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Original Article

Effect of induced astigmatism through cylindrical lenses on stereoacuity

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ABSTRACT

Objective: *This study was conducted to determine the effect of induced astigmatism through cylindrical lenses on stereoacuity.*

Methods: *This interventional pre-post study recruited 57 participants of either gender, between the ages of 7 and 40 years in Shalamar Hospital, Lahore, Pakistan. Only emmetropic participants arriving at the Eye Out-patient department of Shalamar Hospital were recruited. TNO test was used for quantification of stereoacuity. Astigmatism was experimentally induced using trail cylindrical lenses of power ±1.00, ±2.00 and ±3.00 Dcyl at the various axis (180°, 135° and 90°). TNO test was again used to measure the change in stereoacuity induced by these trail cylindrical lenses. Wilcoxon signed ranked test was used for the statistical analysis of the data.*

Results: *Mean baseline stereoacuity ± standard deviation was 61.05±7.947. The highest deterioration in stereoacuity was observed at 135°, followed by 90° and 180°. Higher the dioptric power, the more the deterioration of stereoacuity was observed ($p<0.05$). Experimentally induced binocular hypermetropic astigmatism deteriorated stereoacuity more than experimentally induced binocular myopic astigmatism.*

Conclusion: *This study suggests that stereoacuity significantly deteriorates when cylindrical lenses (especially lenses that induce hypermetropic astigmatism) are used. Axis of cylindrical lenses plays an important role in determining the severity of deterioration in stereoacuity.*

Keywords: *Astigmatism, Depth perception, Stereoacuity, Cylindrical lenses, TNO Test.*

1. INTRODUCTION

Astigmatism, first described by Thomas Young in the early 19th century, is a prevalent refractive error characterized by an irregular curvature of the cornea or lens.[1] This irregularity prevents light from converging into a single focal point on the retina, resulting in blurred or distorted vision.[2] Astigmatism can be classified into two primary types: regular and irregular. Regular astigmatism, which involves symmetrical refractive power changes across the principal meridians, can further be subdivided into with-the-rule (WTR), against-the-rule (ATR), and oblique (OBL) astigmatism. Irregular astigmatism, characterized by asymmetrical changes, poses greater challenges for correction.[3]

The prevalence of astigmatism varies globally, with studies indicating a significant percentage of the population affected. In Pakistan, for example, the crude prevalence is reported to be 18.1%.[4,5] Correction methods include spectacles, contact lenses, and refractive surgery, with cylindrical lenses commonly used to address regular astigmatism.[6] Interestingly, cylindrical lenses can also be employed to induce astigmatism temporarily in emmetropic (normal) eyes, facilitating research into its effects on various aspects of visual perception, such as stereoacuity.[7]

Stereoacuity, the ability to perceive depth based on the slight differences in images seen by each eye (binocular disparity), is essential for tasks requiring precise depth perception.[8] It represents the highest level of binocular single vision (BSV), which encompasses simultaneous perception, fusion, and stereopsis.[9] Factors such as anisometropia (unequal refractive power in the two eyes), amblyopia (reduced vision in one eye), and general refractive errors can significantly impact stereoacuity.[10] The ability to perceive depth accurately is not only critical for everyday activities but also for professional tasks requiring fine motor skills and precise visual discrimination.[11,12]

Research indicates that induced astigmatism, achieved through the use of cylindrical lenses, can provide valuable insights into how astigmatism affects stereoacuity.[13,14] This line of investigation is crucial because stereoacuity is vital for various activities, including driving, sports, and specific professional duties.[15,16] Moreover, poor stereoacuity can impact social interactions, as individuals may avoid activities requiring good depth perception, ultimately affecting their quality of life.[17]

This study aims to explore the effects of induced astigmatism on stereoacuity, shedding light on the relationship between refractive errors and depth perception. By examining these effects, we hope to enhance our understanding of visual processing and inform better strategies for managing and correcting astigmatism, thereby improving visual function and quality of life for those affected.

