Assessment of Corneal High Order Aberrations by Scheimpflug Placido Topography among Children with Myopia

Fareeha Ayyub, Nimra Gul, Sohail Ahmad, Bilal Khalid, Zahid Siddiq

1 Introduction

Myopia is a type of refractive error where rays of light form a focus in front of the retina, and high in East Asia, and approximately one in six of the world's population is myopic also it is the most common refractive error among the Pakistani population with a prevalence of 36.5% in adults and 51.0% in school-going children[1, 2]. The scientific literature on myopia does not fully explain its pathophysiology but is mostly considered due to genetic material and environmental/behavioral interactions. The development and progression of myopia have been influenced by the tremendous improvement of modern society, the urbanization process, and the advancement in living conditions. The environmental factors which affect the development of myopia include near-work activities, a high level of education, an urban environment, and excessive exposure to the digital screen[3, 4, 5].

The eye optical system experiences some sort of errors or aberrations which reduces the visual acuity and retinal image quality. The cornea is majorly affected by these aberrations due to its high refractive power contribution to the overall eye power[6]. There are two types of aberrations in the eye termed lower and high order aberrations. The high order aberrations are higher than second and first order and can't be corrected by the conventional method using spectacles and contact lenses. The HOAs constitute the least part of the total aberrations but they affect the retinal image quality and exaggerate the myopia development [7]. Literature showed the association between myopia progression and high order aberration without spherical aberrations moreover, it was predicted that HOAs may cause accommodative anomalies. The studies showed that HOAs aberrations are greater in myopic patients as compared to emmetropia [8,9,10]. The different ocular aberrations have recently been determined using data from the aberrometer. The Scheimpflug–Placido topographer (Galilei) combines a rotating Scheimpflug camera and Placido-disk technology. A single scan, provides anterior segment imaging and measurements, anterior and posterior corneal topography, wavefront analysis, and corneal pachymetry. Most of the previous studies conducted the research in adults, the purpose of this study was to assess the distribution of high order aberrations among myopia children and its correlation with the degree of refractive error.

Fareeha Ayyub: Pakistan Institute of Ophthalmology, Al-Shifa Trust Eye Hospital, Rawalpindi. Email: Fareeha.ayub74@gmail.com. Contact No. +923376208567
Co-Author:
Dr. Nima Gul. Email: nimra.gul@tuf.edu.pk
Dr. Sohail Ahmad. Email: sohailahmad583@gmail.com
Bilal Khalid: Bilal.Khalid7456@gmail.com
Dr Zahid Siddiq:

2 Materials and Method

This cross-sectional study was conducted at Al-Shifa Children's eye hospital from December 2021 to May 2022. By using the purposive non-probability sampling technique data was collected from school-going children of 8 to 18 years with myopia. This study followed the principles outlined in the Declaration of Helsinki, and also the permission was taken from the hospital and every participant before inclusion in the study.

Inclusion and Exclusion

The inclusion criteria were (1) patients with ages between 8 to 18 years, (2) patients with myopia of all categories i.e. Mild (0-3Ds), Moderate (3-6Ds), and High (>3Ds), (3) patients with best-corrected visual acuity not less than 6/9, (4) patients with less than 2.00Dc cylindrical correction, (4) both eyes of the patients were included.

The exclusion criteria were (1) patients with any ocular disease, (2) patients with refractive error other than myopia, (3) patients wearing contact lenses, and (4) patients with any ocular surface disorder.

Ocular Examination

After collection of the demographic data from patients, the cyclopentolate was instilled into the

subject eyes and kept them waiting for 20 minutes, when full cycloplegia of both eyes was attained objective refraction was carried out using retinoscopy by the experienced single Optometrist. Based on the spherical equivalent myopia was categorized into mild (0-3Ds), moderate (3-6Ds), and high (>6Ds). After that patient was instructed to sit comfortably in front of the Galilei Corneal Topographer machine, place the chin on the chin rest and forehead against the forehead rest, and also was instructed to keep his/her eyes open while looking straight and then K-reading of both corneal anterior and posterior curvature and Zernike's coefficients values of up to 5th order aberrations were recorded on clinical proforma.

Statistical Analysis

The data analysis was performed using the Statistical Package of Social Sciences (SPSS) version-22. For descriptive analysis, continuous variables were presented in the form of mean and standard deviation, whereas categorical or continuous variables were reported in the form of frequency and percentages. For the analysis of the HOA, Zernike's coefficient up to 8th order was transformed into standard values recommended by the Optical Society of America. The RMS values of HOA, HOA with Z_4^0, coma, and trefoil were calculated. The RMS coma was calculated by taking the square root of the sum of the squared coefficients of Z_3^{-1}, Z_3^1, Z_5^{-1}, and Z_5^1; similarly, the total trefoil was the square root of the sum of the squared coefficients of Z_3^{-3}, Z_3^{-3}, Z_5^{-3}, Z_5^3; and HOA without Z_4^0 is the higher-order aberration without spherical aberration. For the quantitative variable, the normality of the assumption was checked by using Shapiro-Wilk and Kolmogorov Smirnov tests. For inferential statistics, One-way ANOVA was used to compare the mean difference of HOAs among myopia groups. The correlation was used to compare the SE, CCT, and K-readings with High order aberrations. The p-value <0.05 was considered statistically significant.

