The Influence of Different Types of Induced Astigmatism on Visual Acuity

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ABSTRACT

PURPOSE: *The main purpose of this study is to find the effect of different types of induced Astigmatism on visual acuity on the basis of diopteric power, orientation of axes and minimum magnitude of cylinder that can affect and reduce the visual acuity by at least one line.*

MATERIALS AND METHODS: *A quasi-experimental study was conducted among emmetropic subjects. A total of 45 subjects presenting in Institute of Ophthalmology, Mayo Hospital Lahore were examined. Data was collected by using a self-designed proforma. After taking consent of the subjects, visual acuity was recorded using different diopteric powers of cylinder in different meridians on LogMar Chart. Then Astigmatism was induced by using different cylindrical defocus on the basis of different principal meridians and visual acuity re-taken.*

RESULTS: *The Analysis of Variance (ANOVA) showed significant relationship between visual acuity and induced astigmatism (p<0.05). It showed that when astigmatism was induced in accordance to simple myopic astigmatism , visual acuity was significantly affected in principal meridians at 0 and 135 axes (p<0.05) by minimum cylindrical power of +0.75D, while in meridians at 45 and 90 axes no significant changes were observed in visual acuity. Astigmatism was induced following simple hyperopic astigmatism and visual acuity was reduced in principal meridians at 90 and 135 axes (p<0.05) by minimum cylindrical power of -1.00D, while in meridians at 0 and 45 axes no significant changes were observed in visual acuity. In compound myopic astigmatism, visual acuity was reduced in principal meridian at 0 and 135 axes (p<0.05) by minimum cylindrical power of +0.75D taking spherical power as constant, while in meridians at 45 and 90 axes no significant changes were observed in visual acuity. By inducing the compound hyperopic astigmatism, the visual acuity was significantly reduced in principal meridians at 45, 90 and 135 axes (p<0.05) by minimum cylindrical power of -1.00D taking constant spherical power in each meridian, while in meridian at 0 axis no significant changes were observed in visual acuity. It showed that astigmatism was induced following mixed astigmatism, visual acuity was reduced in principal meridian at 90 axis(p<0.05) by minimum cylindrical power of +0.75D with constant power of sphere, while in meridians at 0,45 and 135 axes no significant changes were observed in visual acuity.*

CONCLUSION: *This cross-sectional study found that visual acuity was significantly reduced by inducing astigmatism on the basis of refractive power which was introduced in principal meridians i.e. 0, 45, 90 and 135 axes. The minimum cylindrical power was found out that could induce astigmatism and had significant effect on visual acuity. For each type of astigmatism which was included in this study, diopteric power of minimum cylinder was different and had different influence on the visual acuity in each meridian taken.*

KEYWORDS: *Visual Acuity, Induced Astigmatism, Minimum Cylindrical Power*

INTRODUCTION

Visual Acuity is the main visual function and is one of the standard parameters by which the result of most clinical trials is determined. Especially essential is the connection amongst visual acuity and the refractive condition of the eye.[1] However, the former is affected by different extrinsic parameters, such as the design of the optotype chart, its luminance and contrast, since these factors can affect the chart readability.[2,3]

Astigmatism is that form of refractive error wherein parallel rays of light from infinity passing through the optical media form two or more far lines rather than a point focus due to unequal refraction of light in different meridians. It results when one principal meridian of the corneal and/ or lenticular surface is flatter than the other or the radii of curvature of the two principal meridians are unequal. In regular astigmatism two principal meridians are perpendicular to each other.[4]

Contingent upon the position of the two images (far lines) in connection to the retina, regular astigmatism has been named simple, compound and mixed. In 'simple ' astigmatism, one meridian is emmetropic; hence, just a single far line is either in front (basic nearsighted) or behind (basic hypermetropic) the retina. In 'compound' astigmatism, both the far lines are either in front (compound myopic) or behind (compound hypermetropic) the retina. When one far line misses the mark regarding the retina and alternate falls behind the subsequent astigmatic error is called 'mixed'.[5,6]

