Original Article

The effects of experimentally induced graded monocular and binocular astigmatism on near stereoacuity

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Abstract

Purpose: To determine the effects of experimentally induced graded monocular and binocular astigmatism on near Stereoacuity in healthy adults.
Method: This prospective cross-sectional study was performed on 60 healthy adults ranging between 19 and 33 years of age recruited from College of Applied Medical Sciences. All subjects were emmetropic with normal binocular single vision, and stereoacuity of 40 sec of arc. Enrolled subjects were divided into four groups, each with 15 participants. Myopic astigmatism was induced in two groups, either monocularly or binocularly using +1.00 DC and +2.00 DC at different axes 45, 90 and 180. The remaining two groups were subjected to induced hypermetropic astigmatism using −1.00 DC and −2.00 DC at different axes 45, 90 and 180. The Titmus Fly Stereo Test was used to measure near stereoacuity both before and after induction of astigmatism.
Results: There was a reduction in stereoacuity with an increase in dioptric power of astigmatism ($p < 0.05$). In all groups, oblique astigmatism had the most significant effect followed by against the rule astigmatism and then with the rule astigmatism. Binocular induced hypermetropic astigmatism caused more reduction in stereoacuity than binocular induced myopic astigmatism, but statistically not significant. A similar impact was noted between monocular myopic astigmatism and monocular hyperopic astigmatism ($p = 0.037$), ($p = 0.049$) and ($p = 0.044$) with 2.00 D cylinder at 180, 90 and 45 axes, respectively.
Conclusion: The results indicate that the small amount of monocular or binocular astigmatism will affect on Stereoacuity, and the amount of reduction varies according to the axis of orientation.

Keywords: Stereopsis, Titmus, Astigmatism, Amblyopia, Anisometropia

Introduction

Stereoscopic vision is the unique phenomenon of binocular vision in humans where the eyes receive slightly disparate images due to being separated horizontally by about 6 cm. Then, the two slightly dissimilar images produced in both eyes are combined into a single image. There are three prime requirements for stereoscopic vision: a large binocular overlap of the visual fields, partial decussation of the afferent visual fibres and coordinated conjugate eye movements.[1]

Stereopsis can be influenced by several factors which are related to clinical testing conditions such as illumination, colour, and contrast. Moreover, stereoacuity is affected by refractive errors, anisometropia and binocular anomalies such as strabismus and amblyopia.[1,2]

Measurement of stereopsis is important in predicting the prognosis for successful treatment of certain binocular

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anomalies in which the better the stereoacuity means the better the prognosis. Furthermore, it is useful in the detection of certain neurologic conditions especially right posterior cerebral lesions. That is why the stereopsis is a crucial factor in the clinical evaluation of the vision of the patient.[3]

The difference between our study and the previous study that had done in 2016 by Kulkarni and his colleagues[4] is our study controlled the monocular cues by examining the stereothresholds of participants under monocular and binocular viewing conditions and compared to each other. Since the biggest fault in the Titmus fly stereo test is that under monocular viewing condition, subjects may pass the Wirt circles to set 4, stereoacuity level of 140 second of arc, indicating that monocular cues are present. Patients who reach a score greater than 140 sec of arc must use horizontal retinal disparity to perform the test.[5]

The purpose of this study was to investigate the effect of dioptric power and the orientation of the axis of monocular and binocular myopic and hyperopic astigmatism on the near stereoacuity.

Material and methods

This prospective cross-sectional study was performed on 60 healthy adults ranging between 19 and 33 years of age recruited from students and employees of various departments at the College of Applied Medical Sciences, King Saud University in Riyadh, Saudi Arabia from December 2016 to June 2017. Written informed consent was obtained from all enrolled subjects and the study was approved by Research Ethics Committee at the college of applied medical sciences. All subjects underwent several eye examinations and assessment including visual acuity using Snellen E letter acuity chart, objective and subjective refraction, Cover test and Worth4 dot to assess the binocularity, slit lamp biomicroscopic examination and fundus examination. Subjects with normal binocular single vision, emmetropic individuals (SE up to ±0.50 D) with Visual Acuity of 20/20 in both eyes, those with the stereoacuity of 40 sec of arc or better were included. Subjects who have strabismus, amblyopia, anisometropia, cataract or glaucoma were excluded from this study.

