The Relationship between Ocular Higher-Order Aberrations and Mesopic Pupil Size with Age and Gender in Iranian Myopic Candidates for Refractive Surgery

Seyed Javad Hashemian, MD[1] • Mohammad Soleimani, MD, FICO[2] • Alireza Foroutan, MD[1]
Mahmood Joshaghani, MD[1] • Mohammad Jafar Ghaempanah, MD[1]
Mohammad Ebrahim Jafari, MD[3] • Hassan Nikoueinejad[4]

Abstract

***Purpose*:** To analyze the correlation of ocular higher-order aberrations (HOAs) and mesopic pupil size (MPS) with age and gender in myopic patients screened for refractive surgery

***Methods*:** Ocular HOAs and MPS were examined in 1,641 females eyes and 749 males eyes with myopia and also in two different age groups, under 30-year-old (1,675 eyes) and over 30-year-old (715 eyes), using the Zywave aberrometer (Busch & Lomb) wavefront aberrometer. Root-mean-square (RMS) values of HOA and MPS were analyzed. All patients had correctable refractive error without history of refractive surgery or underlying diseases. Pupil size measurement was performed under mesopic condition and ocular HOAs were examined across a ≥6.0 mm pupil.

***Results*:** The mean value of HOAs in 18-30-year-old group was 0.354±0.137 µm (range, 0.10 to 0.97 µm) and in over 30-year-old group was 0.417±0.158 µm (range, 0.10 to 0.99 µm) ($P<0.001$). The difference of HOAs between males and females was not significant. The mean value of MPS in 18-30-year-old group was 6.36±0.90 mm (range, 3.1 to 8.9 mm) and in over 30-year-old group was 5.60±0.99 mm (range, 2.8 to 8.5 mm) ($P<0.001$). The mean value of MPS in females group was 6.10±0.98 mm (range, 2.8 to 8.7 mm) and in males group was 6.20±1.01 mm (range, 2.8 to 8.9 mm) ($P=0.010$).

***Conclusion*:** Significant levels of HOAs were found in our population. The mean value of HOAs in older subjects had statistically significant greater levels, while there was no difference between males and females. Young men had the highest value of MPS.

***Keywords*:** Higher Order Aberrations, Pupil Size, Myopia, Refractive Surgery

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1. Associate Professor of Ophthalmology, Eye Research Center, Rassoul Akram Hospital, Tehran University of Medical Sciences, Tehran, Iran
2. Fellowship in Anterior Segment, Eye Research Center, Rassoul Akram Hospital, Tehran University of Medical Sciences, Tehran, Iran
3. General Practitioner, Eye Research Center, Rassoul Akram Hospital, Tehran University of Medical Sciences, Tehran, Iran
4. Department of Immunology, Tehran University of Medical Sciences, Tehran, Iran

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Correspondence to: *Mohammad Soleimani, MD*
Fellowship in Anterior Segment, Eye Research Center, Rassoul Akram Hospital, Tehran University of Medical Sciences, Tehran, Iran,
Email: soleimani_md@yahoo.com

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Introduction

Ocular aberrations may play a major role in image formation of the optical eye system. Lower order aberrations such as astigmatism and defocus can easily be corrected and it may be less concerning, however higher order aberration can cause more degradation of visual acuity.[1-5]

Measurement of the eye wavefront has been used for customized corneal ablation. The true clinical significance of higher-order aberrations (HOAs) is not fully understood, and there are existing questions regarding the clinical significance of HOAs and their role in laser refractive surgery.

Associated with increasing amounts of interests in both management and treatment of ocular aberration, preoperative aberrometry is more usual than the past. Also, HOAs cannot be corrected by sphero-cylindric lenses and it is representing of their clinical significance.

In this article, we studied the effect of factors such as gender and age on pupil size and HOAs.