Astigmatisms are commonly encountered refractive errors, which account for about 13% of refractive errors.[7] In adults, astigmatism greater than 0.5% is frequent, usual and ubiquitous, and the proportion enhances with age in people; 28% people are suffering in 40s and 38% in age of 80s.[8]

In different studies, in children aged 3-6 years, the percentage and amount of astigmatism is different. According to a report, in children the percentage of astigmatism of 1D or greater was 44% in 3-4 years old children in American population, 28.4% in US, 22% in Canada, 21% in Hong Kong, preschool children, 24.8% in Sydney, and 11.4% in Taiwan. Australian study had described the percentage of nearly 5% in individuals aged 6 years old.[8]

In UK more than 11,000 individuals are using eyeglasses. Among them almost 47.4% are suffering from astigmatism of 0.75D uniocularly, and 24.1 % individuals with binocular astigmatism of same amount. The proportion of myopic astigmatism is greater than the hyperopic astigmatism. Infants are more prone to the high proportion and high amount of astigmatism associated with corneal origin. It falls down in percentage and amount at the level of first few years of childhood from against the rule. In preschool children, the amplitude and prevalence is low while in infants the prevalence is greater.[9] Under some experimental conditions, essential parameter like subject's higher-order aberrations affect the visual acuity.[9,10]

It was reported in a study that the connection between spherical and astigmatic refractive errors and the visual acuity related to them was examined by two various methods. In first method, the normal subjects were induced with different refractive errors with the help of trial lenses. In second method, images which were defocused were simulated numerically with the help of optical transfer function of a standard model eye and then investigated by the identical subjects. The magnitude of defocus, which was needed to decrease the vision to 0.1 logMAR and to 0.4 logMAR was analysed with both of the methods and then the comparison between them was noticed. They proposed that the visual structure was obviously high tolerant to lens-induced defocus as compared to computer simulated method. Though, no major differences in visual acuity were caught for astigmatism of the equal power but different axes in both methods.[11]

METHODOLOGY:

Ethical clearance to conduct the study was obtained from College of Ophthalmology and Allied Vision Sciences, King Edward Medical University Lahore. A quasi-experimental study design was utilized. A total of 45 subjects presenting to Mayo Hospital Lahore were examined. The participants who were not willing, had a refractive error, had a history of any comorbid ocular condition or had a history of psychological disorders or of taking longterm psychiatric medications were excluded. A consent form in English & Urdu containing information related with purpose, significance and intended procedures of the research study was completed and signed by each participant. Data was collected by clinical examination and recorded the readings by self designed Proforma. This study involved the emmetrope subjects. After taking consent of the subject, visual acuity was recorded on LogMar chart by inducing the five types of astigmatism to that emmetrope on 0, 45, 90 and 135 meridians. And then visual acuity in all types of induced Astigmatism was re-taken.

Data were collected using SPSS Version 20 and were analyzed using non-parametric tests with a probability of $p < 0.05$ to evaluate the influence of different types of astigmatism on visual acuity. To maintain confidentiality the use of a code rather than the participant's name was employed.

RESULTS:

Table 01: Simple Myopic Astigmatism

	Frequency	Percent
+0.75 Cyl	40	88.9
+1.00 Cyl	5	11.1
Total	45	100.0

Table 02: Simple Hyperopic Astigmatism

	Frequency	Percent
-0.75 Cyl	5	11.1
-1.00 Cyl	35	77.8
-1.25 Cyl	5	11.1
Total	45	100.0

Table 03: Compound Myopic Astigmatism

	Frequency	Percent
+0.50 DS/+0.75 DC	40	88.9
+0.50 DS/ +1.00 DC	5	11.1
Total	45	100.0

Table 04: Descriptive Statistics of Compound Hyperopic Astigmatism

	Frequency	Percent
-0.50 DS/ -0.75 DC	5	11.1
-0.50 DS/ -1.00 DC	35	77.8
-0.50 DS/ -1.25 DC	5	11.1
Total	45	100.0

Table :05: Descriptive Statistics of Mixed Astigmatism

	Frequency	Percent
-0.50 DS/+0.75DC	30	66.7
-0.50 DS/ +1.00 DC	15	33.3
Total	45	100.0

