



Original article



## Gender and wavefront higher order aberrations: Do the genders see the world differently?

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### Abstract

**Introduction:** Wavefront sensing technology has emerged as a means to advance our understanding of high-order aberrations of the human eye.

**Purpose:** To evaluate the differences in ocular high-order aberrations between males and females and the distribution of high-order aberrations in males and females.

**Subjects and methods:** 3,597 eyes (1,029 female and 2,568 male) of 1,874 patients who obtained wavefront measurements performed using the VISX Wavescan device were included in this study. Mean RMS (root mean square) values of high-order aberrations (HOAs) and the mean of each Zernike polynomial from the second to the sixth order were calculated from multiple scans of each eye. Analysis was performed to assess the association between HOAs and gender, and symmetry of HOAs between eyes in both males and females.

**Results:** Overall HOA did not differ significantly between males and females ( $p=0.93$ ). Overall HOA did not differ between left eyes ( $p=0.852$ ) or right eyes ( $p=0.76$ ). Individual Zernike polynomials did reveal a significant difference between male and female eyes: Z14 (Tetrafoil x,  $p=.036$ ); Z16 (Secondary Trefoil y,  $p=0.015$ ); Z24 (Secondary Spherical,  $p=0.003$ ); Z25 (Tertiary Astigmatism x,  $p=0.010$ ); and Z26 (Secondary Tetrafoil x,  $p=0.004$ ).

**Conclusion:** Overall HOA does not differ between the genders; however, individual HOA Zernike terms do demonstrate statistically significant differences between males and females. This is the first such study to describe these differences. The clinical significance of these differences has yet to be determined.

**Keywords:** refractive surgery, high-order aberrations, cornea, gender

### Introduction

Wavefront sensing technology has emerged as a means to advance our understanding of high-order aberrations of the human eye. Recently it has been used for customized refractive surgery to correct aberrations beyond sphere and cylinder in hopes to obtain uncorrected visual acuities in the supernormal ranges (Thibos et al 1999; Thibos 2004; Liang et al 1997). This technology has also furthered our understanding of high-order aberrations and how it effects visual acuity

and visual symptoms (Chalita et al 2004). By using this expertise we can also expand our knowledge of the distribution of high-order aberrations of the human eye within the population. To date there have been studies describing the prevalence of the different high-order aberrations in the population and changes with aging. To date, none of these studies have looked at the significance of gender on the prevalence of high-order aberrations and their distribution within these subpopulations (Wang et al 2003).

All fields of medicine have described some aspect of gender difference. Examples include the increased prevalence of autoimmune disease in females and the increased risk of heart disease in men. In ophthalmology we see differences between males and females in the prevalence of certain diseases and an

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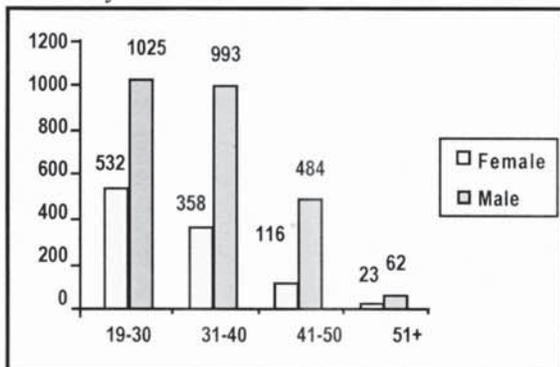
increased prevalence of refractive error in females (Kempen et al 2004). Most of these differences can be attributed to the various hormonal differences and the difference in sex chromosomes. However, there are many differences in the sexes that cannot be ascribed to these factors.

The purpose in this study was to evaluate the (1) differences in ocular high-order aberration between males and females and (2) the distribution of high-order aberrations in males and females.

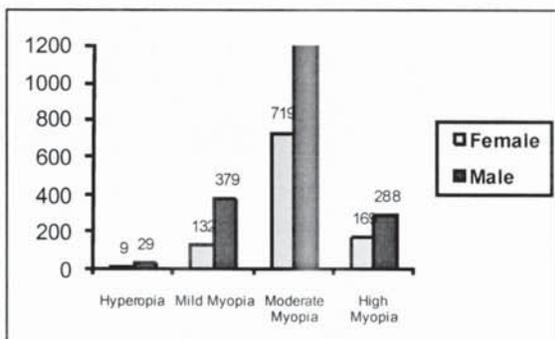
### Subjects and methods

All patients selected for the study were evaluated at the United States Air Force Warfighter Refractive Surgery Center, Lackland AFB, San Antonio, TX between 20<sup>th</sup> September 2002 and 14<sup>th</sup> June 2005 after taking an informed consent from all of them. Of the 1,874 patients, 71.4% were male and 28.6% were female.