Methods

Ocular HOAs and mesopic pupil size (MPS) were examined in subjects presented for performing refractive surgery at our centre from January 2006 to December 2007 and participated in a cross sectional study.

Wavefront aberrometry

The present study used the Zywave aberrometer developed by Busch & Lomb based on the Hartmann-Shack principle. All wavefront measurements were performed by the same examiner.

All wavefronts were repeated 3 times for each eye. The best image was included in the study based on the image quality. If wavefront refraction of the patient was in the range: (spherical diopter: ±0.75 D, cylindrical diopter: ±0.5 D and astigmatic axis: ±15°) of subjective refraction, it was included in the study and then HOAs and root-mean-square (RMS) values were documented. At first we performed pupillometry using Zywave aberrometer under mesopic condition. All measurements were performed between 4 PM and 7 PM. The subjects were placed in the testing room under 0.8 lux lighting condition (that was checked by a light meter) and for every subject, the pupillary image was captured using infrared camera in the device after that pupillary diameter was documented. Then we used tropicamide 0.5% eye drop for medically dilating of the pupil. A pupillary diameter of 6.0 mm was used as the analytical value for wavefront aberrometry.

All patients were studied to exclude other contributing factors such as previous ocular or corneal disease, cataract, corneal scar or other media opacities, and surgery or trauma that could alter wavefront measurements. Patients with a best corrected visual acuity (BCVA) of less than $^{20}/_{40}$ also were excluded. The present study was approved by the Institutional Review Board and Ethics Committee of Iran Eye Research Center at Tehran University of Medical Sciences (TUMS).

RMS values of HOAs were analysed based on 6 mm zone. Pupil size measurements under mesopic condition were also included. Data were analyzed using the Statistical Program for Social Sciences (SPSS) version 15. T-test and χ^2 test were used for the quantitative and qualitative data, respectively. A probability of ≤5% ($P \leq 0.05$) was considered statistically significant.

Results

Our study comprised 2,390 eyes. 1,641 females eyes and 749 male eyes with myopia and also two different age groups: under 30-year-old (1,675 eyes) and over 30-year-old (715 eyes), enrolled in our study.

The mean value of HOAs in 18-30-year-old group was 0.354±0.137 µm (range, 0.10 to 0.97 µm) and in over 30-year-old group was 0.417±0.158 µm (range 0.10 to 0.99 µm) ($P<0.001$) (Figure 1).

The mean value of HOAs in females was 0.372±0.147 µm (range, 0.10 to 0.98 µm) and 0.375±0.145 µm in males (range 0.10 to 0.99 µm) respectively ($P=0.660$). Also there were not significant differences in coma, total spherical aberration and total coma (TC) between male and female (Figure 2). The mean value of HOAs was 0.372 in our population.

The mean value of MPS in 18-30-year-old group was 6.36±0.90 mm (range, 3.1 to 8.9 mm) and in over 30-year-old group was

5.60±0.99 mm (range, 2.8 to 8.5 mm) (P<0.001) (Table 1).

The mean value of MPS in female group was 6.10±0.98 mm (range, 2.8 to 8.7 mm) and in male group was 6.2±1.01 mm (range, 2.8 to 8.9 mm) (P=0.010). (Table 2) The mean value of MPS was 6.13 in our population.

