·Original article·

Ocular higher-order aberrations and mesopic pupil size in individuals screened for refractive surgery

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Abstract

• AIM: To study the distribution of ocular higher-order aberrations (HOAs) and mesopic pupil size in individuals screened for refractive surgery.

• METHODS: Ocular HOAs and mesopic pupil size were studied in 2458 eyes of 1240 patients with myopia, myopic astigmatism and compound myopic astigmatism and 215 eyes of 110 patients with hyperopia, hyperopic astigmatism and compound hyperopic astigmatism using the Zywave aberrometer (Busch&Lomb). All patients had correctable refractive errors without a history of refractive surgery or underlying diseases. Root-mean-square values of HOAs, total spherical aberration, total coma and mesopic pupil size were analyzed. Ocular HOAs were measured across a ≥6.0mm pupil, and pupil size measurements were performed under the mesopic condition.

• RESULTS: The mean values of HOAs, total spherical aberration and total coma in the myopic group were 0.369±0.233μm, 0.133±0.112μm and 0.330±0.188μm, respectively. In the hyperopic group the mean values of HOAs, total spherical aberration and total coma were 0.418±0.214μm, 0.202±0.209μm and 0.343±0.201μm, respectively. Hyperopes showed greater total HOAs ($P<0.01$) and total spherical aberration ($P<0.01$) compared to myopes. In age-matched analysis, only the amount of total spherical aberration was higher in the hyperopic group ($P=0.05$). Mesopic pupil size in the myopic group was larger ($P\leqslant 0.05$).

• CONCLUSION: The results suggested that significant levels of HOAs were found in both groups which are important for planning refractive surgeries on Iranians. There were significantly higher levels of total spherical aberration in hyperopes compared to myopes. Mesopic pupil size was larger in myopic group.

• KEYWORDS: corneal wavefront aberration; pupil; mesopic vision; race; myopia; hyperopia

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INTRODUCTION

Ocular aberrations may play a major role in the image formation in the ocular optical system. Lower order aberrations such as astigmatism and defocus can easily be corrected and may be less problematic, however higher order aberrations (HOAs) can cause more degradation of the visual performance[1-5].

Customized corneal ablation has been successfully used to address wavefront aberrations of the eye. Given increasing interest in the management of ocular aberrations, performing preoperative aberrometry is more usual than the past. Higher order aberrations cannot be corrected by sphero-cylindric lenses which make them very important in clinical practice. The pupil size can affect the results of refractive surgeries due to its role in post operative visual symptoms such as glare and halo. The larger pupil size may also produce greater HOAs[1,4]. Thus the pupil diameter is an important factor to consider especially for those patients who are candidates for refractive surgery.

In this study we investigated the distribution of HOAs and mesopic pupil size (MPS) in individuals screened for refractive surgery.

MATERIALS AND METHODS

Materials Totally 2458 eyes of 1240 patients with myopia, myopic astigmatism and compound myopic astigmatism and 215 eyes of 110 patients with hyperopia, hyperopic astigmatism and compound hyperopic astigmatism were enrolled in our study. Subjects were selected from patients referred for refractive surgery to our center from September 2006 to November 2008 who participated in a cross sectional study.

Methods

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 wavefront measurements were repeated 3 times for each eye. The best image was included in the study based on the image quality. If the wavefront refraction of the patient was consistent with the subjective refraction (differences between spherical diopter: ±0.75D, cylindrical diopter: ±0.5D and astigmatic axis: ±15°), it would be included in the study and then HOAs and root mean square (RMS) values were documented. At first we performed pupillometry under mesopic condition ($5cd/m^2$) and then a pupillary diameter of at least 6.0mm using tropicamide 0.5% eye drop was used for the analysis in this study.

All patients were examined to exclude other contributing factors such as previous ocular or corneal diseases, cataract, corneal scar or other media opacities and surgery or trauma which could alter wavefront measurements. Patients with a best-corrected visual acuity (BCVA) of less than 20/40 were excluded.

Statistical Analysis RMS values of HOAs and MPS were analyzed. Data were analyzed using the Statistical Program for Social Sciences (SPSS) (Version 15, SPSS Inc., Chicago, Illinois, USA). To evaluate normal distribution of quantitative data, we employed Kolmogorov-Smirnov test. Based on this test, we used T- test to compare myopic and hyperopic subjects after the design effect of bilateral cases had been adjusted. P values of equal or less than 0.05 were considered to be statistically significant.

RESULTS

Myopic spherical equivalent (SE) was in the range of -0.75 to -16.0D with a mean±SD of -3.76D±2.94 and a cylinder of -1.24D±1.75. In the hyperopic group hyperopic SE was in the range of +0.50 to +8.25D with a mean±SD of +3.26D±2.57 and a cylinder of -1.56D±1.87. The mean age was 28.31±7.32 and 37.69±10.09 for myopic and hyperopic patients, respectively (Table 1).

