Comparison of Refractive Errors measured using Auto-Refractometer and calculated using Zernike Coefficients

Sang-Deok Lee

Abstract: Background/Objectives: This research aims to identify the relationship between refractive errors measured by a refractometer and refractive errors using Zernike coefficients measured by an aberrometer. Methods/Statistical analysis: This study measured Zernike coefficients C_2^0,C_2^2, and C_2^(-2) of 6mm and 4mm-pupil areas using a wave-front aberrometer. They compared and analyzed sphere, cylinder, and cylindrical axes calculated by the coefficients and the values measured by the auto-refractometer. Findings: The study showed that the average difference between the sphere value measured by refractometer and 4mm-aberrometer was -0.03D, smaller than the difference of 0.15D between the sphere values measured by the refractometer and 6mm-aberrometer. The difference between the refractometer and 4mm-aberrometer was 0.12D for the cylinder, smaller than the difference of 0.17D between the refractometer and 6mm-aberrometer; next, as in sphere and cylinder, the difference between the refractometer and 4mm aberrometer was smaller than difference between the refractometer and 6mm-aberrometer for SE values. The correlation analyses showed that the correlation between the refractometer and 4mm-aberrometer was higher than correlation between the refractometer and the 6mm-aberrometer in all of sphere, cylinder, and SE values. Improvements/Applications: When simple refraction values of lower-order aberration replaced values measured using wave-front aberrometer, it seems adequate to set the measuring range as 4mm of pupil diameter than 6mm.

Keywords: refractive error, Zernike coefficients, sphere, cylinder, cylindrical axis

I. INTRODUCTION

Test measuring the refractive errors for glasses or contact lens corrections are classified into objective refraction test and subjective refraction test. A common objective refraction tests uses retinoscopy and auto-refractometer, and an auto-refractometer that does not require a tester's skills is widely used in optical shops or ophthalmology. Subjective tests include the ones using trial lens sets and phoropter.Many studies have identified that autorefraction tests have higher accuracy and reproducibility than subjective refraction tests[1-4].

Zernike Polynomials is widely used as a standard format to arithmetically quantify wavefront aberration, which were used to develop various aberrometers to measure aberrations, identify the status of refraction, and use them in wavefront surgeries considering these[5,6]. Various researches have been conducted on the relationship between refractive errors, which are refractive errors measured by aberrometers, and values measured by auto-refractometers, reporting that there are correlations between refractive errors measured by two methods[7-9]. The HOAs measured by an aberrometer are affected by the size of pupil diameter, which have been reported to show a difference depending on the type of aberration[10,11]. This research divided the refractive errors measured using an aberrometer to be within 6mm and 4mm of measurement range, and compared these values to the refractive errors measured using an auto-refractometer.

II. MATERIALS AND METHODS

This study was conducted on eyes that have no ophthalmology diseases in cornea and retina and have not received relates surgeries. Also, research subjects included 318 eyes of 159 people who did not wear hard contact lens for more than 6 weeks and did not wear soft contact lens for more than 4 weeks. The average age of 91 male and 68 female research subjects was 29, and their age ranged from 19 to 35 years old.

The study measured the refractive errors and Zernike coefficients of eyes using KP-9000pw, the wavefrontaberrometer of Hartmann-Shack method. The spherical equivalent power vector M and Jackson cross cylinder J_0 and J_{45} were calculated as follows by Zernike coefficients C_2^0, C_2^2, and C_2^{-2} that were measured[12].

$$M = -4\sqrt{3}C_2^0/r^2 \quad (1)$$

$$J_0 = -2\sqrt{6}C_2^2/r^2 \quad (2)$$

$$J_{45} = -2\sqrt{6}C_2^{-2}/r^2 \quad (3)$$

The values calculated by the conversion formulas below were used for sphere (S), cylinder (C), and cylindrical axes (A).

$$C = 2\sqrt{(J_0^2 + J_{45}^2)} \quad (4)$$

$$S = M - C/2 \quad (5)$$

$$A = \frac{1}{2}\tan^{-1}\left(\frac{J_{45}}{J_0}\right) \quad (6)$$

The study compared and analyzed the sphere, cylinder, and cylindrical axes calculated and the values measured by the auto-refractometer, and the measurement range of aberrometer was divided into a 6mm-pupil area and 4mm-pupil area.

Revised Manuscript Received on May 22, 2019.
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The cylindrical axes values were converted for analysis so that the difference of two measured values would not exceed 90 degrees. A paired t-test and bivariate correlation analysis were performed using SPSS 18.0, and it was set to have a significant difference if the p-value was less than 0.05

III. RESULTS AND DISCUSSION

Table 1 shows the average values of sphere, cylinder, and SE(spherical equivalent) measured using a refractometer and aberrometer. The average sphere measured by the refractometerwas -2.47D. The average of sphere values measured within 6mm of pupil diameter using the aberrometer was -2.63D, and the average value measured within 4mm was -2.44D.