2. METHODOLOGY

The study was designed as a pre-post quasi-experimental study and was conducted at the Eye outpatient Department of Shalamar Hospital in Lahore, from January 1, 2021, to July 1, 2021. A total of 54 participants (108 eyes) were included, with the sample size calculated using GPower 3.1.9.7 software, considering a power of 0.80, an effect size of 0.1005038, and a significance level of $\alpha = 0.05$. To reduce confounding factors, 57 participants (114 eyes) were ultimately recruited.

Participants selected were 7-40 years with unaided monocular visual acuity of 6/6, while those with any ocular pathology were excluded. Detailed patient histories were taken to rule out systemic pathologies affecting visual acuity. A pen torch examination was performed to assess the anterior eye structures, and refraction was estimated using an auto-refractometer and refined with a Snellen's chart. A slit lamp examination ensured the exclusion of ocular pathologies.

The TNO test was used to assess baseline stereoacuity, followed by the intervention with cylindrical lenses of ±1.00, ±2.00, and ±3.00 diopters at axes of 180°, 135°, and 90°. The order of lens power and axis insertion was randomized, and adequate rest was given between interventions to prevent fatigue.

Data analysis was performed using SPSS version 20.0, with frequencies calculated for qualitative data such as gender, and means and standard deviations computed for quantitative variables such as age. The Wilcoxon Signed Rank test was used to compare quantitative variables, with a 5% level of significance applied to all statistical tests.

3. RESULTS

A total of 57 participants (37 males and 20 females) were recruited for this study, ranging in age from 7 to 40 years, with a mean age ± standard deviation of 25.42±8.515 years. The mean baseline stereoacuity ± standard deviation for experimentally induced binocular myopic and hypermetropic astigmatism was 61.05±7.947 seconds of arc, with a range from 480 to 60 seconds of arc. The Shapiro-Wilk test of normality was used to determine the normality of the data distribution, p-value was less than 0.05, indicating that the data significantly deviates from a normal distribution. Therefore, the Wilcoxon signed-rank test, a non-parametric test, was employed for statistical analysis.

Figure 1: Stereoacuity with experimentally induced binocular myopic astigmatism.

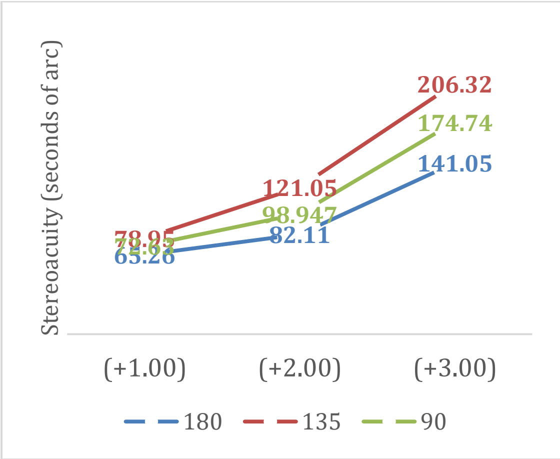

Figure 1 represents the mean stereoacuity with the increasing power of convex cylindrical lenses at a different axis. The highest mean deterioration of stereoacuity was observed at 135° followed by 90° and 180° respectively. In terms of power, the highest deterioration was seen with +3.00 DC, followed by +2.00DC and +1.00DC respectively.

Figure 2: Stereoacuity with experimentally induced binocular hypermetropic astigmatism.

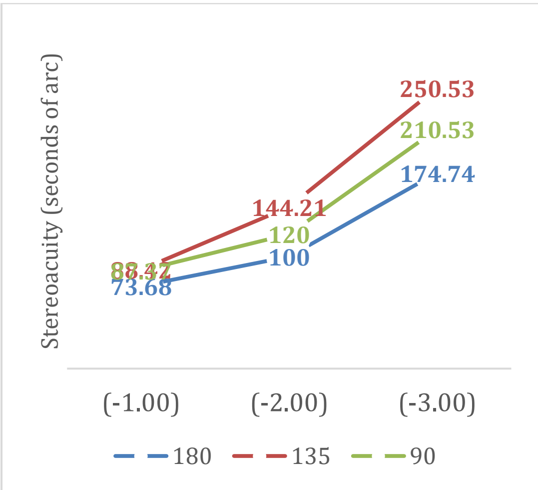

Figure 2 represents the mean stereoacuity with the increasing power of concave cylindrical lenses at different axis. The highest deterioration of stereoacuity was observed at 135° followed by 90° and

180° respectively. In terms of power, the highest deterioration was seen with -3.00 DC, followed by -2.00DC and -1.00DC respectively.

