ORIGINAL ARTICLE

Comparison of Aberrations in Corneal Topography Between Young Adults with More Than 1 Diopter Versus Less Than 1 Diopter Astigmatism

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Abstract:

Objectives: To evaluate the impact of anterior segment parameters and high-order and Low-Order aberrations on visual quality in young adults with different astigmatism levels using corneal topography.

Methods: The research was approved by the Ethical Review Board of the College of Ophthalmology and Allied Vision Sciences, Mayo Hospital (Ref # 1620/2023). The study was conducted on patients visiting Mayo Hospital, Lahore, with a sampling size of 74 eyes (34 in each group). Patients with > ± 1D astigmatism (study group) and < ± 1D astigmatism (control group) were recruited. Corneal astigmatism, keratoconus indices, keratometry findings, anterior segment parameters, high-order aberrations, and low-order aberrations were assessed and compared between groups. These parameters were measured using Sirius corneal Topography. All dependent and independent variables were considered. Data were entered and analyzed using SPSS 27.0. A P value ≤ 0.05 was considered significant.

Results: Thirty-seven eyes of 37 young adults and 37 eyes of 37 children were analyzed. The mean astigmatism was -2.3776 ± 2.25034 and -0.3878 ± 0.29369, respectively. Total corneal astigmatism was -3.03 ± 1.73 and -0.44 ± 0.25 diopters. Significant differences were seen in keratoconus-indices, mean corneal-thickness, high-order-aberrations (HOAs) and low-order-aberrations (LOAs), and visual quality were observed between the groups between.

Conclusion: Young adults with ± 1D astigmatism showed higher corneal astigmatism, thinner mean CT, and increased keratoconus indices, with higher HOAs and LOAs. *Al-Shifa Journal of Ophthalmology 2025; 21(1): 43-49. © Al-Shifa Trust Eye Hospital, Rawalpindi, Pakistan.*

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Introduction:

Optometrists and ophthalmologists must analyze corneal topography, anterior segment, aberrations, and astigmatisms to improve visual quality, as refractive errors can affect Visual acuity due to complex optical system defects[1]. Astigmatism is a refractive error that has a significant impact on the eye's optical characteristics[2]. Past studies have looked at the anterior region, corneal topography, and higher-order aberrations (HOAs) in children who have astigmatism > 2D [3]. Corneal topography is a non-invasive technique used to measure the shape and curvature of the cornea, crucial for refractive surgery and contact lens fitting, to assess visual perception. Visual quality includes not only sharpness but also sensitivity to contrast, an impression of depth, and the perceptual experience as a whole [4]. The ability of the eye to concentrate light onto the retina is crucial to the sharpness of human vision. However, there are a number of factors that may affect the eyes optical skills, leading to distorted or blurred vision. Scheimpflug imaging, ultrasonic biomicroscopy, slit-lamp biomicroscopy, and anterior segment optical coherence tomography are all methods that fall under the umbrella of anterior segment imaging. Scheimpflug imaging is a corneal topography technique that uses a spinning camera to measure anterior segment parameters like central corneal thickness, anterior chamber depth, white-to-white distance, and pupil size. These factors are vital for several eye diagnoses, including glaucoma, cataracts, keratoconus, and the probability of angle closure, as well as for selecting the best intraocular lens implant and deciding if refractive surgery is necessary[5]. Astigmatism is a refractive error that occurs when the cornea or the lens has an irregular shape that causes light rays to focus at different points on the retina. Astigmatism, a condition affecting the corneal topography, anterior segment, and HOAs, can cause blurred vision, eye strain, headaches, and reduced contrast sensitivity in individuals of all ages. The uneven shape of the cornea causes corneal astigmatism, the irregular shape of the lens causes lenticular astigmatism, and a blend of the two causes mixed astigmatism [6]. The optical quality of the eye is also affected by the presence of aberrations, which are deviations from the ideal wavefront of light that passes through the eye [7]. Corneal topography assesses complex aberrations and affects visual quality. Poor illumination leads to worsening vision, causing symptoms like gloss, halos, starbursts, diplopia, and diminished contrast sensitivity.[7] Corneal abnormalities, trauma, illness, or surgery cause higher-order aberrations, while most visual impairments are low-order aberrations caused by uneven corneal curvature, which are easily corrected with corrective lenses.[8] Aberrometers are instruments that measure high-order and low-order aberrations by capturing and analyzing the form and abnormalities of the eye's optical system using wavefront technology.[9] Wave front technology focuses on the unique three-dimensional shape of a uniform wave front of light, governed by eye optical properties and Zernike polynomials. High-order aberrations (HOAs) are subtle optical system aberrations that affect vision clarity and accuracy. They can cause vision impairments like diminished contrast perception, double vision, halos, starbursts, excessive glare, and blurred vision.[10] Myopia, hyperopia, and astigmatism are examples of low-order aberrations (LOAs) that may coexist alongside higher-order aberrations (HOAs). Despite extensive research on corneal topography and refractive errors, prior studies have predominantly focused on children or individuals with high degrees of astigmatism (>2D), leaving a gap in understanding how moderate astigmatism (> ±1D) affects anterior segment characteristics and optical aberrations in young adults. Furthermore, while studies have examined high-order aberrations (HOAs) in various refractive conditions, their direct impact on visual quality, particularly in individuals with mild to moderate astigmatism, remains underexplored. Additionally, most previous research has not sufficiently addressed whether habitual spectacle prescription significantly improves visual quality in such cases. This study fills this gap by providing a detailed comparative analysis of anterior segment parameters, HOAs, and LOAs in young adults with different astigmatism levels, contributing to a more comprehensive understanding of their clinical implications.

