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The Association between Ocular Dominance and Refractive Errors in Chinese Myopic Subjects

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Abstract

Background: To determine the association between ocular dominance and myopic anisometropia in Chinese myopic subjects. This relevance would facilitate to identify the ocular dominance in bilateral cataract patients.

Design: Retrospectively case study.

Participants: 1503 Chinese myopic subjects, mean age 27 years, who were candidates for corneal myopic refractive surgery were reviewed between 2011 and 2012.

Methods: The ocular dominance was determined by the hole-in-the-card test. The associations between ocular dominance laterality and refractive characters, including the sphere, cylinder, spherical and astigmatic anisometropia, were analyzed.

Main outcome measures: Ocular dominance, manifest refraction, cycloplegic refraction.

Results: 992 (66%) subjects were right-eye dominant while 511 (34%) subjects were left-eye dominant. The dominant eyes had lower spherical equivalents (SE) and cylinders than the non-dominant eyes (-5.36 D vs. -5.48 D and -0.70 D vs. -0.76 D, respectively, $P<0.001$). The ocular dominance was significantly associated with the lower myopic eye in subjects with SE anisometropia >0.5 D ($P<0.05$). There was also significant association between the dominant eyes and the lower astigmatic eyes in the subjects with astigmatic anisometropia > 0.25 D ($P<0.05$). In unilateral astigmatic subjects, non-astigmatic eyes were noted to be the dominant eyes in 111 (57.51%) subjects and astigmatic eyes represented dominance in 82 (42.49%) subjects. The difference was not statistically significant ($P=0.249$). The ocular dominance was not associated with the sex.

Conclusion: In Chinese myopic subjects, the dominant eye usually had lower myopic SE and lower astigmatism compared with the non-dominant eye, especially in subjects with high amount of anisometropia.

Keywords: Ocular dominance; Myopia; Astigmatism; Cataract

Introduction

Ocular dominance is the tendency to prefer visual input from one eye over the other. It may be further characterized as one of the eyes commonly dominates or leads the other eye [1] in fixation and attention or in perceptive function. Ocular dominance was first described by Porta in 1593. Assessing ocular dominance is important in treating a variety of ophthalmic conditions, such as the prescription of correcting spectacle lenses, strabismus surgeries, covering therapy for amblyopia and refractive surgeries.

Currently, knowledge of ocular dominance is also widely used in cataract surgeries when using a 'monovision' approach to treat presbyopia [2]. In a monovision approach, the dominant eye is usually corrected for distance vision and the non-dominant eye for near vision. It is considered that perception with the dominant eye will be less easily suppressed by the relatively blurred image than the non-dominant eye [3]. In such cases, being sure of ocular dominance before surgeries would ensure a high rate of success and patient satisfaction. However, in most bilateral cataract subjects, the different visual impairments that arise from inconsistent crystalline lens opacity in two eyes would make the results of the subjective ocular dominance test unreliable. Could some objective information assist with the prediction of individual ocular dominance more accurately?

Ocular biometry before cataract surgery usually measures several important parameters of the eye that are closely related to ocular refraction, such as axial length, corneal curvature, and anterior chamber depth. With these data, we could speculate on the preexisting ocular refractive errors before a cataract emerged. In the present study, we sought to analyze the association between ocular dominance and refractive errors in a large series of Chinese myopic subjects, which might facilitate identification of the dominant eye in bilateral cataract patients.

Materials and Methods

Study population

The study population consisted of 1503 Chinese individuals attending the refractive clinic in our hospital for the treatment of myopia. Most of these subjects subsequently underwent excimer laser corneal refractive surgeries. This study was performed adhering to the tenets of the Declaration of Helsinki. Informed written consent was obtained from the subjects after the nature of the study was fully explained. The including criteria were: subjects over 17 years old, stable refraction had been reached over 2 years, both eyes were myopic or with myopic astigmatism and the best spectacle corrected visual acuity (BSCVA) of each eye was 20/20 or better. The excluding criteria included: ocular surface diseases, strabismus, nubecula, abnormalities of the crystalline lens, elevated intraocular pressure, vitreoretinal diseases and individuals who had ever undertaken corneal refractive surgeries.