Figure-3: Comparison of deterioration in stereoacuity with experimentally induced myopic and hypermetropic astigmatism

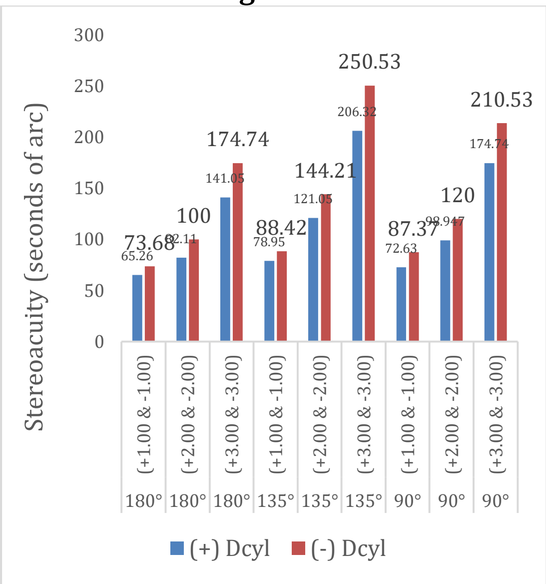

Figure 3 compares the deterioration of mean stereoacuity with convex (+) and concave (-) cylindrical lenses. Concave cylindrical lenses induced hypermetropic astigmatism whereas convex cylindrical lenses induced myopic astigmatism. Experimentally induced hypermetropic astigmatism deteriorated stereoacuity more than experimentally induced myopic astigmatism. For both types of astigmatism, the highest deterioration of stereoacuity is observed at 135° followed by 90° and 180° respectively. In terms of power, the highest deterioration is being observed at 3.00Dcyl followed by 2.00Dcyl and 1.00Dcyl respectively.

Table-1: Difference between baseline stereoacuity and experimentally induced binocular myopic astigmatism

	Difference	Mean ± SD	Sig. (2 Tailed)
	At 180		
1	(Baseline SA) – (+1.00 × 180°)	-4.211 ± 15.463	.044
2	(Baseline SA) – (+2.00 × 180°)	-21.053 ± 28.889	.000
3	(Baseline SA) – (+3.00 × 180°)	-80.000 ± 44.401	.000
	At 135°		
4	(Baseline SA) – (+1.00 × 135°)	-17.895 ± 27.693	.000
5	(Baseline SA) – (+2.00 × 135°)	-60.000 ± 56.695	.000
6	(Baseline SA) – (+3.00 × 135°)	-145.263 ± 63.079	.000
	At 90°		
7	(Baseline SA) – (+1.00 × 90°)	-11.579 ± 23.889	.001
8	(Baseline SA) – (+2.00 × 90°)	-37.947± 40.300	.000
9	(Baseline SA) – (+3.00 × 90°)	-113.684 ± 63.825	.000

Table 1 quantifies the deterioration in stereoacuity with experimentally induced hypermetropic astigmatism when subtracted from baseline stereoacuity. It shows the total degradation of stereoacuity with induction of convex cylindrical lenses. The degradation is statistically significant ($p<0.05$). The degradation is highest at 135° followed by 90° and 180°. Stereoacuity is maximally degraded with +3.00Dcyl, followed by +2.00Dcyl and +1.00Dcyl.