Methodology:

The study was approved by the Ethical Review Board of the College of Ophthalmology and Allied Vision Sciences, Mayo Hospital (Ref # 1620/2023). The study was conducted on patients visiting Mayo Hospital, Lahore, Sample size was calculated using a formula with a significance level (α) taken as 5%. Power of the study was (1-β): 80%. A sample size of 74, with 34 patients in each group was taken. with astigmatism > ± 1D (study group) and < ± 1D astigmatism (control group) were recruited.[3] Corneal astigmatism, keratoconus indices, keratometry findings, anterior segment parameters, high-order aberrations, and low-order aberrations were assessed and compared between groups. These parameters were measured using , Sirius Corneal Topography. All dependent and independent variables were considered. Data were entered and analyzed using SPSS 27.0. A P value < 0.05 was considered significant. The exclusion criteria include corneal scars, epithelial healing issues, previous ocular infections, pregnancy/breathing, previous corneal surgery/cross-linking, and other ocular diseases affecting corneal shape or quality.

Results:

A total of 37 young adults participated in the study group and 37 in the control group, with each group having 37 eyes. The mean astigmatism was -2.3776 ± 2.25034 and -0.3878 ± .29369 in the study and control groups, respectively (p < 0.05). The study found that corneal astigmatism was -3.03 ± 1.73 diopters in study group and -.44 ±.25 diopters in the control groups This difference was statistically significant (p < 0.05).

There was a notable disparity among the groups in the keratoconus indices, namely Sif (symmetry index front) in Diopters SIB (Symmetry Index Back) in Diopters, KVF (keratoconus vertex front) in Microns, KVB (keratoconus vertex back) in Microns, Bcvb (Baiocchi Colossi Versaci Back) in Diopters, BCVF (Baiocchi Colossi Versaci Front) in Diopters and Sim-k (simulated keratometry) in Diopters. When considering anterior segment factors, the average corneal thickness (CT) varied significantly between the groups. The data analysis was performed using SPSS 27.0 with a significance level set at p ≤ 0.05. Independent Samples t-test – To compare the means of continuous variables.

Data analysis was conducted using SPSS 27.0, with a significance level of p ≤ 0.05. Independent Samples t-tests were performed to compare the means of continuous variables across Tables 1, 2, and 3. Additionally, a Chi-square test was used for categorical data presented in Table 4.