Clinical measures

We examined all the patients in detail. In addition to the general medical and ocular histories, ocular examinations included uncorrected distance visual acuity (UCVA), cycloplegic refraction with tropicamide (SR-7000; Shin-Nippon, Japan), manifest refraction with spectacle lens, BSCVA, tonometry, pachymetry, corneal topography (Pentacam; Oculus, Wetzlar, Germany), slit-lamp examination of the anterior segment, and fundoscopy. All the refractive data were record in minus cylinder form.

Ocular dominance assessment

To determine ocular dominance, the hole-in-the-card test was performed. While the distance visual acuity was corrected by spectacle lens, the subjects were asked to hold a card with a 40-milimeter-diameter hole in the middle using both hands at arm's length and view the distance target 5 meters away through this hole. The examiner then covered each eye of the subject alternately. After repeating the tests thrice, the eye that could always see the distance target while the other eye was covered was recorded as the dominant eye.

Statistical analysis

All the data, including subjects' name, sex, age, sphere, cylinder and spherical equivalent (SE) of the spectacle lens, were input into a spreadsheet program (Excel 2003, Microsoft, Redmond, WA) and statistical analyses were performed using SPSS (version 16.0, SPSS Inc., Chicago, IL). The arithmetic means of the sphere, cylinder and SE of both eyes were calculated and a significance test of the difference between the two eyes were performed using a paired-sample T test. Similarly, the differences between the dominant eyes and the non-dominant eyes were also calculated and statistically analyzed. The differences in the ocular dominance distribution between the two eyes and sexes were analyzed with Crosstab Chi-Square tests. According to different myopic degrees, the individuals with homogeneous refraction in both eyes were subdivided into low (-3.00 D ≤ SE <0 D), moderate (-6.00 D ≤ SE <-3.00 D) and high (SE <-6.00 D) myopia groups. The differences in the ocular dominance distribution among the three groups were compared with Crosstab Chi-square tests. The ocular dominance distribution differences between astigmatic and non-astigmatic eyes in unilateral astigmatic individuals were tested with Chi-square tests. The individuals were divided into subgroups by different SE anisometropia and astigmatic anisometropia, the associations between ocular dominance and degree of anisometropia were also determined with Crosstab Chi-square tests. The statistical significance was identified when the P value was less than 0.05.

Results

General aspect

A total of 1,503 individuals who had complete data for ocular dominance and refraction were enrolled in this study. The mean age was 27.32 ± 6.60 years (ranging from 17 years to 62 years). The mean and range of the sphere, cylinder and SE in the right and left eyes are listed in Table 1. The right eyes had significantly higher myopic sphere and SE values than the left eyes. The myopic cylinder was significantly higher in the left eyes than in the right eyes.

A total of 992 individuals (66.00% of the whole study population) had right ocular dominance, while 511 individuals (34.00%) had left ocular dominance. The ratio of the number of right to left ocular dominant subjects was 1.94:1 in this study population. The mean and range of the sphere, cylinder and SE in the dominant and the non-dominant eyes are listed in Table 2. The dominant eyes had lower sphere, cylinder and SE values compared with the non-dominant eyes, and the differences were statistically significant.

	Right eye		Left eye		t	P#
	Mean, D	Range, D	Mean, D	Range, D		
Sphere	-5.18 ± 1.94	-13.50 ~ -0.75	-4.94 ± 1.95	-12.50 ~ -0.50	-8.229	0.000*
Cylinder	-0.71 ± 0.71	-5.50 ~ 0	-0.75 ± 0.71	-6.50 ~ 0	2.734	0.006*
SE	-5.53 ± 1.99	-14.50 ~ -1.25	-5.31 ± 1.99	-13.125 ~ -0.50	-7.711	0.000*
#Tested with Paired-Sample T test *Significant at P ≤ 0.05						

Table 1: Data of the sphere, cylinder and SE in the right and left eyes and the comparison between two eyes.