Table-2: Difference between baseline stereoacuity and experimentally induced binocular hypermetropic astigmatism

	Difference	Mean ± SD	Sig. (2 Tailed)
	At 180°		
1	(Baseline SA) – (-1.00 × 180°)	-12.632 ± 24.678	.000
2	(Baseline SA) – (-2.00 × 180°)	-38.947 ± 28.889	.000
3	(Baseline SA) – (-3.00 × 180°)	-113.684 ± 65.809	.000
	At 135°		
4	(Baseline SA) – (-1.00 × 135°)	-27.368 ± 30.150	.000
5	(Baseline SA) – (-2.00 × 135°)	-83.158 ± 68.743	.000
6	(Baseline SA) – (-3.00 × 135°)	-189.474 ± 81.601	.000
	At 90°		
7	(Baseline SA) – (-1.00 × 90°)	-26.316 ± 35.888	.000
8	(Baseline SA) – (-2.00 × 90°)	-58.947± 65.620	.000
9	(Baseline SA) – (-3.00 × 90°)	-149.48 ± 89.333	.000

Table 2 quantifies the deterioration in stereoacuity with experimentally induced myopic astigmatism when subtracted from baseline stereoacuity. It shows the total degradation of stereoacuity with induction of concave cylindrical lenses. The degradation is statistically significant ($p<0.05$). The degradation is highest at 135° followed by 90° and 180°. Stereoacuity is maximally degraded with -3.00Dcyl, followed by -2.00Dcyl and -1.00Dcl.

Table-3: Difference between experimentally induced myopic and hypermetropic astigmatism

	Difference	Mean ± SD	Sig. (2 Tailed)
	At 180°		
1	(+1.00 × 180°) – (-1.00 × 180°)	8.421 ± 26.443	.020
2	(+2.00 × 180°) – (-2.00 × 180°)	17.895 ± 37.547	.001
3	(+3.00 × 180°) – (-3.00 × 180°)	33.684 ± 82.562	.003
	At 135°		
4	(+1.00 × 135°) – (-1.00 × 135°)	9.474 ± 35.477	.049
5	(+2.00 × 135°) – (-2.00 × 135°)	23.158 ± 84.667	.044
6	(+3.00 × 135°) – (-3.00 × 135°)	44.211 ± 103.007	.002
	At 90°		
7	(+1.00 × 90°) – (-1.00 × 90°)	14.737 ± 42.850	.012
8	(+2.00 × 90°) – (-2.00 × 90°)	21.053 ± 71.256	.030
9	(+3.00 × 90°) – (-3.00 × 90°)	35.79 ± 114.232	.013

Table 3 quantifies the deterioration in stereoacuity with hypermetropic astigmatism when subtracted from myopic astigmatism. This shows that how much stereoacuity is degraded with experimentally induced hypermetropic astigmatism more than experimentally induced myopic astigmatism. The association is statistically significant ($p<0.05$) for all the values which suggest that the quantity by which experimentally induced hypermetropic astigmatism deteriorates stereoacuity more than experimentally induced myopic astigmatism is significant in nature.

Figure 4: Difference of stereoacuity between experimentally induced hypermetropic and myopic astigmatism.

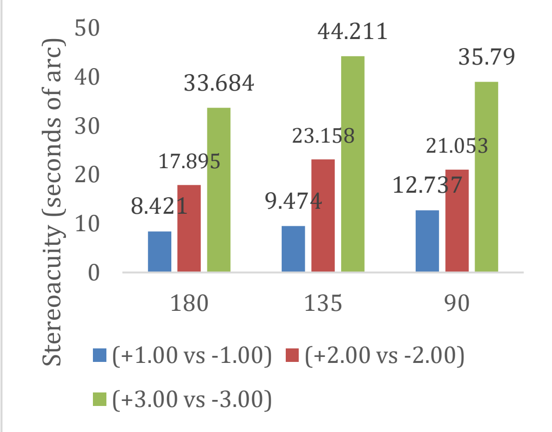

Figure 4 represents the deterioration in stereoacuity with hypermetropic astigmatism when subtracted from myopic astigmatism. The difference is greatest at 135° followed by 90° and 180°. More difference is observed by increasing the power of cylindrical lenses.

4. DISCUSSION

This study recruited 57 participants between the ages of 7-40 years (mean age: 25.421 years). After obtaining the consent from the participants who fell in the inclusion criteria, baseline stereoacuity (mean: 61.05 seconds of arc) of these participants using TNO Test was noted. Then myopic and hypermetropic astigmatism was experimentally induced using cylindrical lenses in both eyes. Deterioration in stereoacuity was noted. Astigmatism was induced at three axes i.e., 180°, 90° and 135°.