Table 1: Keratometry values and Keratoconus indices

Keratometry Values and Keratoconus Indices				
		Mean	Standard Deviation	p-Value
Symmetry index front (Diopters)	Study Group	2.37	5.01	.008
	Control Group	.11	.40	
Symmetry index back (Diopters)	Study Group	.59	1.19	.002
	Control Group	-.02	.11	
Keratoconus vertex front (Microns)	Study Group	19.48	19.52	<.001
	Control Group	3.37	.92	
Keratoconus vertex back ((Microns)	Study Group	42.59	43.74	<.001
	Control Group	12.48	3.70	
Baiocchi colossi versaci front (Diopters)	Study Group	1.66	2.26	<.001
	Control Group	.15	.13	
Baiocchi colossi versaci back (Diopters)	Study Group	1.54	2.24	
	Control Group	.07	.13	<.001
Simulated keratometry (Diopters)	Study Group	46.07	3.80	<.001
	Control Group	43.87	1.10	

Table 2: Anterior Segment Parameters

ANTERIOR CHAMBER PARAMETERS				
		Mean	Standard Deviation	p-Value
Anterior Chamber Depth (mm)	Study Group	3.22	.34	.692
	Control Group	3.19	.26	
Pupil Diameter (mm)	Study Group	.26	.12	.025
	Control Group	.20	.10	
Anterior Chamber Width (mm)	Study Group	12.42	1.05	.007
	Control Group	11.90	.44	
Anterior Chamber Angle (Degree)	Study Group	42.70	6.02	.78
	Control Group	44.94	4.66	
Central Corneal Thickness (mm)	Study Group	.47	.07	<.001
	Control Group	.53	.02	
White-To-White Distance (mm)	Study Group	12.19	.34	.325
	Control Group	12.12	.27	
Corneal Astigmatism (Diopters)	Study Group	-3.03	1.73	<.001
	Control Group	-.44	.25	
Corneal Astigmatism Axis (Degree)	Study Group	94.62	72.60	.894
	Control Group	96.75	64.15	
Anterior Chamber Depth (mm)	Study Group	3.22	.34	.692
	Control Group	3.19	.26	

Table 3: Mean, SD and P value of High-Order Aberrations (HOAs)

Higher-Order Aberrations Parameters				
		Mean	Standard-Deviation	p-Value
RMS High-orderAberrations (microns)	Study Group	0.9335	0.96684	<0.01
	Control Group	0.2405	0.06240	
Comma Aberrations (microns)	Study Group	0.7270	0.92374	<0.01
	Control Group	0.1354	0.05743	
Spherical Aberrations (microns)	Study Group	0.1535	0.13730	0.59
	Control Group	0.1327	0.10057	
Residual Aberrations (microns)	Study Group	0.4665	0.40640	<0.01
	Control Group	0.1511	0.5924	

Table 4: Visual Quality Assessment

Visual Quality Assessment								
		Not at all Satisfied	Rarely Satisfied	Sometimes satisfied	Often satisfied	Extremely Satisfied	Total	p-Value
Clarity of Vision	Study Group	08	10	08	06	05	37	<0.001
	Control Group	06	07	02	05	17	37	
Colour Perception	Study Group	00	07	11	13	06	37	<0.001
	Control Group	00	07	00	05	25	37	
Overall Visual Comfort	Study Group	00	07	08	05	17	37	<0.001
	Control Group	00	07	04	08	17	37	

Discussion:

A comparative cross-sectional study was conducted to assess keratometry values, keratoconus indices, high-order aberrations, low-order aberrations, and quality of vision in individuals with >1D astigmatism and emmetropes or those with <1D astigmatism. The study included 74 eyes that were divided into two groups: the study and control groups. The study group had a mean SIf of 2.37, whereas the control group had a mean KVb of 19.42. The study group also had a mean BCVb of 1.66 and a mean SimK of 46.07. The study also evaluated anterior chamber parameters, such as the anterior chamber depth, pupil diameter, anterior chamber width, anterior chamber angle, central corneal thickness, white-to-white distance, corneal astigmatism, and Corneal Astigmatism Axis. [11]