	Dominant eye		Non-dominant eye		T	P#
	Mean, D	Range, D	Mean, D	Range, D		
Sphere	-5.01 ± 1.91	-13.50 ~ -0.50	-5.10 ± 1.99	-13.50 ~ -0.50	2.976	0.003*
Cylinder	-0.70 ± 0.68	-5.50 ~ 0	-0.76 ± 0.73	-6.50 ~ 0	4.319	0.000*
SE	-5.36 ± 1.94	-13.50 ~ -0.87	-5.48 ± 2.04	-14.50 ~ -0.50	4.130	0.000*
#Tested with Paired-Sample T test * Significant at P ≤ 0.05						

Table 2: Data of the sphere, cylinder and SE and the comparison between the dominant and the non-dominant eyes.

Ocular dominance and sex

In the whole study population, 527 subjects were male and 976 subjects were female. The average age of male subjects was 26.56 ± 6.91 years, the mean sphere values of the right and left eyes were -4.97 ± 1.98 D and -4.72 ± 1.97 D, respectively, the mean cylinder values were -0.74 ± 0.67 D and -0.81 ± 0.74 D, and the mean SE were -5.34 ± 2.04 D and -5.12 ± 1.99 D, respectively.

Sex	Right ocular dominance		Left ocular dominance		χ2	P#
	n	%	n	%		
Male	350	66.41	177	33.59	0.061	0.804
Female	642	65.78	334	34.22		
# Tested with Pearson Chi-Square test, * Significant at P ≤ 0.05						

Table 3: Distribution of the ocular dominance in male and female subjects.

For female subjects, the average age was 27.71 ± 6.41 years, the mean sphere of the right and left eyes were -5.22 ± 1.88 D and -5.00 ± 1.88 D, the mean cylinder were -0.67 ± 0.70 D and -0.68 ± 0.66 D, and the mean SE were -5.55 ± 1.90 D and -5.34 ± 1.91 D, respectively. There was no statistically significant difference in the distribution of ocular dominance between male and female subjects, as shown in Table 3.

Ocular dominance and myopic SE

We divided the subjects who had similar binocular myopic refraction into low myopia (-3.00 D ≤ SE<0 D), moderate myopia (-6.00 D ≤ SE<-3.00 D) and high myopia (SE<-6.00 D) groups according to different myopic SE. The ocular dominance distributions in different groups are shown in Table 4. The statistically significant difference in the ocular dominance distribution between lower and higher myopic eyes was only observed in the high myopia group.

Myopic subgroups	Dominant eyes with lower SE power		Dominant eyes with higher SE power		χ^2	P#
	n	%	n	%		
Low myopia	32	50.00	32	50.00	0.005	0.942
Moderate myopia	297	50.00	297	50.00	3.454	0.063
High myopia	192	56.14	150	43.86	8.277	0.004*

Table 4: Ocular dominance distributions in different myopic subgroups.

Ocular dominance and SE anisometropia

Among the 204 subjects who had equal SE in both eyes, 133 cases (65.20%) had right ocular dominance and 71 cases (34.80%) had left ocular dominance. The ratio of right to left ocular dominance was 1.87:, which was similar to the ocular dominance distribution in the whole study population.

A total of 1,299 subjects had different SE bilaterally. In 677 cases (52.12%), the dominant eyes had lower myopic SE than the non-dominant eyes, while in the other 622 cases (47.88%), the dominant eyes had higher myopic SE. The association between the myopic SE and ocular dominance was statistically significant (χ^2=17.004, P=0.000).

According to different SE anisometropia (δSE) degrees, we sub-divided the subjects into four groups (δSE ≤ 0.50 D, 0.50 D <δSE ≤

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1.00 D, 1.00 D <δSE ≤ 2.00 D and δSE>2.00 D). The ocular dominance distributions between higher and lower myopic eyes in each group are listed in Table 5 and demonstrated in Figure 1. In the subgroup in which the SE anisometropia was ≤ 0.5 D, the difference between the dominant eyes accompanied with higher myopia or lower myopia was not significant. When the SE anisometropia was >0.50 D, the eyes with lower myopic SE were prone to be the dominant eyes. Compared with the total 1,299 SE anisometropic subjects, the lower myopic eyes were more likely to be the dominant eyes in subjects with SE anisometropia >2.00 D (52.12% and 65.56%, respectively). The difference was statistically significant (χ^2=6.102, P=0.014).