Table 1: Average values of refractive errors measured using the refractometer, 6mm-aberrometer, and 4mm-aberrometer

Refractive Errors	Refractometer	6mm Aberrometer	4mm Aberrometer
Sphere(D)	-2.47	-2.63	-2.44
Cylinder(D)	-0.99	-1.16	-1.11
SE(D)	-2.97	-3.21	-2.30
CylindricalAxis(°)	121.51	120.95	122.32

The value of cylinder measured using the refractometer was -0.99D, and the value of cylinder measured using the aberrometer was -1.16D within 6mm of measurement range and -1.11D within 4mm. The SE average values measured using refractometer, 6mm-aberrometer, and 4mm-aberrometerwere -2.97D, -3.21D, and -2.30respectively.The average value of cylindrical axes measured using a refractometerwas 121.51degrees, and the average values measured by 6mm-and 4mm-aberrometer were 120.95° and 122.32°respectively.

To examine the difference of sphere, cylinder, and SE values measured using the refractometer, 6mm-aberromete, and 4mm-aberrometer, the differences of values subtracting 6mm-aberrometer measured values from the refractometermeasured values, and the refractometer measured values subtracting 4mm-aberrometer measured values were shown on Table 2. The average value of difference between the sphere value measured by the refractometer and the sphere value measured by the 4mm-aberrometer was -0.03D, which was smaller than the difference of 0.15D between the sphere values measured using the refractometer and 4mm-aberrometerand had a statistically significant difference. As for cylinders, the difference between the refractometer and 4mm-aberrometer values were 0.12D, which was smaller than the difference of 0.17D between the refractometer and 6mm-aberrometer values. For SE values, the difference between refractometer and 4mm-aberrometer values was smaller than the difference between the refractometer and 6mm-aberrometer values as in the sphere and cylinder. The differences were statistically significant.

Table 2: Comparison of differences between the value measured using the refractometer and 4mm-aberrometer measured as well as the value measured using the refractometer and 6mm-aberrometer

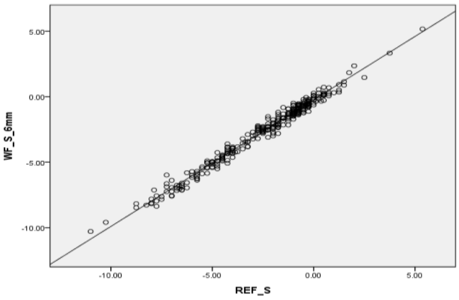
Refractive Errors	Differences		p-value
	REF–WF(6mm)	REF–WF(4mm)	
Sphere(D)	0.15	-0.03	0.00
Cylinder(D)	0.17	0.12	0.00
SE(D)	0.24	0.03	0.00

REF–WF(6mm): Average value subtracting the values measured using the 6mm-aberrometer from the refractometer-measured values.

REF–WF(4mm): Average value subtracting the values measured using the 4mm-aberrometer from the refractometer-measured values.

Pearson correlation analyses were conducted to identify the relationship among the spheres measured using the refractometer, 6mm-aberrometer, the 4mm-aberrometer. As shown in Figure 1, the values measured by all 3 methods had high correlations. The correlation between the 4mm-aberrometer and refractometer measured values was 0.995, which was quite higher than the correlation of 0.911 between the 6mm-aberrometer and refractometer measured values.

According to the results of Pearson correlation analyses among the cylinders measured by the 3 methods, all of the values had significant correlations to each other and were very high with almost 1 correlation as in the sphere(Figure 1). The cylinder correlation between the 4mm-aberrometer and refractometer was 0.975, which was quite higher than the correlation of 0.959 between the 6mm and refractometer(Figure 2). The SE measured by the 6mm-aberrometerand the refractometer had a correlation of 0.991 while the SE of 4mm-aberrometer and refractometer showed a correlation of 0.995, thus making the correlation between the 6mm and refractometer higher (Figure 3). Figure 4 shows correlations of cylindrical axes measured by the 3 methods. According to the analysis result, 6mm-aberrometer and the refractometer had 0.939 of correlation while the 4mm-aberrometer and refractometerhad 0.909 of correlation. Unlike the refractive errors of above result, the correlation between the 6mm-aberrometer and refractometer was higher than the correlation between 4mm-aberrometer and refractometer.