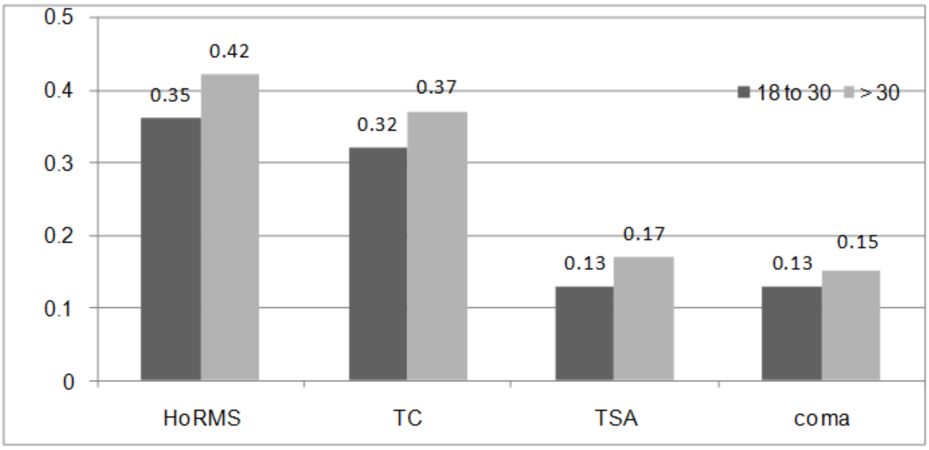

Figure 1. Higher order-aberrations in relation to age
TC: Total coma, TSA: Total spherical aberration

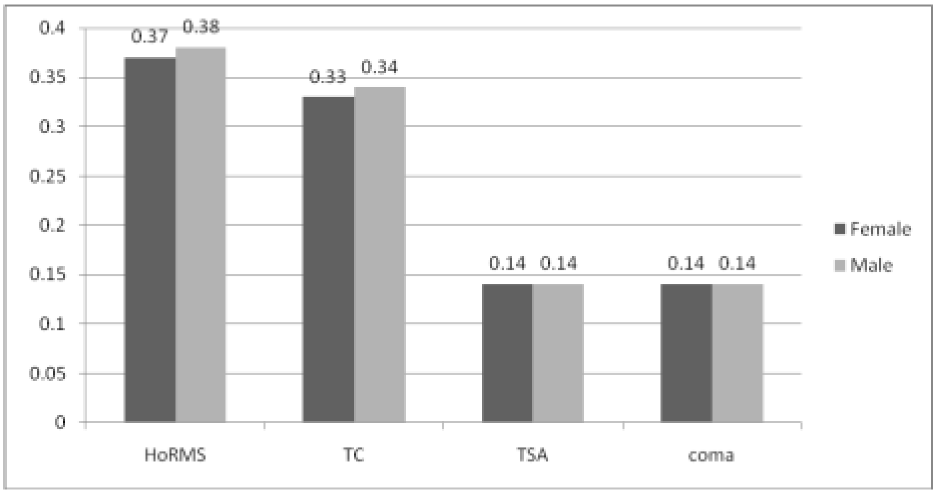

Figure 2. Higher order-aberrations in relation to gender
TC:Total coma, TSA: Total spherical aberration

Table 1. Pupil diameter in relation to gender

Sex	Mean	Std. Deviation	P	Minimum	Maximum
Female	6.10	0.98	0.019	2.8	8.7
Male	6.20	1.01		2.8	8.9

Table 2. Pupil diameter in relation to age

Age	Mean	Std. Deviation	P	Minimum	Maximum
18 to 30	6.36	0.90	<0.001	3.1	8.9
>30	5.60	0.99		2.8	8.5

Discussion

In this study, we investigated ocular HOAs and MPS in both myopic and hyperopic patients. Aberrometry is a valuable method for detecting eyes with abnormal optic situation. Consistent with previous studies, the ocular wavefront aberrations differed widely between subjects, with a mean SD of approximately 0.10 µm for the total HOAs. The supposed mean total higher-order RMS value is 0.33 µm for a 6.0-mm pupil.[6-10]

In our study, HOAs were significantly higher among patients over 30. It seems that this increase in higher order aberration has a small role in degradation of visual quality.[11] There is a compensation between corneal aberrations that predominates and lens aberrations in young people but in older ages, there is not such balance and so total value of HOAs may increase.[2,12-15] On the other hand, there is increasing lens opacity or nuclear sclerosis in older age that may be associated with higher optical aberrations.[12,16-18] These features may explain the increase in HOAs in older people. Brunette et al proposed a bit different suggestion; he noted that the total RMS error and also third and fourth order RMS decreased progressively during childhood and also adolescence, stabilizing during adulthood (age 30 to 50 years). He proposed that progressive increase in RMS occurs only after that age point,[19] the source of such difference between studies is unknown, but situations such as race and also selection of subjects, data analysis (such as distribution in different groups) and probably the number of participants may have a role in this difference.