SE anisometropia, D	Dominant eyes with lower SE power		Dominant eyes with higher SE power		χ^2	P#
	n	%	n	%		
≤ 0.5	355	49.37	364	50.63	0.504	0.478
0.51-1.00	163	51.10	156	48.90	5.265	0.022*
1.01-2.00	100	58.48	71	41.52	11.987	0.001*
>2.00‡	59	65.56	31	34.44	11.429	0.001*

Table 5: Ocular dominance distributions in the different SE anisometropia subgroups.

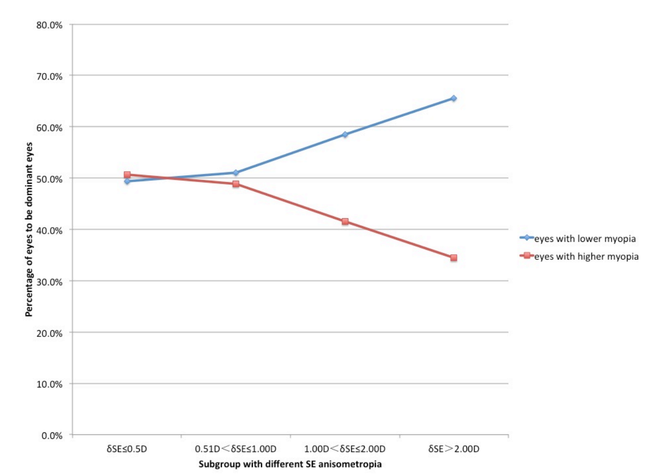

Figure 1: The percentage of the higher and the lower myopic eyes to be the dominant eyes in the different SE anisometropia subgroups. In subgroups with the δ SE>0.50 D, the lower myopic eyes were more likely to be the dominant eyes.

Ocular dominance and astigmatism

In the subjects whose SE anisometropia was ≤ 0.50 D, the ocular dominance distribution was not significantly associated with myopic SE. We further studied the association between ocular dominance and astigmatism. A total of 193 subjects had unilateral myopic astigmatism while the other eye had simple myopia. The non-astigmatic eyes were confirmed to be the dominant eyes in 111 cases (57.51%). The astigmatic eyes exhibited dominance in 82 other cases (42.49%). The difference was not statistically significant (χ^2=1.329, P=0.249).

Ocular dominance and astigmatism anisometropia

A total of 330 subjects had bilateral myopic astigmatism and had different astigmatic power between the two eyes. According to different astigmatic anisometropia (δastig), we sub-divided the cases into three subgroups (δastig ≤ 0.25 D, 0.25 D<δastig ≤ 0.50 D and δastig>0.50 D). The distributions in ocular dominance between higher and lower astigmatic eyes in each subgroup are shown in Table 6 and demonstrated in Figure 2.

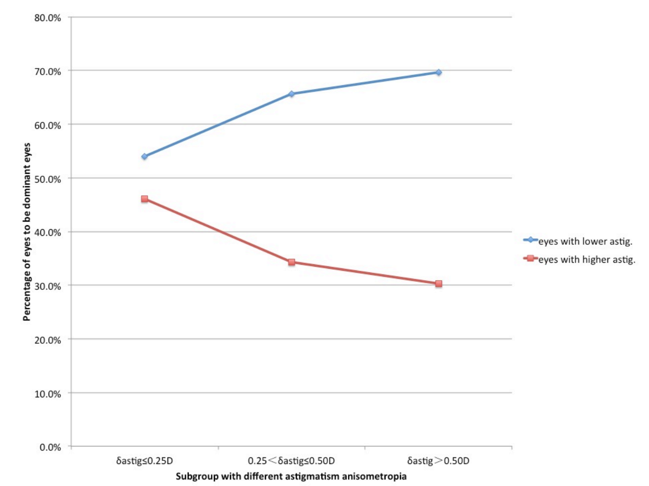

Figure 2: The percentage of the higher and the lower astigmatic eyes to be the dominant eyes in the different astigmatism anisometropia subgroups. In subgroups with the δastig>0.25 D, the lower astigmatic eyes were prone to be the dominant eyes.