Results

A total of 360 eyes of one hundred and sixty patients including 216 (60%) male and 144 (40%) female with a mean age of 13.1±3.38 (8-18) years met the inclusion criteria. The mean spherical equivalent was -4.45±.57 Diopters (range -0.5 to -12.00 Ds), whereas the mean anterior corneal curvature was 43.34±1.47 and posterior curvature was -6.22±0.91 diopters. The mean and standard deviation for total wavefront aberrations was found to be 1.22±0.62 whereas the mean and standard deviation of total high order aberrations, total HOA without spherical aberrations, and total RMS coma were 0.45±1.49, 0.38±0.15, 0.22±0.09 and 0.27±0.15 respectively. The mean value of 5th order aberrations was found to be 0.245±1.78 micrometer. Further details are given below.

Table 1. Zernike Coefficients of High Order Aberrations

Sr No.	Variables	Mean	Standard Deviation
1.	**3rd Order Aberrations**		
	Z_3^{-3}	-0.02	0.13
	Z_3^{-1}	0.02	0.18
	Z_3^1	0.01	0.24
	Z_3^3	-0.03	0.12
2.	**4th Order Aberrations**		
	Z_4^{-4}	0.006	0.77
	Z_4^{-2}	-0.002	-0.05
	Z_4^0	0.211	0.11
	Z_4^4	-0.01	0.08
	Z_4^1	-0.02	0.11
3.	5th Order Aberrations	0.245	1.78
4.	6th Order Aberrations	0.064	0.042
5.	7th Order Aberrations	0.065	0.370
6.	8th Order Aberrations	0.02	0.01

The mean value of total coma and trefoil was found to be 0.27±0.16 and 0.16±0.11 respectively. Further details are given below.

Table 2. Root Mean Square values of HOA

Sr No.	Variables	Mean	Standard Deviation
1.	RMS of 3rd Order aberrations	0.32	0.15
2.	RMS of 4th Order aberrations	0.26	0.10
3.	RMS of total Coma	0.27	0.16
4.	RMS of total trefoil	0.16	0.11
5.	Total corneal wavefront	1.22	0.62
6.	Total HOAs	0.45	0.15
7.	Total HOAs without SA	0.38	0.15

A one-way ANOVA was conducted to determine the mean difference of HOA between the groups of different myopia categories i.e. mild, moderate, and,

high. Subjects were equally divided into having myopia of mild-moderate and high diopters.

Table 3: One way ANOVA to compare the RMS of aberrations with Myopia

Myopia Category	Total HOA	RMS Coma	RMS trefoil	RMS 3rd Order Aberrations	RMS 4th Order Aberrations	Total Corneal Wavefront	Spherical Aberrations
Mild Myopia	0.42±0.10	0.257±0.15	0.157±0.09	0.287±0.14	0.238±0.06	1.02±0.52	0.206±0.05
Moderate Myopia	0.45±0.12	0.273±0.14	0.151±0.09	0.324±0.14	0.268±0.05	1.10±0.43	0.241±0.06
High Myopia	0.49±0.15	0.279±0.17	0.185±0.131	0.364±0.15	0.2803±0.16	1.53±0.75	0.230±0.12
ANOVA	0.001*	0.55	0.03*	0.001*	0.009*	0.001*	0.008*

***Statistically Significant at p-value < 0.05**

Pearson correlation was used to find the relationship between dependent and independent variables. The strong negative relationship found between RMS of total high order aberrations and CCT has been found [r = -0.197, n=360, p <0.05].

