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# Higher order aberrations in a normal adult population

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## Abstract

***Purpose*:** To determine the distribution of Zernike coefficients and higher order aberrations in a normal population and its relationship with age, gender, biometric components, and spherical equivalent.

***Methods*:** During the first phase of the Shahroud cohort study, 6311 people of the 40-64-year-old population of Shahroud city were selected through random cluster sampling. A subsample of participants was examined with Zywave aberrometer (The Bausch & Lomb, Rochester, NY) to measure aberrations. Measurements of aberrations were done before cycloplegic refraction, and values generated from a minimum pupil diameter of 5 mm were reported in this analysis.

***Results*:** After applying exclusion criteria, 904 eyes of 577 people were analyzed in this study and mean age in this study was 49.5 ± 5.7 years and 62.9% were female. Mean root-mean-square (RMS) of the third−, fourth−, and fifth-order aberrations was 0.194 μm (95%CI: 0.183 to 0.204), 0.115 μm (95%CI: 0.109 to 0.121), and 0.041 μm (95%CI: 0.039 to 0.043), respectively. Total RMS coma ($Z_3^{-1}$, $Z_3^1$, $Z_5^{-1}$, $Z_5^1$), Total RMS trefoil ($Z_3^{-3}$, $Z_3^3$, $Z_5^{-3}$, $Z_5^3$), and spherical aberration ($Z_4^0$) in the studied population was 0.137 μm (95% CI:0.129−0.145), 0.132 μm (95% CI: 0.123−0.140), and −0.161 μm (95%CI:−0.174 to −0.147), respectively. Mean higher-order Zernike RMS in this study was 0.306 (95% CI: 0.295−0.318) micrometer, and in the multiple model, it significantly correlated with older age and short axial length. The highest amounts of higher-order RMS were observed in hyperopes, and the smallest in emmetropes. Increased nuclear opacity was associated with a significant increase in HO RMS ($p < 0.001$). Analysis of Zernike coefficients demonstrated that spherical aberration ($Z_4^0$) significantly correlated with nuclear cataract only (age-adjusted Coef = 0.37 and $p = 0.012$).

***Conclusion*:** This report is the first to describe the distribution of higher-order aberrations in an Iranian population. Higher-order aberrations in this study were on average higher that those reported in previous studies.



*Keywords:* Zernike coefficients; Higher order aberrations; Population based study; Adult

## Introduction

Higher-order aberrations (HOAs), one of the important subjects in the science of vision and optics, received very little attention before 2000. However, advances in diagnostic and therapeutic methods in recent years have brought them to the attention of ophthalmologists and optometrists.[1,2] As we know, HOAs are part of the refractive errors which are

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not correctable with sphere and cylinder corrections. They are also among errors of the optical system of the eye which can deteriorate the quality of the retinal image.[3,4] Since HOAs can impact visual performance and contrast sensitivity, they are considered important indices in the field of quality of vision and deserve attention.[5–7] In addition, today, attention to HOAs after laser refractive surgery has become one of the important issues in the assessment of the quality of laser refractive methods.[6,8–10] Implantation of intraocular lenses has caused many studies to demonstrate changes in HOAs after surgery.[11–13] There has been more attention to HOAs among cataract patients and myopes compared to other ocular conditions.[14–16] The decision to correct HOAs or not is a challenging one for which no definite answer has been found. Therefore, knowledge of the distribution of these errors in the normal population can be helpful in more accurate corrections using novel techniques in refractive surgery or customized contact lenses. Knowledge of the normal values of HOAs in the normal population can also be helpful in early diagnosis of pathologic conditions such as keratoconus. To date, few studies have examined the distribution of HOAs in different races.[15,17–20] Cervino et al[21] and Lim et al[17] have shown the differences among some ethnic groups. Considering changes in HOAs in different ethnicities, describing their distribution and other components in different populations provides valuable information for each geographic region. Knowledge of the normal distribution of these values can be very useful for developing nomograms for refractive surgery. Previously, some studies described differences in ophthalmic indices such as corneal thickness, keratometry, anterior chamber depth, pupil diameter, corneal diameter, and even distribution of refractive errors in Iranian populations.[22–31] Nonetheless, no study has yet reported the distribution of HOAs in an Iranian population. The aim of this report is to determine the distribution of HOAs and their relationship with other components in a normal Iranian population. The results of this report can also be used as a baseline for the Middle East region. This report also studies the relationship between HOAs and variables of age, gender, ocular biometrics, and refractive errors.

## Methods

The present report is part of the first phase of the Shahroud cohort study in which data was collected cross-sectionally. Details of the sampling strategy and methodology have been published elsewhere, and given here only in brief.[32]

In this study, the 40- to 64-year-old citizens of Shahroud, a city in the north of Iran, were selected as the target population. 300 clusters were randomly selected in the city using multistage sampling. Clusters were selected proportionate to the population of the 9 health care centers of Shahroud. After selecting samples in each cluster, a total of 6311 people were invited to participate in the study. In light of time and cost considerations, some of the examinations were conducted for a subsample of participants. After enrollment and obtaining written informed consent, each participant had complete eye examinations at the study clinic, and their demographics and medical and ophthalmic history were recorded through interviews.

### *Examinations*

Participants had various examinations including optometry tests, ophthalmic examinations, corneal imaging, and biometry. Optometry tests included vision test using the LogMAR chart, as well as subjective, cycloplegic, and manifest refraction. Ophthalmic examinations were done in two stages before and after pupil dilation. Before dilation, slit lamp biomicroscopy and measurement of intraocular pressure was done. After pupil dilation, clinical lens opacities grading, assessment of vitreous opacities with the slit lamp, and retinal examinations using direct and indirect ophthalmoscopy was conducted. Measurement of HOAs in the subsample was also done before instilling cycloplegic drops. In these samples, the Zywave aberrometer (The Bausch & Lomb, Rochester, NY) was used to assess HOAs and Zernike indices. The accuracy of this device in measuring aberrations has been studied before.[33,34] Those images without error by the device were included in this report. Fig. 1 illustrates a sample of the device output and HOA values.

To determine lens opacity, slit lamp examination was. An ophthalmologist conducted lens opacity grading with a slit lamp, and graded any nuclear, posterior subcapsular (PSC), and cortical opacity by making comparisons against standard photographs of the Lens Opacities Classification System III (LOCS III).

### *Exclusion criteria*

Since certain aberrations tend to change as an effect of surgery, cases with any history of surgery were excluded. Cases with a pupil diameter less than 5.0 mm were also excluded from the analysis. The higher order aberrations were reported for 5 mm.

### *Statistical analysis*

In this study, since the correlation between eyes was low in terms of root mean square (RMS) of HOAs ($r = 0.277$), data from both eyes was used in the analysis. For descriptive values, the mean and 95% confidence intervals (CI) were determined. The correlation between the two eyes of each case was accounted for in calculating the standard deviation and 95% CIs. To examine relationships between Zernike coefficients and RMS of HOAs with variables of age, gender, spherical equivalent, axial length, corneal power, central corneal thickness, intraocular pressure, and different types of cataract, multiple Generalized Estimation Equation linear models were used.

## Results

Of the 6311 people selected for this study, 5190 participated, and 1017 were selected as the subsample. Aberrations were measured in 749 people in the subsample group. After