The study found that the anterior chamber in hyperopes is shallower than that in myopes and hyperopes.[12 13]The study group had a mean Corneal Astigmatism Axis of 94.62 and for control group it was 96.75. The study also found that myopic astigmatism had more negative Y-trefoil and positive vertical coma, along with more oblate nasal and temporal corneal morphologies.[14, 15] High-order aberrations were found to be associated with all types of refractive errors, with a notable increase in spherical aberration in the hypermetropia group.[16] The cornea-induced high-order aberration is limited in normal corneas and regular refractive errors.[12, 17]

This study aimed to assess the quality of vision in young adults aged 18-35. The participants were categorized into two distinct groups: the study and control groups. Among the 74 participants, 38 were men and 36 women. The study population consisted of 21 males and 16 females. The control group consisted of 17 males and 20 females. The age cohort consisted of individuals aged 18–35 years.

The study group had a higher frequency of blurriness than the control group, with 5 individuals experiencing blurriness persistently. The control group consisted of 36 participants: most reported, occasional impaired vision and only one reported persistent hazy vision. The study group had a higher frequency of both diplopia and ocular fatigue than the control group.[18]

High-order aberrations were assessed and compared between the two groups, with astigmatism linked to high-order aberrations.[12] The study group experienced

halos more often, whereas the control group never experienced them.[19, 20] The low-order aberrations were also evaluated, with 33 participants experiencing blurriness more often than the control group.[21] The study group had more difficulty with focusing and distortions in peripheral vision, whereas the control group had less difficulty.[22]
The quality of vision was also assessed; among the participants in the study group, eight were dissatisfied with their vision acuity, ten were occasionally dissatisfied, eight were occasionally satisfied, six were frequently satisfied, and five were always satisfied.[23]

Conclusion:

Young adults with ± 1D astigmatism showed higher corneal astigmatism, thinner mean CT, and increased keratoconus indices, with higher High-order aberrations (HOAs) and low-order aberrations (LOAs).

References:

1. Verhoeven VJ, Wong KT, Buitendijk GH, Hofman A, Vingerling JR, Klaver CC. Visual consequences of refractive errors in the general population. Ophthalmology. 2015;122(1):101-9. DOI: 10.1016/j.ophtha.2014.07.030
2. Wang L-L, Wang W, Han X-T, He M-G. Influence of severity and type of astigmatism on visual acuity in school-aged children in southern China. Int J Ophthalmol 2018;11(8):1377-80. DOI: 10.18240/ijo.2018.08.20
3. Çakır B, Aksoy NÖ, Özmen S, Bursalı Ö, Çelik E, Horozoğlu F. Corneal topography, anterior segment, andhigh-order aberration assessment in children with≥ 2 diopter astigmatism. Int J Ophthalmol 2020;40:1461-7. DOI: 10.1007/s10792-020-01313-8
4. Suliman A, Rubin A. A review of higher order aberrations of the human eye. African Vision and Eye Health. 2019;78(1):8-10. Available from https://doi.org/10.4102/aveh.v78i1.501
5. Martin R. Cornea and anterior eye assessment using placido-disc keratoscopy, slit-scanningevaluation topography and scheimpflug imaging tomography. Indian J Ophthalmol. 2018;66(3):360-5. DOI: 10.4103/ijo. IJO_850_17
6. Ueno Y, Nomura R, Hiraoka T, Kinoshita K, Ohara M, Oshika T. Comparison of corneal irregular astigmatism by the type of corneal regular astigmatism. Sci Rep. 2021;11(1):15769-772. DOI: 10.1038/s41598-021-95358-z
7. McLellan JS, Prieto P, Marcos S, Burns SA. Effects of wave- aberration interactions on optical image quality. Vision Res. 2006;46(18):3009-16. DOI: 10.1016/j.visres.2006.03.005
8. Yu X, Dong L, Lai B, Yang P, Liu Y, Kong Q et al. Automatic low-order aberration correction using geometrical optics for slab lasers. Appl Opt 2017;56(6):1730-9. DOI: 10.1364/AO.56.001730
9. Maeda North Clinical applications of wavefront aberrometry–a review. Exp Ophthalmol. 2009;37(1):118-29. DOI: 10.1111/j.1442-9071.2009.02005.x
10. Fernandez de Castro LE, Sandoval HP, Bartholomew LR, Vroman DT, Solomon KD. High-order aberrations and preoperative associated factors. Acta Ophthalmol Scand. 2007;85(1):106-10. DOI: 10.1111/j.1600-0420.2006.00757.x
11. Mirzajani A, Vishteh RA, Masroor R. Analysis of Anterior Segment Parameters and Wavefront Aberrations of the Myopic Eyes Using Two Scheimpflug-based devices: Pentacam vs Sirius. 2021. Available from https://doi.org/10.21203/rs.3.rs-298563/v1
12. Hughes RP, Vincent SJ, Read SA, Collins MJ. High order aberrations, refractive error development, and myopia control: a review. Clin Exp Optom. 2020;103(1):68-85. DOI: 10.1111/cxo.1296