In the subgroups with the astigmatic anisometropia>0.25 D, the eyes with lower astigmatism showed a stronger trend to be the dominant eyes than did the eyes with higher astigmatism.

Astigmatism anisometropia, D	Dominant eyes with lower astigmatism		Dominant eyes with higher astigmatism		χ^2	P#
	n	%	n	%		
≤ 0.25	89	53.94	76	46.06	0.659	0.417
0.26-0.50	65	65.66	34	34.34	7.429	0.006*
>0.50	46	69.70	20	30.30	5.328	0.021*

#Tested with Pearson Chi-Square test, *Significant at P ≤ 0.05

Table 6: Ocular dominance distributions in the different astigmatism anisometropia subgroups.

Discussion

As well as handedness, footedness, and the transposition arm, ocular dominance is one of the familiar lateral asymmetries of the human species. The ocular dominance columns in the primary visual cortex are the aggregation of neural cells with similar eye preference [4]. With functional magnetic resonance imaging (fMRI) techniques, Rombouts and colleagues demonstrated that the dominant eye activated a larger area and a higher signal of the primary visual cortex than the non-dominant eye [5,6]. These results provided the neuroanatomical basis for ocular dominance.

Currently, we know that development of ocular dominance involves two phases: the initial establishment phase before birth and a later plastic phase, corresponding to a critical stage [7]. The initial establishment phase relies on an innate molecular mechanism and endogenous retinal activities in the prenatal period before the onset of vision [8]. Subsequently, the visual input-dependent competition between the two eyes would promote the formation of the ocular dominance column in the primary visual cortex in a critical stage after birth [9].

We usually term the eye that corresponds to the ocular dominance columns in the visual cortex as the sensory dominant eye, and the sighting dominant eye indicates the eye that people prefer to use in unilateral ocular tasks or specific viewing conditions [10]. Di and colleagues found that the dominant eyes usually had better visual acuity in bilateral cataract patients. After cataract surgeries, the eyes with better visual acuity were usually prone to be the dominant eyes [11]. This fact indicates that the visual cortex tends to choose the eye with better retinal image clarity to be the dominant eye when there are different visual inputs between the two eyes. Thus, it can be observed that dominant eyes that are determined by the clinical ocular dominance tests in bilateral cataract patients usually reflect the information of the sighting dominant eye rather than sensory dominant eye. Therefore, objective methods and indexes need to be established to precisely predict the ocular dominance in bilateral cataract patients. In this study, we analyzed the association between ocular dominance and refractive errors in myopic subjects. The subjects with ocular abnormalities that might lead to different clarity of the retinal images between two eyes were excluded with hope that the results could as far as possible reliably reveal the distribution of sensory ocular dominance.

Although the manifestation of ocular dominance is different according to the different races, many previous studies have elucidated that the human species is predominantly right-eye dominated [12,13]. In this study, the right eye was the dominant eye in 66% of the subjects, while the other 34% of subjects were left-eye dominant, which was in accordance with former studies. Our study also found that ocular dominance had no association with gender.

The association between ocular dominance and refraction is a topic of controversy. Previously, ocular dominance was thought to be independent of refraction. Cheng et al. were the first to show that the dominant eyes, determined by the hole-in-the-card test, had a significantly higher myopic SE than the non-dominant eyes in anisometropic (>0.5 D) subjects [14]. The difference was more evident in those subjects with higher anisometropia (>1.75 D). Chia et al. found no significant effect of ocular dominance on the spherical equivalence in anisometropic myopic Singaporean children [15]. Qiu et al. revealed a significant association between higher ocular dominance prevalence and greater myopic refractive error. However, the strength of that association would attenuate with increases in anisometropia between two eyes. They considered that the clarity of the retinal images influenced the choice of dominant eye in individuals [16]. He et al. also found a significant correlation between the dominant eyes and lower diopters in hyperopic anisometropia subjects while there was no relationship between the dominant eyes and lower diopters in myopic patients [17]. On the contrary, Linke et al. showed that non-dominant eyes had higher myopic refractive error in an investigation of 10264 myopic subjects [13]. Our study enrolled 1,503 myopic subjects and found that dominant eyes had significant lower average myopic SE than did the non-dominant eyes. In subjects with anisometropia >0.5 D, there was a significant association between the dominant eye and lower myopic refractive error. This association was strengthened as the extent of anisometropia increased. Our results were in accordance with Linke's findings. We speculated that the different sample sizes and different study populations might account for the differences between the present study and those earlier studies.