Ages ranged from 19 to 89 years with a mean age of  $33.2 \pm 8.1$  years. The mean refractive error was  $-3.8$

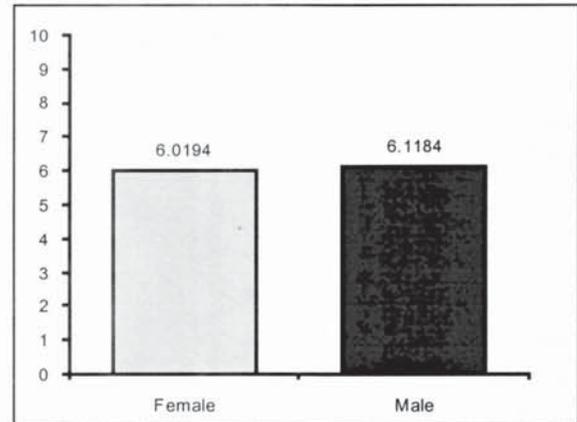


Age - Ages ranged from 19 to 89 with a mean age of  $33.2 \pm 8.1$  years



**Refractive Error** - Population refractive error interpreted as diopters of sphere of  $>0$  = Hyperopia;  $<0$  = Myopia with categories of Mild - (0 to  $-2.00$ ); Moderate ( $-2.00$  to  $-6.00$ ); Severe ( $-6$  and greater); mean refractive error was  $-3.8 \pm 1.9$  diopters of sphere.

$\pm 1.9$  diopters of sphere and  $0.77 \pm 0.65$  diopters of cylinder. All patients were to refrain from contact lens use for 90 days (or one month for each decade of wear) for gas permeable lenses and 30 days for soft contact lenses. Patients were excluded if there was any previous corneal pathology; best spectacle-corrected visual acuity worse than 20/40; history of autoimmune disease (including diabetes); use of imitrex, accutane, cordarone, immunosuppressants, or steroids; pregnancy or breastfeeding within six months.



Wavefront Diameter (mm) - Average wavefront diameter of Male vs. Female. Total population had a

Wavefront scans were performed using the VISX Wavescan Wavefront System. This instrument uses Hartmann-Shack sensing and incorporates a fogging fixation target to control for accommodation. The instrument is intended to measure and display hyperopic, myopic, and astigmatic refractive errors and higher order optical aberrations up to 6<sup>th</sup> order Zernike polynomials. Scans were done using the same wavescan machine for all patients. Each patient was scanned a minimum of three times and only scans with maximum quality (four checked boxes) were accepted. Scans with a pupil diameter  $<5.0$  mm were excluded. Scans accepted had pupil diameters ranging from 5.0 mm to 7.0 mm with a mean of  $6.11 \pm 0.47$ . Patient's exams were then averaged to obtain the mean of the high-order aberration root mean square and each of the Zernike polynomials up to the 6<sup>th</sup> order.

Patient data was then matched for age, refractive error, pupil diameter and eye. Statistical analysis of the data was performed by an experienced biostatistician who performed t-test for equality of means for overall high-order aberrations between groups as well as for individual Zernicke terms.



## Results

Overall HOA did not differ significantly between males and females ( $p=0.93$ ).