The mean MPS in myopic group was 6.17±1.35mm (range: 2.80 to 8.90mm), and in hyperopic group was 5.60±1.30mm (range: 2.80 to 8.00mm). MPS was larger in myopic patients ($P<0.01$, Table 2).

The mean value of HOAs in myopic group was 0.369μm±0.233 (range: 0.100 to 0.990μm). The mean total spherical aberration (TSA) was 0.133±0.112μm and the mean total coma was (TC) 0.330±0.188μm in this group. In hyperopic group the mean value of HOAs was 0.418±0.214μm (range: 0.160 to 0.970μm). The mean TSA was 0.202±0.209μm and the mean TC was 0.343±0.201μm for hyperopic group. Compared to myopic patients, hyperopic patients had significantly higher total HOAs and TSAs ($P<0.01$) in both cases. In age-matched analysis, only TSA was higher in hyperopic eyes ($P=0.05$). The majority of HOA were related to the third and fourth order aberrations (Figure 1, Table 2).

Table 1　Patient demography

Number		Myopia 2458 eyes of 1240 patients	Hyperopia 215 eyes of 110 patients
Refraction	Mean±SD	-3.76±2.94	+3.26±2.57
	Range	-16.00 to -0.75	+0.50 to +8.25D
Cylinder	Mean±SD	-1.24±1.75	-1.56±1.87
	Range	-7.00 to 0.0	-6.80 to 0.0
Age	Mean±SD	28.3±7.32	37.69±10.09
	Range	18 to 56	20 to 64
Gender		70% (1707)	60% (128)
		30% (741)	40% (85)

Table 2　Refractive error, higher order aberration and mesopic pupil size

		Myopia	Hyperopia	*P*
Mesopic pupil size	Mean±SD	6.17±1.35	5.60±1.30	<0.01
	Range	2.8 to 8.9	2.8 to 8.0	
Ho-RMS*	Mean±SD	0.37±0.23	0.42±0.21	<0.01
	Range	0.10 to 0.99	0.16 to 0.97	
Total Coma	Mean±SD	0.33±0.19	0.34±0.20	0.48
	Range	0.08 to 0.96	0.13 to 0.95	
Total spherical aberration	Mean±SD	0.13±0.11	0.20±0.21	<0.01
	Range	0.0 to 0.65	0.0 to 0.56	

*Ho-RMS: Higher order RMS.

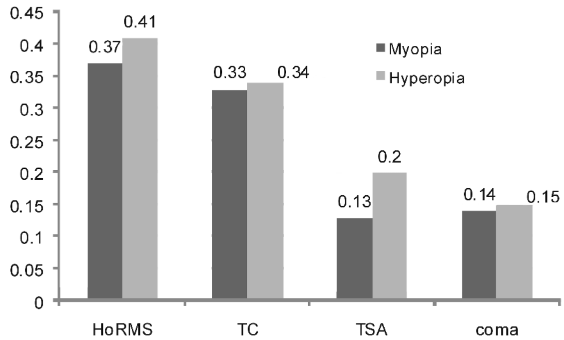

Figure 1　Higher order aberrations and refractive error　TC: total coma; TSA: total spherical aberration.

DISCUSSION

In this study, we investigated ocular HOAs and MPS in both myopic and hyperopic patients. Aberrometry is a valuable method to detect eyes with an abnormal optical condition. Consistent with previous studies, ocular wavefront aberrations differed widely between subjects, with a mean SD of approximately 0.10μm for the total HOAs. The mean total higher-order RMS value is 0.33μm for a 6.0-mm pupil[6-10]. RMS values can be calculated from aberration coefficients and represent a summary of optical quality. In the present study, HOAs in myopic patients (average: 0.369μm) were lower than those in hyperopic patients (average: 0.418μm). This might be because of the confounding role of the age in our study, since the mean age of hyperopic subjects was significantly higher than myopic subjects and as other studies have shown HOAs increase with age[11-14]. In age-matched analysis, only TSA was higher in hyperopic patients. Liorente *et al*[15] also have reported greater spherical aberration in hyperopia compared to myopia. Bisneto *et al*[16] suggested that hyperopic patients with less than -0. 75D astigmatism show greater amount of spherical aberration and hyperopic patients with more than -0. 75D astigmatism show a greater amount of other HOAs (other than coma and spherical aberration) and also high-order RMS aberrations. HOAs may be more common in ammetropic eyes than emmetropic eyes, as He *et al*[17] proposed that myopic patients may present with greater HOAs compared to emmetropes. On the other hand, there are some studies that propose no relationship or even an opposite relationship between myopia or hyperopia and higher order aberrations[15-21]. Kirwan *et al*[22] reported greater higher order aberrations in myopes compared to hyperopes, however they studied on children, a population different from our study. In our study, the most significant components of HOAs were third order aberrations and fourth order aberrations respectively and the fifth order RMS value was the smallest among the three which is supported by other studies[1-4].