The mean value of HOAs in our population was 0.372. There were higher amounts of ocular HOAs in our subjects than Caucasian population[20]; also in Chinese population there were higher amounts of HOAs value than Caucasian population.[21,22] Wei et al postulated that one reason may be the differences in precorneal tear film stability.[23] The variation in ocular tear film may cause differences in local thickness and refractive index and cause optical path differences and different wave front aberrations; and thus there are higher levels of aberrations in patients with dry eyes than normal cases.[24] There are documents that confirm us that tear film stability in Asian eyes is less than that in Caucasian and Indonesian eyes.[25-27]

Golnik et al documented the impact of biomechanical factors, such as external eyelid pressure on HOAs and so proposed another cause of ethnic and geographic differences.[28] Compatible with other studies, there was not any significant difference in HOAs between males and females in our study.[1,29]

In patients with greater pupil diameter, total value of RMS increases.[30] The quality of image may decrease as pupil diameter increases.[31,32] On the other hand, despite the controversy about the role of pupil diameter in night vision problems after refractive surgery, the ablation zone should ideally be larger than pupil size in each level of ambient light.[33-35] Also pupil size can affect our surgical plan for implanting a multifocal IOL[36]; thus knowing pupil size under low level of ambient light such as mesopic conditions, and also probable determinant factors of MPS would be invaluable. Several studies have been shown that pupil size decreases with age under different illumination states.[36-43] It was compatible with our study, supporting larger pupil size in young subjects, in one study by Nakamura et al on Japanese population, it was shown that pupil size decreases with age until 60 yr and then remained unchanged,[36] however because our subjects had been referred for refractive surgery and so rationally had some limitation of age, we couldn't study such higher age group. Previous studies showed that we may have different measurements of pupil size based on the corneal plane, monocular or binocular state and difference in brightness, pupillary diameter may be reduced based on corneal refraction that may decrease pupil measurements by 14% and also monocular measurement can show significantly lower amounts of pupillary measurements than binocular measurements probably because binocular measurement can induce light conditions more appropriately.[44-47] There were not any organized data about MPSs in different races and different iris colors. Kokh et al reported that brown iris color may be associated with larger pupil size.[45] Schnitzler et al proposed that blue and brown irises had larger pupil diameter than green,[48] however other studies did not support this hypothesis.[36,49-52] There were larger pupil sizes (mean value: 6.13) in our Iranian patients having darker iris color.

In our study, the pupil size was significantly larger in males, it was consistent with Dain's study, who believed that male had larger pupils,[51] however some other studies did not report any difference in pupil diameter between males and females.[29,37,49,52] The reason may be related to contributing factors such as race, the device for measurement of pupil diameter and the number or situation of participants. In this study, we performed pupillometry using a wavefront aberrometer based on the Hartmann-Shack principle. However Cheng et al documented that although pupillometry using Zywave pupillometry (an aberrometer based on the Hartmann-Shack principle), produced statistically significant smaller values than a Colvard pupillometer, the difference was not clinically significant. Also, Zywave produced an inter-observer repeatability comparable to other devices.[53]

Conclusion

The existing documents concerning the clinical significance of HOAs and MPS and their relations to visual function, and also regarding the potential effectiveness of trying to correct HOAs in refractive surgery encouraged us to study HOAs and MPS in our population and also in relation to age and gender. We think that these data are important to try to assess their clinical significance and role in laser refractive surgery in Iranian patients that may have higher value of HOAs and MPS.

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