13. Sun J. Refractive status in patients with age-related cataract and shallow anterior chamber after phacoemulsification. International Eye Science. 2020:1775-9.
14. Shen L, Wei C, Yang W, Xiong Y, Li Y, Li D et al. Analysis of the relationship between lens morphology and aberrations in patients with myopia: a cross-sectional study. Int Ophthalmol. 2023:1-9. DOI: 10.1007/s10792-023-02894-w
15. Lee DC. Analysis of real corneal astigmatism and changes in high-order aberration that cause visual disturbance after lower eyelid epiblepharon repair surgery. Sci Rep. 2020;10(1):7498. DOI: 10.1038/s41598-020-64386-6
16. Salman A, Kailani O, Ghabra M, Omran R, Darwish TR, Shaaban R et al. Corneal higher-order aberrations by Sirius topography and their relation to different refractive errors. BMC Ophthalmo. 2023;23(1):104. DOI: 10.1186/s12886-023-02841-4
17. Anbar M, Mohamed Mostafa E, Elhawary AM, Awny I, Farouk MM, Mounir A. Evaluation of Higher-Order Corneal Aberrations by Scheimpflug-Placido Topography in Patients with Different Refractive Errors: A Retrospective Observational Study. J Ophthalmol. 2019;2019:5640356. DOI: 10.1155/2019/5640356
18. Martins C, Amorim-De-Sousa A, Faria-Ribeiro M, Paune J, Gonzalez-Meijome JM, Queiros A. Visual Performance and High-order Aberrations of Contact Lens Prototypes with Potential for Myopia Control Curr Eye Res. 2020;45(1):24-30. DOI: 10.1080/02713683.2019.1645182
19. Liu Y., Pang C., Ming S., Fan Q. Effects of deepening myopia and astigmatism on the corneal biomechanical parameter stress-strain index in individuals of Chinese ethnicity. Front Bioeng Biotechnol. 2022;10:1018653. DOI: 10.3389/fbioe.2022.1018653
20. Chang, C. F., Cheng, C. H. Effect of Orthokeratology Lens Design on Contrast Sensitivity Function and High-Order Aberrations in Children and Adults. Eye Contact Lens. 2020;46(6):375-80. DOI: 10.1097/ICL.0000000000000667
21. Cufflin, MP; Mallen, EA. Blur adaptation: clinical and refractive considerations. Clin Exp Optom. 2020;103(1):104-11. DOI: 10.1111/cxo.13033
22. Swiatczak B, Schaeffel F. Emmetropic, but not myopic, human eyes distinguish positive defocus from calculated blur. Invest Ophthalmol Vis Sci. 2021;62(3):14. DOI: 10.1167/iovs.62.3.14
23. Goldstein JE, Bradley C, Gross AL, Jackson M, Bressler N, Massof RW. NEI VFQ-25C: calibrating items in the National Eye Institute Visual Function Questionnaire-25 to enable comparison of outcome measures. Transl Vis Sci Technol. 2022;11(5):10-. DOI: 10.1167/tvst.11.5.10

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