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Blue Eyes Intelligence Engineering
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ISSN: 2278-3075, Volume-8 Issue-8S2, June 2019

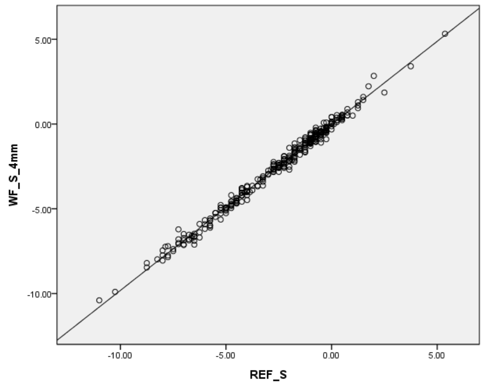

Figure 1. Correlation between the sphere values measured using a refractometer and aberrometer.

REF_S :Sphere values measured using therefractometer

WF_S_6mm: Sphere values within 6mm of pupil diameter measured using the aberrometer

WF_S_4mm: Sphere values within 4mm of pupil diameter measured using the aberrometer

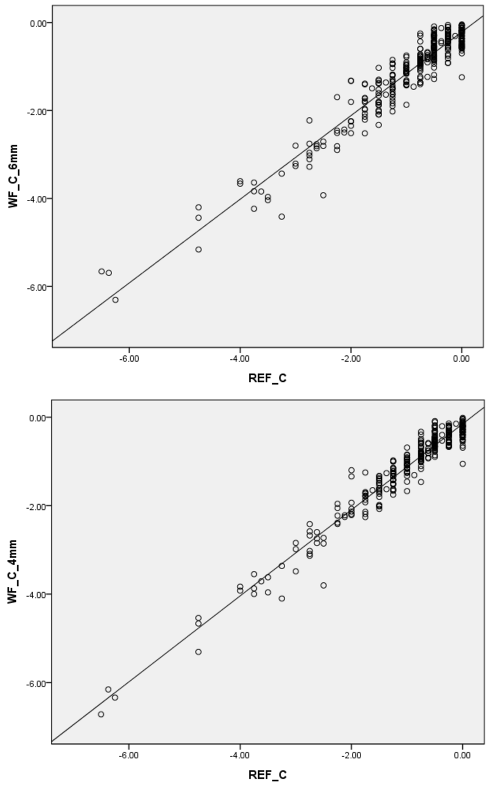

Figure 2. Correlation between the cylinder values measured using a refractometer and aberrometer.

REF_C :Cylinder values measured using the refractometer

WF_C_6mm: Cylindervalues within 6mm of pupil diameter measured using the aberrometer

WF_C_4mm: Cylindervalues within 4mm of pupil diameter measured using the aberrometer

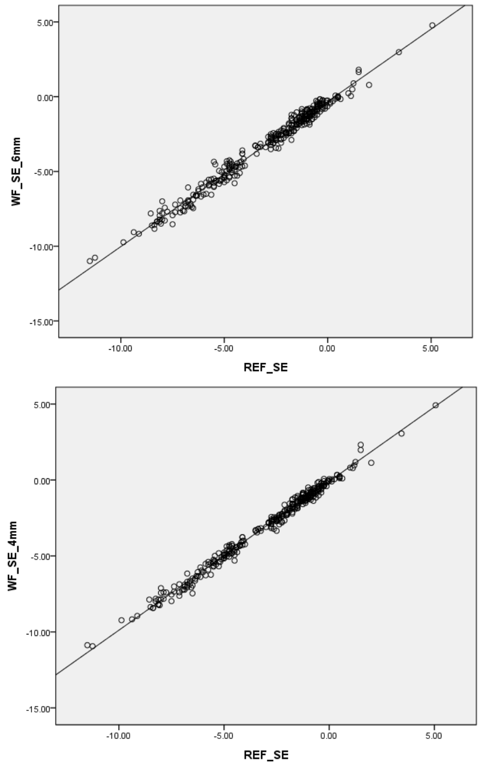

Figure 3. Correlation between the SE values measured using a refractometer and aberrometer.