Table 06: Correlation b/w Visual Acuity and Simple Myopic Astigmatism By ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
VA at 0 degree	Between Groups	13.611	1	13.611	33.444	.000
	Within Groups	17.500	43	.407		
	Total	31.111	44			
VA at 45 degree	Between Groups	5.625	1	5.625	2.867	.098
	Within Groups	84.375	43	1.962		
	Total	90.000	44			
VA at 90 degree	Between Groups	4.444	1	4.444	1.470	.232
	Within Groups	130.000	43	3.023		
	Total	134.444	44			
VA at 135 degree	Between Groups	33.611	1	33.611	21.412	.000
	Within Groups	67.500	43	1.570		
	Total	101.111	44			

Table 07: Correlation b/w Visual Acuity and Simple Hyperopic Astigmatism By ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
VA at 0 degree	Between Groups	.159	2	.079	.045	.956
	Within Groups	74.286	42	1.769		
	Total	74.444	44			
VA at 45 degree	Between Groups	2.540	2	1.270	.911	.410
	Within Groups	58.571	42	1.395		
	Total	61.111	44			
VA at 90 degree	Between Groups	24.444	2	12.222	12.833	.000
	Within Groups	40.000	42	.952		
	Total	64.444	44			
VA at 135 degree	Between Groups	43.968	2	21.984	13.752	.000
	Within Groups	67.143	42	1.599		
	Total	111.111	44			

Table 08: Correlation b/w Visual Acuity and Compound Myopic Astigmatism By ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
VA at 0 degree	Between Groups	13.611	1	13.611	6.689	.013
	Within Groups	87.500	43	2.035		
	Total	101.111	44			
VA at 45 degree	Between Groups	4.444	1	4.444	1.737	.194
	Within Groups	110.000	43	2.558		
	Total	114.444	44			
VA at 90 degree	Between Groups	5.625	1	5.625	3.252	.078
	Within Groups	74.375	43	1.730		
	Total	80.000	44			
VA at 135 degree	Between Groups	30.625	1	30.625	11.031	.002
	Within Groups	119.375	43	2.776		
	Total	150.000	44			

Table 09: Correlation b/w Visual Acuity and Compound Hyperopic Astigmatism By ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
VA at 0 degree	Between Groups	3.968	2	1.984	1.768	.183
	Within Groups	47.143	42	1.122		
	Total	51.111	44			
VA at 45 degree	Between Groups	11.429	2	5.714	3.500	.039
	Within Groups	68.571	42	1.633		
	Total	80.000	44			
VA at 90 degree	Between Groups	41.429	2	20.714	14.854	.000
	Within Groups	58.571	42	1.395		
	Total	100.000	44			
VA at 135 degree	Between Groups	71.429	2	35.714	15.217	.000
	Within Groups	98.571	42	2.347		
	Total	170.000	44			

Table 10: Correlation b/w Visual Acuity and Mixed Astigmatism By ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
VA at 0 degree	Between Groups	.000	1	.000	.000	1.000
	Within Groups	80.000	43	1.860		
	Total	80.000	44			
VA at 45 degree	Between Groups	1.111	1	1.111	.494	.486
	Within Groups	96.667	43	2.248		
	Total	97.778	44			
VA at 90 degree	Between Groups	27.778	1	27.778	12.798	.001
	Within Groups	93.333	43	2.171		
	Total	121.111	44			
VA at 135 degree	Between Groups	.000	1	.000	.000	1.000
	Within Groups	80.000	43	1.860		
	Total	80.000	44			

Tables 1 to 5 shows the minimum cylinder of dioptric power +0.75,-1.00, +0.75DC (Sph=constant), -1.00DC (Sph=constant) and +0.75DC (Sph=constant), induced astigmatism in maximum number of subjects respectively.

Table 6 shows that astigmatism was induced influencing visual acuity in principal meridians at 0 and 135 axes ($p<0.05$), while in meridians at 45 and 90 axes no significant changes were observed in visual acuity.

Table 7 shows that astigmatism was induced influencing visual acuity in principal meridians at 90 and 135 axes ($p<0.05$), while in meridians at 0 and 45 axes no significant changes were observed in visual acuity.

