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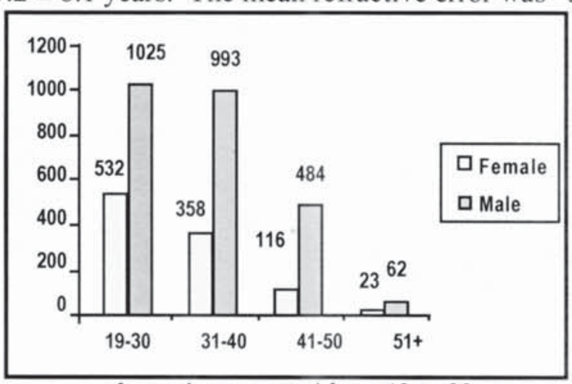
increased prevalence of refractive error in females (Kempen et at 2004). Most of these differences can be attributed to the various hormonal differences and the difference in sex chromosomes. However, there are many differences in the sexes that cannot be ascribed to these factors.

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.

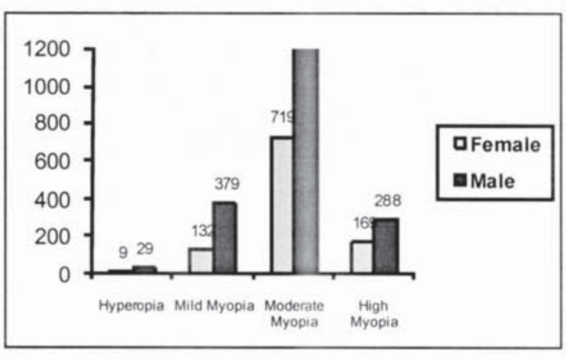
Subjects and methods

All patients selected for the study were evaluated at the United States Air Force Warfighter Refractive Surgery Center, Lackland AFB, San Antonio, TX between 20th September 2002 and 14th 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 ± 8.1 years. The mean refractive error was –3.8

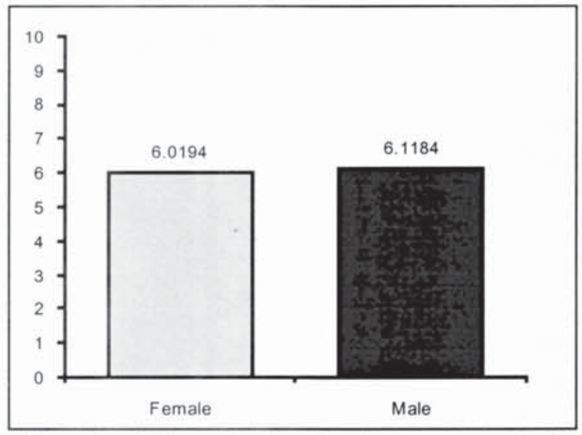


Age *- Ages ranged from 19 to 89 with a mean age of 33.2 ± 8.1 years*



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 ± 1.9 diopters of sphere.*

± 1.9 diopters of sphere and 0.77 ± 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 6th 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 ± 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 6th order.

Patient data was then matched for age, refractive error, pupil diameter and eye. Statistical analysis of the data was performed by an experienced biostastician 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						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
HOARMS	Equal variance assumed	2.243	.134	.083	3714	.934	.0003943	00477422	-.008966	0975463
	Equal variance not assumed			.081	1919.108	.935	.0003943	00485928	-.009136	0992432

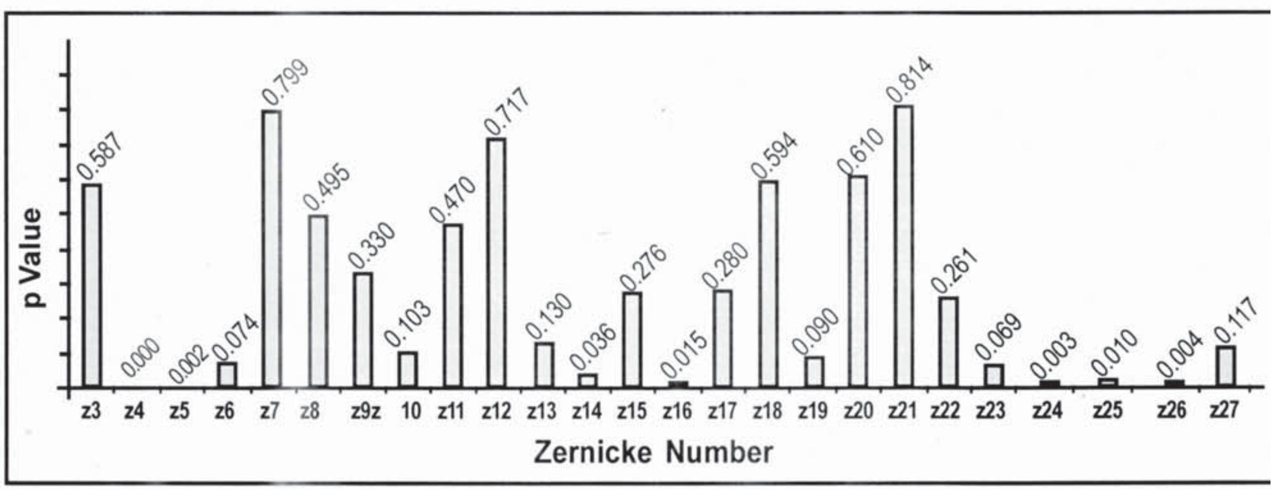
Overall HOA did not differ between left eyes (p=0.852) or right eyes (p=0.76).