REF_SE :SE values measured using the refractometer

WF_SE_6mm: SE values within 6mm of pupil diameter measured using the aberrometer

WF_SE_4mm: SE values within 4mm of pupil diameter measured using the aberrometer

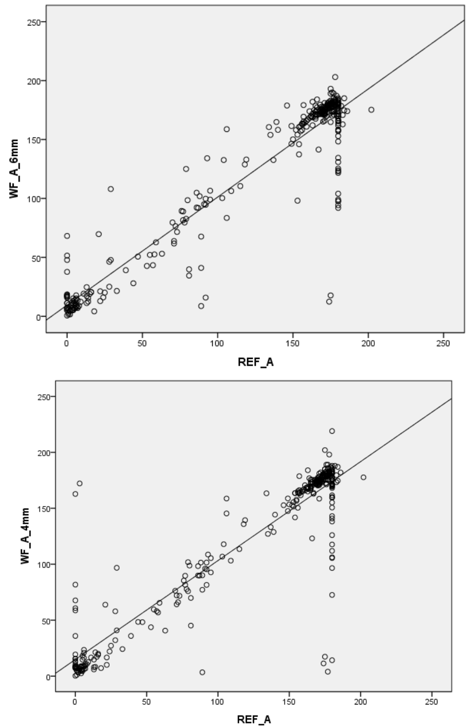

Figure 4. Correlation between the cylindricalaxes measured using a refractometer and aberrometer.

REF_A : Cylindricalaxes measured using the refractometer

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WF_A_6mm: Cylindricalaxes within 6mm of pupil diameter measured using the aberrometer

WF_A_4mm: Cylindricalaxes within 4mm of pupil diameter measured using the aberrometer

IV. CONCLUSION

The average difference value between the sphere value measured by the refractometer 4mm-aberrometer was -0.03D, which was smaller than the difference of 0.15D between the sphere values measured by the refractometer and 6mm-aberrometer. The difference between the refractometer and 4mm-aberrometer was 0.12D for the cylinder, which was also smaller than the difference of 0.17D between the refractometer and 6mm-aberrometer, and as in sphere and cylinder, the difference between the refractometer and 4mm aberrometer was smaller than difference between the refractometer and 6mm-aberrometer for SE values. The correlation analysis showed that the correlation between the refractometer and 4mm-aberrometer was higher than the correlation between the refractometer and the 6mm-aberrometer in all of sphere, cylinder, and SE values. The above results show that when simple refraction values of lower-order aberration replaced the values measured using wave-front aberrometer, it seems more adequate to set the measuring range to be within 4mm of pupil diameter than 6mm.

ACKNOWLEDGMENT

This study was supported by the 2017Gimcheon University Research Grant.

REFERENCES

1. Mallen EA, Wolffsohn JS, Gilmartin B, Tsujimura S. Clinical evaluationof the Shin-Nippon SRW-5000 autorefractor in adults.Ophthalmic Physiol Opt 2001;21:101-7.
2. Rosenfield M, Chiu NN. Repeatability of subjective and objective refraction. Optom Vis Sci. 1995 Aug;72(8):577-9.
3. Gwiazda J, Weber C. Comparison of spherical equivalent refractionand astigmatism measured with three different models ofautorefractors. Optom Vis Sci 2004;81:56-61
4. Wübbolt IS, von Alven S, Hülssner O, Erb C.Comparisons of manual and automatic refractometry with subjective results. Klin Monbl Augenheilkd. 2006 Nov;223(11):904-7.
5. Doane JF, Slade SG. An introduction to wavefront-guided refractivesurgery. IntOphthalmolClin 2003;43:101-17.
6. Shetty R, Matalia H, Nandini C, Shetty A, Khamar P, Grover T, et al.Wavefront-Guided LASIK Has Comparable Ocular and Corneal Aberrometric Outcomes but Better Visual Acuity Outcomes Than SMILE in Myopic Eyes. J Refract Surg. 2018 Aug 1;34(8):527-532.
7. Lebow KA, Campbell CE.A comparison of a traditional and wavefront autorefraction.Optom Vis Sci. 2014 Oct;91(10):1191-8.
8. McCullough SJ, Little JA, Breslin KM, Saunders KJ.Comparison of refractive error measures by the IRX3 aberrometer and autorefraction.Optom Vis Sci. 2014 Oct;91(10):1183-90.
9. Pesudovs K, Parker KE, Cheng H, Applegate RA. The precision of wavefront refraction compared to subjective refraction and autorefraction.Optom Vis Sci. 2007 May;84(5):387-92.
10. Wang Y, Zhao K, Jin Y, Niu Y, Zuo T.Changes of higher order aberration with various pupil sizes in the myopic eye.J Refract Surg. 2003 Mar-Apr;19(2 Suppl):S270-4.
11. McKelvie J, McArdle B, McGhee C.The influence of tilt, decentration, and pupil size on the higher-order aberration profile of aspheric intraocular lenses.Ophthalmology. 2011 Sep;118(9):1724-31.
12. Thibos LN, Hong X, Bradley A, Cheng X.Statistical variation of aberration structure and image quality in a normal population of healthy eyes.J Opt Soc Am A Opt Image Sci Vis. 2002 Dec;19(12):2329-48.