Table 8 shows that astigmatism was induced influencing visual acuity in principal meridian at 0 and 135 axes ($p<0.05$), while in meridians at 45 and 90 axes no significant changes were observed in visual acuity.

This table shows that astigmatism was induced influencing visual acuity in principal meridians at 45,90 and 135 axes ($p<0.05$), while in meridian at 0 axis no significant changes is observed in visual acuity.

This table shows that astigmatism was induced influencing in principal meridian at 90 axis ($p<0.05$), while in meridians at 0, 45 and 135 axes no significant changes were observed in visual acuity.

DISCUSSION:

This cross-sectional study was carried out in an outpatient department and involved emmetropic subjects of different age groups. This study found that visual acuity was significantly reduced by inducing astigmatism on the basis of refractive power which was introduced in principal meridians i.e. 0, 45, 90 and 135 axex. The minimum cylindrical power was found out that induce astigmatism and had significant effect on visual acuity. For each type of astigmatism which was included in this study, dioptric power of minimum cylinder was different and had differently influence the visual acuity in each meridian taken.

The Analysis of Variance (ANOVA) showed significant relationship between visual acuity and induced astigmatism ($p<0.05$). It showed that when astigmatism was induced in accordance to simple myopic astigmatism , visual acuity was significantly affected in principal meridians at 0 and 135 axes ($p<0.05$) by minimum cylindrical power of +0.75D, while in meridians at 45 and 90 axes no significant changes is observed in visual acuity. Astigmatism was induced following simple hyperopic astigmatism and visual acuity was reduced in principal meridians at 90 and 135 axes ($p<0.05$) by minimum cylindrical power of -1.00D, while in meridians at 0 and 45 axes no significant changes were observed in visual acuity. In compound myopic astigmatism, visual acuity was reduced in principal meridian at 0 and 135 axes ($p<0.05$) by minimum cylindrical power of +0.75D taking spherical power as constant, while in meridians at 45 and 90 axes no significant changes were observed in visual acuity. By inducing the compound hyperopic astigmatism, the visual acuity was significantly reduced in principal meridians at 45, 90 and 135 axes ($p<0.05$) by minimum cylindrical power of -1.00D taking constant spherical power in each meridian, while in meridian at 0 axis no significant changes were observed in visual acuity. It showed that astigmatism was induced following mixed astigmatism, visual acuity was reduced in principal meridian at 90 axis($p<0.05$) by minimum cylindrical power of +0.75D with constant power of sphere, while in meridians at 0,45 and 135 axes no significant changes were observed in visual acuity.

It was proposed that influence of astigmatism on Visual acuity was significantly reliant on the orientation of the induced astigmatism, even in subjects who were non-astigmats. Earlier experience to astigmatism contributed a major role on Visual acuity, had a powerful bias in the direction of the natural axis. In contrary to apparent isotropy, the correction of astigmatic refractive error did not change the bias in Visual acuity from natural axis of astigmatic refractive error.[12]

Remon et al. studied the visual acuity in Simple myopic Astigmatism and they recorded the visual acuity on different meridians. In this study, they investigated the distance VA in emmetropes having 20 years age. Four subjects were taken in this study with the following corrections: E1: _0.50/_0.50 _ 180°; E2: _0.75/ _0.50 _ 10°; E3: _0.50/0.00; and E4: 0.00/_0.50 _ 90° with which the visual acuity was 20/20 or better. Simple Myopic Astigmatism having diopteric powers ranging from 0.00 D to -3.00 D, with the gradual increase of -0.25 D, were applied on the correction in all the subject eyes using in all cases a positive sphere and a minus cylinder having the same powers. In all cases, five axes were taken to measure: 0°, 30°, 45°, 60°, and 90°.[13]

They proposed that when accommodation is relaxed, the influence of the cylinder axis has less significance than other clinical variables such as the preferred VA chart. Furthermore, the equal power and axis in astigmatism which was induced in different eyes astigmatic error (same power and axis) induced in different eyes gave a large amount of variations in visual acuity in comparison of those provided by astigmatic error of equal powers but different axes which were induced in the same subject eye.[13]

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