At 40 cm and under normal room lighting conditions, the baseline stereoacuity was measured for all participants using the Titmus stereo-test before inducing astigmatism. The participants were divided into four groups, each with 15 participants to produce either a binocular myopic astigmatism, binocular hypermetropic astigmatism, monocular myopic astigmatism or monocular hypermetropic astigmatism. Myopic astigmatism was induced in two groups, either monocularly or binocularly using +1.00 DC and +2.00 DC at different axes 45^0, 90^0 and 180^0. The remaining two groups were subjected to induced hypermetropic astigmatism either monocularly or binocularly using −1.00 DC and −2.00 DC at different axes 45^0, 90^0 and 180^0. Near stereoacuity was measured after 5 minutes of induction of astigmatism in all groups to avoid fatigue and allow the participants to adapt with the cylinder.

To compare the stereoacuity before and after inducing astigmatism paired samples t-test was used. One-way analysis of variance (ANOVA) was used to compare between groups and between the three different axes in each group. The probability values of less than 0.05 was considered statis-

tically significant. SPSS 22.0 was used for data analysis in this study.

Results

A total of sixty subjects with average age 21.07 ± 2.45 years were enrolled in the present study. Demographic characteristics of subjects demonstrated in Table 1.

In binocular induced hypermetropic astigmatism group, statistical analysis revealed a significant difference in Stereoacuity between baseline and the three axes (P < 0.002). The maximum effect of −1.00 D cylinder occurred with oblique astigmatism at 45^0 (51.13 ± 10.18) second of arc, followed by vertical astigmatism at 90^0 (44.67 ± 9.22) second of arc where the least effect occurred at 180^0 (36.47 ± 8.95) second of arc. The same findings were found with −2.00 D cylinder (Table 2).

Table 3 shows the similar findings were obtained in binocular induced myopic astigmatism with both +1.00 D cylinder and +2.00 D cylinder.

Fig. 1 illustrates that binocular induced hyperopic astigmatism caused more reduction in stereoacuity than binocular induced myopic astigmatism, but statistically not significant (P > 0.05).

In monocular induced hyperopic astigmatism with both −1.00 and −2.00 D cylinder, the P-values were equal zero and the most impact on mean Stereoacuity was found at 45^0 followed by 90^0 then at 180^0 axis (Table 4).

Similar results were obtained in monocular induced myopic astigmatism with both +1.00 and +2.00 D cylinder as shown in Table 5.

Monocular hyperopic astigmatism caused more reduction in stereoacuity than monocular myopic astigmatism. This deterioration increased with increasing the induced power (Fig. 2).

Based on the previous outcomes, monocular hyperopic and myopic astigmatism caused more deterioration of stereoacuity than binocular hyperopic and myopic astigmatism.

Discussion

Stereopsis is the highest grade of binocular single vision, it develops in early infancy between 3 and 5 months of age and the adult levels are not achieved until 9 years.[6,7] Wong BPH et al.,[8] have found that there is no significant difference between near and distant stereoacuity in young adults with normal binocularity. In the present study, only the near stereoacuity was tested.

The results of the present study indicated that the near stereoacuity decrease as the dioptric power of astigmatism increase due to the fact that astigmatism results in an image blur and a reduction in the visual acuity which results in dete-

Table 1. Demographic data for participants.

Subjects (n = 60)	Mean ± SD	Range
Age (year)	21.07 ± 2.45	19.00–33.00
Sphere power (DS)	−0.08 ± 0.31	−0.50–0.50
Cylinder power (DC)	−0.27 ± 0.18	−0.50–0.00
Spherical equivalent (D)	0.29 ± 0.20	−0.50–0.50
Uncorrected visual acuity (decimal)	1.00 ± 0.00	–

Table 2. Stereoacuity in binocularly induced hypermetropic astigmatism.

		Mean stereoacuity in BHA with −1.00 D cyl	p-value	Mean stereoacuity in BHA with −2.00 D cyl	p-value
Baseline (sec of arc)		29.8 ± 7.06	–	29.8 ± 7.06	–
Axis	180⁰	36.47 ± 8.95	0.002	47.73 ± 7.84	0.000
	90⁰	44.67 ± 9.22	0.000	57.20 ± 14.48	0.000
	45⁰	51.13 ± 10.18	0.000	69.80 ± 20.42	0.000

Table 3. Stereoacuity in binocularly induced myopic astigmatism.

