disorders, sectional macular thickness changes were usually seen in patients with glaucoma [21]. In our study, we examined the differences between the superior and inferior macular hemispheres within each eye and did not find statistically significant differences for the dominant and nondominant eyes. Normally, retinal nerve fibers arising from the superior macular hemisphere form the superotemporal part of the optic nerve head, whereas fibers from the inferior macula form the inferotemporal part. Because the inferotemporal quadrant peripapillary retinal nerve fiber layer is generally thicker than the superotemporal retinal nerve fiber layer, we would have expected more a prominent difference in thickness between the superior and inferior macular hemispheres in each eye.

Upon comparing the interocular superior and inferior macular hemispheres, the mean superior and inferior macular hemispheres' thicknesses of the dominant eyes were similar to those of the nondominant eyes. We repeated the same comparisons for the central macula (Zone 1) and, again, found no statistically significant interocular differences. According to us, central (Zone 1) macular thickness values are more reliable than peripheral (Zone 2) macular thickness values, because retinal vessels sometimes pass through the peripheral macula and, in turn, affect PPAA measurements.

There are some other studies that have investigated the relationship between ocular dominance and the macula. Park et al. [22] reported that ocular dominance was not an important determinant of human cone photoreceptor density at the fovea. Akaza et al. [23] found that the sighting dominance of some macular disease patients can shift from the affected eye to the other eye. Unlike those studies, we performed morphological macular measurements. In addition to zonal and hemispherical macular thickness analysis, we conducted a cell-to-cell comparison of the dominant and nondominant eyes with PPAA. Our results showed that there was no difference in interocular localized thickness between the dominant and nondominant eyes.

The optic disc—fovea angle is another parameter that we used to detect interocular asymmetry. The optic disc—fovea angle measurement is accepted as the gold standard method for assessing the cycloposition [24]. This angle varies widely among normal individuals, but variation between the left and right eyes of the same person was not significant [25]. Lefèvre et al. [26] reported that the optic disc—fovea angle could be determined by retinophotography and that the mean angle value was 6.3° (SD 3.4) in healthy participants. Our results were similar to the results of those reports [25,26].

The third parameter that we used to detect macular asymmetry in terms of ocular dominance was foveal visible blood vessel counts. Normally, the retinal blood vessels are not symmetrically arranged between the eyes. The center of the fovea, the retinal avascular zone, is devoid of blood vessels, and this accounts for the high visual acuity capability due to the light to be sensed without any dispersion or loss [27]. The retinal blood vessels could prevent the light from passing to the photoreceptor layer-forming angioscotomas, and this situation might be related to ocular dominance [28,29]. We therefore hypothesized that the number of visible blood vessels in the fovea outside the retinal avascular zone might be less in the dominant eyes when compared to the nondominant eyes in order to provide higher visual capacity. Despite this, we found that there was no significant difference in the aspect of visible blood vessel counts passing through the fovea in the dominant and nondominant eyes.

Our study has several limitations. First, the sample size might seem relatively small. Second, quadrant macular thickness values might be compared interocularly, but the Spectralis software only provides hemispheric thickness values. Lastly, fundus fluorescein angiography could be more useful for assessing foveal blood vessels.

Conclusion

In conclusion, our study revealed that sighting ocular dominance is not an important determinant of interocular macular thickness, optic disc—fovea angle, and foveal blood vessel count. In other words, visual sensors (macula) do not have an impact on sighting bias in healthy young adults. We believe that the exact mechanism and effects of sighting ocular dominance still remain unclear.

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