There were higher amounts of ocular HOAs in our subjects compared to Caucasian population[23]. Higher amounts of HOAs in Chinese population have also been reported compared to Caucasian population [24,25]. Wei *et al* [19] postulated that one reason may be the differences in the precorneal tear film stability. The variation in the ocular tear film may cause differences in the local thickness and refractive index and cause optical path differences and different wavefront aberrations; thus there are higher levels of aberrations in patients with dry eyes[26]. Evidences show that tear films in Asian eyes are less stable than those in Caucasian and Indonesian eyes[27-29]. It may be the reason for more prevalent wavefront aberrations in our population.

In patients with a dilated pupil, total HOAs increase[30] and also the quality of image may decrease as the pupil diameter increases[31,32]. Despite the controversy about the role of pupil diameter in night vision problems after refractive surgery, the ablation zone should ideally be larger than the pupil size in each level of ambient light [33-35]. Also the pupil size can affect our surgical plan for implanting a multifocal IOL[36]; thus knowing the pupil size under low levels of ambient light such as mesopic conditions, and also probable determinant factors of MPS would be invaluable. In this study, the pupil sizes under the mesopic conditions in myopic eyes and hyperopic eyes were 6. 17 and 5. 60, respectively. Thus, MPS in the myopic group was larger. Despite the relatively large number of hyperopic cases in our study, the number of myopic cases was significantly higher than hyperopic cases and there was a statistically significant age difference between myopic and hyperopic subjects participating in the study ($P<0.01$). Several studies have shown that pupil size decreases with the age under different illumination states[36-42], thus age may be a confounding factor causing the difference of MPS between myopic and hyperopic subjects in our study. In age-matched analysis, MPS was still larger in myopic group. Hashemi *et al*. reported an inverse relationship between refractive error and pupil size in univariable analysis, but not in the multivariable analysis, supported by other studies[43-45]. They reported smaller pupil sizes among hyperopic patients compared to the myopes probably because of more accommodation in hyperopic subjects[46]. However some studies have reported no relationship between the pupil diameter and refraction among patients with hyperopia and myopia[47,48]. There are not any organized data about mesopic pupil sizes in different races and different iris colors. Kokh *et al*[49] reported that brown iris colors may be associated with larger pupil sizes. Schnitzler *et al*[50] have proposed that the pupil diameter in eyes with blue and brown irises is larger than green iris, however other studies did not support this hypothesis[36,47,51-53]. There were larger pupil sizes in our Iranian patients having darker iris colours.

The existing knowledge concerning the clinical significance of HOAs and MPS, their relationship to the visual function, and the potential effectiveness of correcting HOAs in refractive surgery encouraged us to study HOAs and MPS in our population. We think that our findings are important to assess their clinical significance and role in laser refractive surgery especially among Iranian population because of higher amounts of HOAs and larger pupil sizes.

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屈光手术前个体眼高阶像差与中间视觉状态下瞳孔大小

Seyed Javad Hashemian [1], Mohammad Soleimani [1], Alireza Foroutan [1], Mahmood Joshaghani [1], Mohammad Jafar Ghaempanah [1], Mohammad Ebrahim Jafari [1], Mehdi Yaseri [2]
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摘要

目的:研究眼高阶像差的分布(HOAs)和 mesopic 瞳孔的大小在个体中筛选的屈光手术。

方法:我们采用 Zywave 像差分析仪(博士伦)分别对患有近视、近视散光和复性近视散光患者 1240 例 2458 眼和患有远视、远视散光和复性远视散光患者 110 例 215 眼的高阶像差和瞳孔大小进行检测。所有患者屈光不正均可矫正,无屈光手术史或潜在疾病。HOAs 的均方根值、总球面像差、总斜射球面像差和中间视觉状态下瞳孔的大小进行了分析,眼高阶像差测量均在瞳孔≥6.0mm,且瞳孔大小的测量均为在中间视觉状态下进行。

结果:HOAs 均方根值、总球面像差和总斜射球面像差在近视眼组与远视眼组分别为 0.369±0.233μm、0.133±0.112μm、0.330±0.188μm;0.418±0.214μm、0.202±0.209μm、0.343±0.201μm。与近视患者相比,远视患者的总 HOAs 和总球面像差更大(P 均<0.01)。年龄匹配分析显示在远视眼组只有总球面像差较高($P=0.05$)。近视眼组的中间视觉状态下瞳孔大小较大($P\leqslant 0.05$)。

结论:实验结果表明两组的 HOAs 的水平有显著差异,这对于将行屈光手术的伊朗人很重要。远视眼组的总球面像差显著高于近视眼组,中间视觉状态下瞳孔大小在近视眼组较大。

关键词:角膜波前像差;瞳孔;中间视觉; 种族; 近视; 远视