		Mean stereoacuity in BMA with +1.00 D cyl	p-value	Mean stereoacuity in BMA with +2.00 D cyl	p-value
Baseline (sec of arc)		23.13 ± 5.80	–	23.13 ± 5.80	–
Axis	180⁰	30.07 ± 9.01	0.002	39.87 ± 6.30	0.000
	90⁰	36.07 ± 7.09	0.000	48.93 ± 10.29	0.000
	45⁰	45.40 ± 11.99	0.000	53.87 ± 8.41	0.000
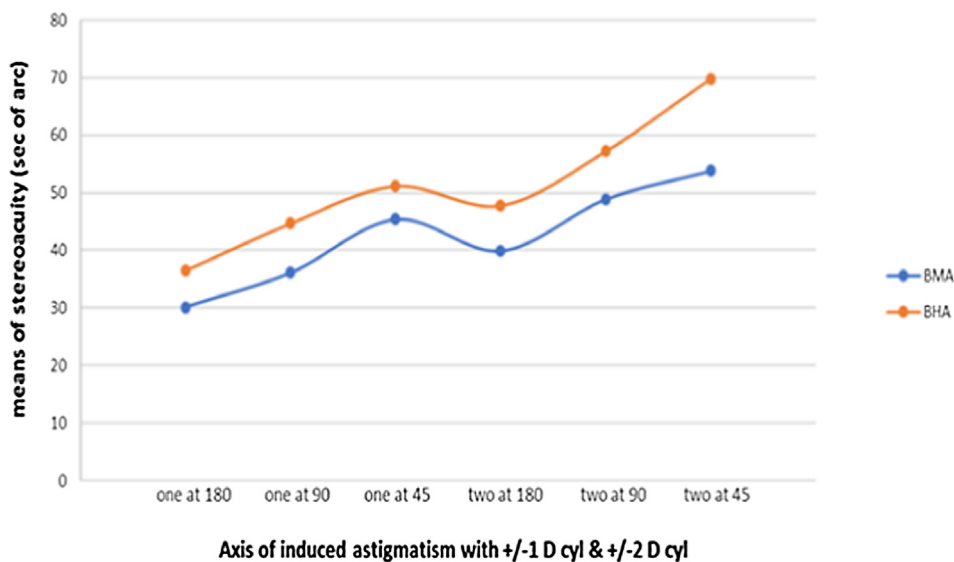
Fig. 1. Comparison between stereoacuity in Binocular Myopic Astigmatism (BMA) & Binocular Hyperopic Astigmatism (BHA).

Table 4. Stereoacuity in monocularly induced hyperopic astigmatism.

		Mean stereoacuity in MHA with −1.00 D cyl	p-value	Mean stereoacuity in MHA with −2.00 D cyl	p-value
Baseline (sec of arc)		22.93 ± 4.30	–	22.93 ± 4.30	–
Axis	180⁰	39.80 ± 9.55	0.000	56.53 ± 15.06	0.000
	90⁰	49.67 ± 10.49	0.000	76.80 ± 22.99	0.000
	45⁰	62.80 ± 20.39	0.000	112.60 ± 37.54	0.000

Table 5. Stereoacuity in monocularly induced myopic astigmatism.

		Mean stereoacuity in MMA with +1.00 D cyl	p-value	Mean stereoacuity in MMA with +2.00 D cyl	p-value
Baseline (sec of arc)		21.80 ± 3.49	–	21.80 ± 3.49	–
Axis	180⁰	36.53 ± 9.36	0.000	45.73 ± 11.29	0.000
	90⁰	45.67 ± 10.79	0.000	60.00 ± 18.78	0.000
	45⁰	50.13 ± 11.93	0.000	84.13 ± 37.79	0.000