Table 2

Independent Samples Test

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

Individual Zernike polynomials did reveal a significant difference between male and female eyes: Z14 (Tetraf x, p=0.036); Z16 (Secondary Trefoil y, p=0.015); Z24 (Secondary Spherical, p=0.003); Z25 (Tertiary Astigmatis 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.

References

Amano S, Amano Y, Yamagami S, Miyai T, Miyata K, Samejima T, Oshika T (2004). Age-related changes in corneal and ocular higher-order wavefront aberrations. *Am J Ophthalmol*; 137(6):988-92.

Carones F. "Diagnostic use of ocular wavefront sensing (2004)." *Ophthalmol Clin North Am*;17(2):129-33.

Carvalho LA, Castro JC, Carvalho LA (2002). Measuring higher order optical aberrations of the human eye: techniques and applications. *Braz J Med Biol Res*;35(11):1395-406.

Castejon-Mochon JF, Lopez-Gil N, Benito A, Artal P (2002). Ocular wave-front aberration statistics in a normal young population. *Vision Res*; 42(13):1611-7.

Chalita MR, Krueger RR (2004). Correlation of aberrations with visual acuity and symptoms. *Ophthalmol Clin North Am*;17(2):135-42.

Chalita MR, Chavala S, Xu M, Krueger RR (2004). Wavefront analysis in post-LASIK eyes and its correlation with visual symptoms, refraction, and topography. *Ophthalmology*;111(3):447-53.

Cheng X, Bradley A, Hong X, Thibos LN (2003). Relationship between refractive error and monochromatic aberrations of the eye. *Optom Vis Sci*;80(1):43-9.

Fam HB, Lim KL(2004). Effect of higher-order wavefront aberrations on binocular summation. *J Refract Surg*; 20(5):S570-5.

Hashemi H, Fotouhi A, Mohammad K(2004). The age- and gender-specific prevalences of refractive errors in Tehran: the Tehran Eye Study. *Ophthalmic*

Epidemiol;11(3):213-25.

Kempen JH, Mitchell P, Lee KE, Tielsch JM, Broman AT, Taylor HR, Ikram MK, Congdon NG, O'Colmain (2004) BJ; Eye Diseases Prevalence Research Group. "The prevalence of refractive errors among adults in the United States, Western Europe, and Australia." *Arch Ophthalmol*; 122(4):495-505.

Klyce SD, Karon MD, Smolek MK (2004). Advantages and disadvantages of the Zernike expansion for representing wave aberration of the normal and aberrated eye. *J Refract Surg*; 20(5):S537-41.

Liang J, Williams DR, Miller DT(1997). Supernormal vision and high-resolution retinal imaging through adaptive optics. *J Opt Soc Am A Opt Image Sci Vis*;14(11):2884-92.

Netto MV, Mohan RR, Ambrosio R Jr, Hutcheon AE, Zieske JD, Wilson SE (2005). Wound healing in the cornea: a review of refractive surgery complications and new prospects for therapy. *Cornea*; 24(5):509-22.

Oshika T, Klyce SD, Applegate RA, Howland HC (1999). Changes in corneal wavefront aberrations with aging. *Invest Ophthalmol Vis Sci*;40(7):1351-5.

Solomon KD, Fernandez de Castro LE, Sandoval HP, Vroman DT (2004). Comparison of wavefront sensing devices. *Ophthalmol Clin North Am*;17(2):119-27.

Smolek MK, Klyce SD (2003). Zernike polynomial fitting fails to represent all visually significant corneal aberrations. *Invest Ophthalmol Vis Sci*;44(11):4676-81.

Suzuki S, Suzuki Y, Iwase A, Araie M (2005). Corneal thickness in an ophthalmologically normal Japanese population. *Ophthalmology* 17; [Epub ahead of print].

Thibos LN, Hong X (1999). Clinical applications of the Shack-Hartmann aberrometers. *Optom Vis Sci*; 76:817-25.

Thibos LN (2004). The optics of wavefront sensing. *Ophthalmol Clin North Am*; 17(2):111-7.

Wang L, Koch DD (2003). Ocular higher-order aberrations in individuals screened for refractive surgery. *J Cataract Refract Surg*; 29(10):1896-903.

Wang L, Dai E, Koch DD, Nathoo A (2003). Optical aberrations of the human anterior cornea. J *Cataract Refract Surg*; 29(8):1514-21.

Yeh SI, Azar DT (2004). The future of wavefront sensing and customization. *Ophthalmol Clin North Am*; 17(2):247-60.

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