**Table 1**  
 Independent Samples Test

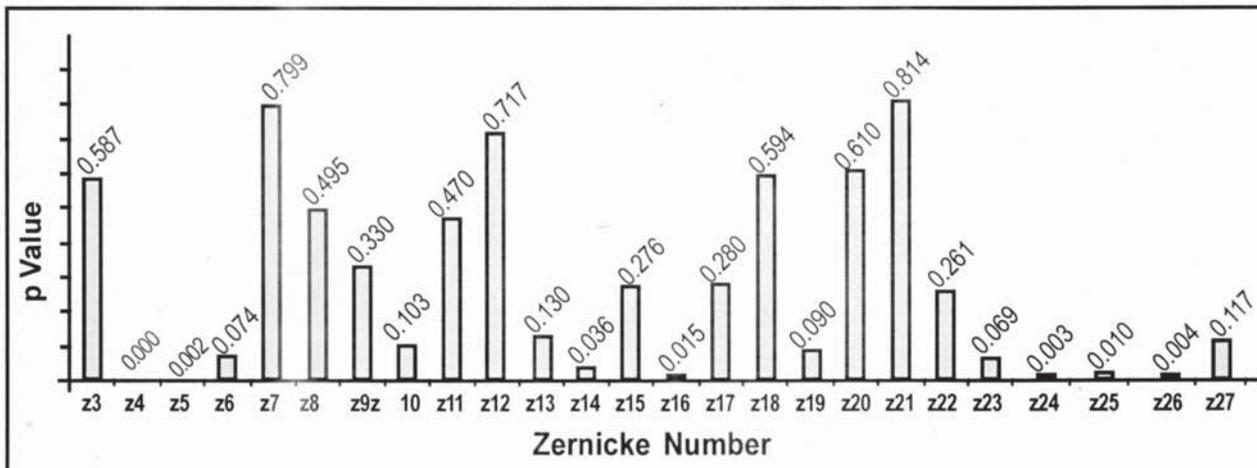
	Levene's Test for Equality of Variances		t-test for Equality of Means						
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
								Lower	Upper
HOARMS	2.243	.134	.083	3714	.934	.0003943	.00477422	-.008966	.0975463
Equal variance assumed			.081	1919.108	.935	.0003943	.00485928	-.009136	.0992432
Equal variance not assumed									

Overall HOA did not differ between left eyes ( $p=0.852$ ) or right eyes ( $p=0.76$ ).

**Table 2**  
 Independent Samples Test

EYE	Levene's Test for Equality of Variances		t-test for Equality of Means						
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
								Lower	Upper
OD	.959	.328	.303	1872	.762	.0020523	.00677446	-.011234	.0153385
			.300	982.830	.764	.0020523	.00684055	-.011371	.0154760
OS	1.200	.274	-.192	1840	.848	-.0012898	.00672674	-.014483	.0119030
			-.187	934.880	.852	-.0012898	.00690285	-.014837	.0122571

Individual Zernike polynomials did reveal a significant difference between male and female eyes: Z14 (Tetrafoil x,  $p=0.036$ ); Z16 (Secondary Trefoil y,  $p=0.015$ ); Z24 (Secondary Spherical,  $p=0.003$ ); Z25 (Tertiary Astigmatism x,  $p=0.010$ ); and Z26 (Hexafoil x,  $p=0.004$ ).





## Discussion

Since the advent of wavefront technology in refractive surgery, there have been numerous studies to examine the optical aberrations of the human eye. In previous studies, investigators have demonstrated that optical higher-order aberrations vary greatly among the population and increase with aging (Wang et al 2003; Castejon-Mochon et al 2002; Amano et al 2004). Studies have also shown that there is no evidence to suggest that aberrations vary systematically with the degree of amblyopia (Cheng et al 2003). No studies have investigated the significance of gender on the prevalence of high-order aberrations and their distribution within these subpopulations. Our study has two objectives: evaluate the differences in ocular high-order aberration between males and females and the distribution of high-order aberrations in males and females.

Other areas of medicine recognize gender differences exist and these factors must be taken into account when assessing a patient, creating a differential diagnosis, and ultimately treating the patient. In ophthalmology we see these differences in dry eye, autoimmune diseases, IOP, and central corneal thickness (Suzuki et al 2005). Recently, in a study performed by the Eye Disease Prevalence Research Group, a higher prevalence of refractive error in female patients in the United States, Western Europe and Australia were described (Kempen et al 2004). We postulated that there may be difference in high-order aberration in the human population with regard to gender.

Overall, we did not discover a difference in total higher-order aberrations between males and females. The amount of total higher-order aberrations does not seem to be impacted by gender; however, we did discover some statistically significant differences in individual Zernicke polynomial terms. Specifically, Z14 (Tetrafoil x), Z16 (Secondary Trefoil y), Z24 (Secondary Spherical), Z25 (Tertiary Astigmatism x), and Z26 (Hexafoil x) were found to be statistically different between male and female eyes. The difference in these terms has uncertain clinical significance at this time; however, it does demonstrate there are definite differences in the optical properties of male and female eyes. These differences may lead to a better understanding of the properties of the eye and what impact correcting these optical aberrations may have

in the areas of quality of vision. Additional studies to confirm these differences and explore the clinical significance of these differences should be performed.

## Conclusion

There is no difference in total higher-order aberrations between males and females. The amount of total higher-order aberrations does not seem to be impacted by gender; however, there are some statistically significant differences in individual Zernicke polynomial terms.

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