rioration of stereoacuity.[4] Binocularly induced myopic astigmatism caused less reduction in the near stereoacuity than in binocularly induced hyperopic astigmatism may be due to the fact that the near vision is better in the myopic subjects than in the hyperopic. Dadeya et al.,[9] in 2001, they reported that binocularity deteriorated with increasing anisometropia but the binocular vision was affected more severely with spherical anisometropia than with astigmatic anisometropia.
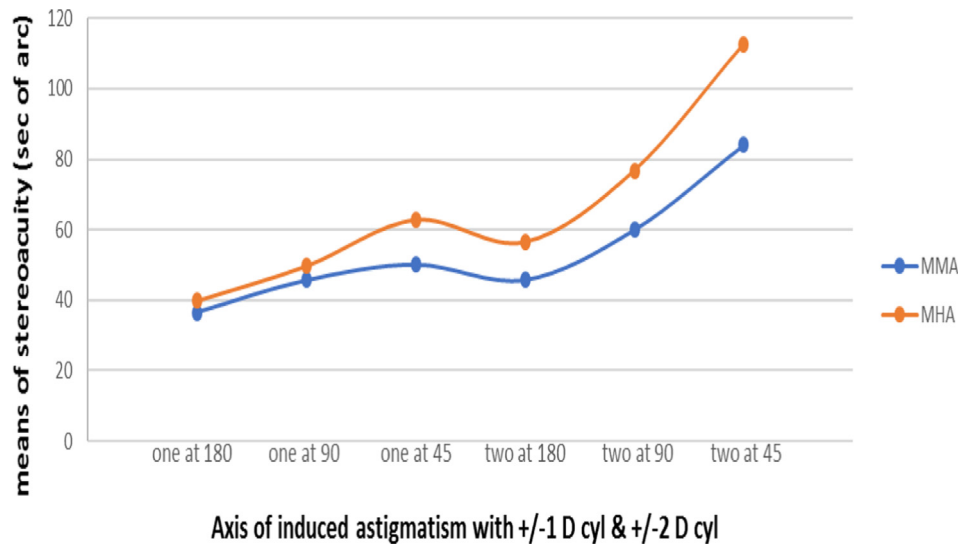
Fig. 2. Comparison between stereoacuity in Monocular Myopic Astigmatism (MMA) & Monocular Hyperopic Astigmatism (MHA).

This study agreed with one conducted by Oguz & Oguz,[10] in 2000. They studied the effects of experimentally induced anisometropia on stereopsis. They concluded that 1.00D of spherical anisometropia decreased the stereoacuity to an average 57–59 seconds of arc while 1.00D of cylindrical anisometropia decreased stereoacuity to an average 51–56 seconds of arc. Three dioptres of anisometropia, regardless of type, caused a marked reduction of stereoacuity in all subjects. In addition, this study also provided an explanation of why the maximum effect occurred with spherical anisometropia than cylindrical anisometropia which may be due to global blur caused by spherical lenses compared to meridional blur caused by astigmatic lenses. In the current study, the spherical amount of anisometropia was not considered as a part of the methodology.

Despite the type of astigmatism, the orientation of the axis of the astigmatism was also appeared to significantly affect the stereopsis. In the current study, we found that oblique astigmatism had the maximum effect followed by against the rule astigmatism (ATR) and then with the rule astigmatism (WTR). This effect can be explained by the fact that oblique astigmatism has more adversely affect on the visual acuity and visual performance than ATR astigmatism and WTR astigmatism.[11]

In 2005, Chen et al.[12] studied the effect of monocularly and binocularly induced astigmatic blur on depth discrimination is orientation dependent, and they have reported that stereoacuity and visual acuity degraded with increasing astigmatic blur. They also found that the deterioration in depth discrimination was based on the axis of astigmatism in which the maximum effect occurred with oblique astigmatism followed by ATR astigmatism while WTR astigmatism had the minimum effect ($p < 0.001$). Effect of monocularly and binocularly induced astigmatic blur on stereopsis was studied by Nakano and his colleagues,[13] in 2012. They found that in binocular and high power astigmatic induction, the stereopsis was affected more grossly by ATR astigmatism than WTR astigmatism ($p < 0.021$). Jethani et al.,[14] in 2015, they reported that the maximum reduction of stereopsis was at the oblique axis. Moreover, ATR astigmatism caused more reduction in stereopsis than WTR astigmatism. Their findings are consistent with our results, but the stereoacuity deterioration was gross in their research which may be due to the fact that some of their enrolled subjects had pre-existing refractive errors and consequently had differing baseline stereoacuities.

Limitation

The effects of experimentally induced astigmatism on near stereoacuity by using trial lenses might be different than the effect of natural corneal astigmatism. In addition, the amount and the axis of the astigmatism are not always the same in both eyes of every cases. Therefore, further investigation in these regards need to be done.

Conclusion

This study indicates that stereoacuity decrease with increase in dioptric power of astigmatism. Hypermetropic astigmatism degraded stereoacuity more than myopic astigmatism. Moreover, the stereoacuity is affected by the orientation of the axis which indicates that it is important to correct astigmatism in children as early as possible to prevent the incidence of amblyopia or any binocular abnormality and to make sure that the amount of astigmatism should be placed at the correct axis during the subjective refraction.

Conflict of interest

The authors declared that there is no conflict of interest.

Acknowledgements

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