Table 04: Correlation between HOAs and independent Variables (N=360)

Variables	Total HOAs (r)	p-Value
TCW	0.248**	0.001
CCT	-1.97**	0.001
SE	-1.88**	0.001
Ka	0.120*	0.001
Kb	-0.138**	0.009

**** Strong Correlation even at 0.01, *correlation at 0.05**

Discussion

This cross-sectional study was conducted to evaluate the pattern of high-order aberrations among children with myopia. The majority of the participants in the current study were males (216, 60%). This disparity could be explained by a higher prevalence of myopia in male youngsters, as evidenced by another study conducted in the same setting, which found that male patients (54.7%) outnumbered female patients (45.25%) and myopia (43.2%) was outnumbered hyperopia [11]. The mean educational years of the current study were (7.16±3.18) years. Out of the total (216, 60%) were belong to urban areas whereas (144, 40%) belong to rural areas. In the present study, the mean and standard deviation of corneal anterior and posterior curvature was (43.34±1.47), and (-6.22±0.91) diopters respectively. The anterior curvature showed a positive correlation with RMS of total aberrations (r=0.120, p-value=<0.05) whereas the mean posterior corneal curvature showed a negative correlation with HOA (r=-0.138, p-value=<0.050) which means the increase in posterior corneal curvature decreases the aberrations. This finding is from a study conducted by Amanda C Kingston, he showed that increasing corneal steepness increases the spherical aberrations. Both corneal curvatures showed a statistically significant relationship with high order aberrations although, posterior curvature showed a negative correlation. Many studies showed that ocular aberrations are mainly due to the corneal anterior and posterior surface [12]. Because there is a considerable difference in refractive index between cornea and air that is why the anterior corneal surface is the most important refractive part of the eye. Because the ratio of refractive indices between air and the anterior corneal surface is 1.0/1.376 and between the aqueous and the posterior corneal surface is 1.376/1.336 [13], the anterior corneal surface is about 14 times more powerful than the posterior surface. This study showed that high order aberrations of the myopic eye statistically showed a negative correlation with central corneal thickness with p-value [r=-1.97, p-value=0.01] which is by the study conducted among the cataract patients which showed that lower the CCT increases the aberrations of the eye. The study was conducted among myopic patients to find the association between HOA and CCT, and IOP found a strong association between IOP but a weak association between CCT with aberrations of the eye [14, 15].

The analysis of this research found that as the order of the Zernike polynomials increased, the contribution to mean RMS of higher-order aberrations decreased: third-order aberrations predominated (0.32±0.15), accompanied by fourth (0.27±0.10) and fifth-order aberrations, which is in the favor of previously published studies. Wang et al used the Wave Scan System to study high order aberrations from 3rd to 6th orders in 532 eyes with the spherical equivalent of 3.392.84 (range, 11.56 to +7.60)Ds and discovered that spherical aberration was the most common error, followed by main vertical coma [16].

The analysis of the current research demonstrated the significant correlation between age and spherical aberrations (r=0.216, p=<0.05) and 4th order aberrations (r=0.218, p<0.05) which is consistent with the previous studies. This relationship can be attributed to the two possible reasons (1) aging variation of the cornea and crystalline lens which causes the shift of with the rule astigmatism to against the rule astigmatism (2) sclerotic changes in crystalline cause variations in the refractive index of the lens and formation of the cataract which in turn increases the aberrations of the eye. Literature also finds the association of increasing the spherical aberrations with aging but the result of current research cannot be related to the literature because of the different age group selections [17].

The present study found a significant mean difference between RMS of high order aberrations and myopia category [F=9.316, p= 0.01] which is the result of a study conducted among young myopes of mild and moderate categories. The RMS of third-order aberrations [0.287±0.14, 0.324±0.14, 0.364±0.15] is greater than the RMS of fourth-order aberrations [0.238±0.06, 0.268±0.05, 0.2803±0.16] among mild, moderate and high myopia respectively, which is by the previous studies [0.137 ± 0.073, 0.066 ± 0.031]. Moreover, horizontal coma is greater than trefoil in the present study [18]. This similarity of a greater amount of 3rd order aberrations and horizontal coma may be explained by the findings of the study

which investigated that astigmatism and third-order aberrations originated from the cornea. Because one of the studies showed that the terms horizontal coma and spherical aberration were the terms that indicated considerable internal optics adjustment of corneal aberrations at relaxed accommodation. The decrease in the mean magnitude of these aberrations in the entire eye is crucial for obtaining a high-quality retinal image. However, a study showed that when RMS coma, trefoil, and total RMS were compared between hyperopia and low, moderate myopia the values were highest in hypermetropia groups.

Total corneal wavefront aberrations are the sum of root mean square of aberrations including first and second order till 8th order when measured using corneal topography wavefront analysis in the current study mean of the corneal wavefront (1.22±0.62) and mean of HOAs without spherical aberrations (0.38±0.15) was found. This study found that HOAs are associated with myopia greater the degree of myopia higher will be the aberrations, spherical aberrations are predominant in young children followed by coma aberrations [19]. Coma aberrations cause the retinal blur and produce the peripheral hyperopic defocus which may lead to myopia development or increase existing myopia.

Conclusion

The corneal third-order, fourth-order, and coma aberrations were predominant along with spherical aberrations in myopia. The high order aberrations increase with the increase of refractive error. The corneal posterior curvature plays a compensatory role in the reduction of aberrations.

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