Linke et al. found the non-dominant eyes usually had significantly higher astigmatism in subjects with astigmatic anisometropia >0.5 D [13]. Chia et al. also showed that the dominant eyes had lower astigmatism in Singaporean children [15]. The results of present study are in accordance with previous studies. In those subjects with myopic astigmatism in both eyes, the dominant eyes had lower astigmatism compared with the non-dominant eyes in subjects with the astigmatic anisometropia >0.25 D. The association was more evident as the astigmatic anisometropia increased. In subjects with unilateral astigmatism, the dominant eye was more likely to have lower astigmatism (57.51%) than higher astigmatism (42.49%), although the difference was not statistically significant. In general, the astigmatism was already in place by birth. We speculate that, compared with eyes with higher astigmatism, lower astigmatic eyes usually have better visual quality, which makes the eyes with lower astigmatism take over the dominance in the visual input-dependent competition during the critical stage. Thus, the eyes with lower astigmatism are always prone to be the dominant ones.

A previous study found that the dominant eye had a greater degree of myopia than the non-dominant eye in subjects with anisometropic myopia [14]. The possible explanation the author suggested was the accommodative response in the dominant eye was higher than in the non-dominant eye. The excessive accommodative response placed the dominant eye in a tonic state and reduced the capacity for accommodation. The blurred retinal images, as the result of the deterioration of the accommodative precision in the dominant eye, might play a primary role in the progression of myopia. The present study revealed that the myopic defocus in the dominant eye is lower than in the non-dominant eyes. From this point of view, we hypothesized that the dominant eye, which was established early in the initial phase and the critical stage, compared with the non-dominant eye, has a more precise accommodative response, more distinct visual input and less retinal image defocusing. Therefore, the dominant eye presents a smaller myopic shift during the following ocular development.

However, several limitations of this study should be considered. First, we only utilized the hole-in-the-card test to determine ocular dominance. We did not support our findings with a second method. There are several frequently used ocular dominance tests employed clinically, including the near-far alignment test, Worth 4-dot test, and the near convergence test among others. The optimum method for evaluating ocular dominance is still controversial. According to different techniques, Mapp and colleagues divided ocular dominance tests into three categories: sighting tests, sensory tests, and asymmetry in visual acuity or contrast sensitivity [18]. The hole-in-the-card test is the typical method used in sighting tests. Compared with the near convergence test, the former presents slightly higher prevalence for right ocular dominance. This might be due to the human species being predominantly right sided [19]. The Worth 4-dot test is one of the sensory-image-fusion tests. The results for ocular dominance determination is a little more different from other tests, as the results are extensively influenced by comprehension, color preference, inhibition in the visual cortex, image fusion response and defocusing on the retina of the individual subject [20]. Secondly, in this study, all subjects were examined with spectacle correction for refractive errors. The different spectacle magnification between the two eyes might influence the results of the ocular dominance tests, especially in those subjects with higher anisometropia. The interchange of ocular dominance between two eyes in some subjects after corneal refractive surgery might indicate that the different methods of refractive error correction could result in different results of ocular dominance tests [21]. Moreover, with a cross-sectional design, we could only hypothesize the association between ocular dominance and lower myopic refractive error in the dominant eye. We could not yet determine whether this association is a cause or a consequence of faster myopia progression in the non-dominant eyes. Further studies need to be designed to investigate the progression of myopia in the dominant eyes compared with that in the non-dominant eyes.

In conclusion, our study revealed that dominant eyes had lower myopic SE and lower astigmatic power than the non-dominant eyes in Chinese myopic refractive surgery candidates, especially in subjects with a higher amount of anisometropia. These findings could improve the accuracy of ocular dominance assessment in cataract patients rather than relying on clinical ocular dominance tests.

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