Bhavna Dhanji and Kavita (2019) reported the mean ± standard deviation of stereoacuities to be 28.03±4.97 with binocularly induced myopic astigmatism and 28.76±4.97 for induced hypermetropic astigmatism.[18] Similarly, Al-Qahtani and Al-Debasi (2018) had baseline stereoacuity of 29.8±7.06 for experimentally induced binocular hypermetropic astigmatism and 23.13±5.80 for experimentally induced binocular myopic astigmatism.[19] However, in this study mean baseline stereoacuity was 61.05±7.947. This change was due to two reasons. A) Bhavna Dhanji and Kavita (2019) and Al-Qahtani and Al-Debasi (2018) used Titmus Fly Stereo Test (which measured stereoacuities from 20 to 480 seconds of arc) whereas TNO test (which measured stereoacuities from 1980 to 60 seconds of arc) was used in this research. Baseline stereoacuity is higher with TNO test because it is based upon random dot stereograms and unlike other tests, monocular depth perception clues are absent in it. B) Difference in baseline stereoacuities between myopic and hypermetropic astigmatism was observed because these were induced in different groups whereas in this study both types of astigmatism were induced in same group of participants.[18,19]

Atchison et al. (2020) reported that stereoacuities were degraded most at the oblique axis (45°) followed by 90° and 180° respectively. His reports were consistent for binocularly and monocularly induced myopic and hypermetropic astigmatism. He further reported that binocularly induced hypermetropic astigmatism reduced stereoacuities more than binocularly induced myopic astigmatism. Similarly, in this study stereoacuities were maximally degraded at the oblique axis (135°) followed by 90° and 180° respectively.[20]

In this study, increasing the power of cylindrical lenses resulted in more deterioration of stereoacuity. These findings were consistent with Kulkarni et al. (2016) who also reported that higher the power of trail cylindrical lenses more the degradation of stereoacuity was observed.[21]

In this study, binocularly induced hypermetropic astigmatism degraded stereoacuity more than binocularly induced myopic astigmatism. These findings were consistent with and Bhavna Dhanji and Kavita (2019) who also reported that hypermetropic astigmatism deteriorates stereoacuity more than myopic astigmatism.[18]

In this study, the highest deterioration in experimentally induced hypermetropic astigmatism, when subtracted from experimentally induced myopic astigmatism, was observed when -3.00×135° Dcyl was subtracted from +3.00×135° Dcyl. Whereas, minimum deterioration was observed when -1.00×180° was subtracted from +1.00×180°. This was seen because stereoacuity deteriorated more at +3.00 Dcyl than -3.00Dcyl and the highest deterioration was present at 135° whereas the lowest was present at 180°.

Increasing the power of cylindrical lenses was indirectly proportional to stereoacuity because cylindrical lenses induce astigmatism which in return induces image blur and reduces visual acuity. An increasing amount of image blur and decreased visual acuity in return decreases stereoacuity. Therefore, the highest deterioration was observed with ±3.00Dcyl followed by ±2.00 and ±1.00Dcyl respectively.

The lowest deterioration in stereoacuity was seen at 180° probably because the vertical disparity is less affected when compared to the horizontal disparity. This is because vertical disparity represents the symmetry of our eyes whereas horizontal disparity represents the position of a particular object in space. More deterioration at 90° was seen probably due to the same above stated reason that horizontal disparity deteriorates stereoacuity more than vertical disparity. The highest deterioration was seen at 135° probably because the oblique axis involves horizontal and vertical disparity.

Higher deterioration with experimentally induced hypermetropic astigmatism may have been because near vision is relatively better in myopic patients than hypermetropic patients. Since the light rays from a near object are divergent in nature, therefore, are easier to focus on the retina in myopia as compared to hypermetropia unlike objects situated at far distance where the reflected light rays are parallel.

5. CONCLUSION

This study suggests that stereoacuity significantly deteriorates when cylindrical lenses (especially lenses that induce hypermetropic astigmatism) are used. Axis of cylindrical lenses plays an important role in determining the severity of deterioration in stereoacuity.

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