Unfocused Effect on the Measurement of Ocular Aberrations

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Objectives: *To evaluate the effect of unfocused measurement in the value of ocular aberrations.*
Material and Method: *The present study was conducted at Siriraj Hospital, Mahidol University. Ocular aberrations of 20 eyes in 10 myopic patients (myopia less than -6.00 diopters (D) and astigmatism less than -2.00 diopters (D)) were analyzed by using Zywave aberrometer® (Bausch & Lomb, USA). The measurements were done at the pupillary plane (focus) and 6 other different planes (unfocus); 5, 10 and 15 mm inside and outside pupillary plane respectively. The value of each measurement was analyzed to find the effect of unfocused measurement on ocular aberrations.*
Results: *The magnitude of error (root mean square, RMS) of the spherical component of refraction at 5, 10, 15 mm inside and outside the pupillary plane was 0.16, 0.44, 0.57 D and 0.21, 0.38, 1.35 D respectively. The RMS of astigmatic component of refraction inside and outside the pupillary plane at the same distance was 0.19, 0.50, 0.80 and 0.18, 0.52, 1.55 D respectively. The RMS of higher order aberrations inside and outside the pupillary plane at the same distance was 0.05, 0.13, 0.15 and 0.06, 0.1, 0.1 microns respectively.*
Conclusion: *There was more effect of outward unfocused measurement in the value of refraction (spherical and astigmatism) than inward unfocused measurement. Higher order aberration showed a similar error in both inward and outward defocus. The magnitude of error was 10 - 12% within 5 mm unfocused planes.*

Keywords: *Unfocused, Aberrations*

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Wavefront guided refractive surgery is currently interested by most ophthalmologists and patients. There are several principles of wavefront analysis; among them is Hartman-Shack's principle. By capturing the reflected beam of light from the retina which travels outside through the entire optic of the eye, the aberrations can be measured. The data derived from the measurement is used to adjust the profile of the laser treatment on the cornea. Therefore, the measurement itself should have maximal predictability or least errors which consist of precise alignment and accurate quantity of aberration measurement. But in clinical practice, the precision of the alignment sometimes is difficult to obtain, especially in non-cooperative patients. The aberration data from the misaligned measurement can be the cause of unsuccessful treatment. The validity of the data needs to be approved before utilization. There are several causes of misaligned measurement. Previous reports have shown the effect of lateral decentration and torsional misalignment in wavefront sensing measurement[1,2]. To the authors' knowledge, there is no study on the defocus effect of the measurement.

The present study was conducted to evaluate the effect of defocus on the measurement of ocular aberrations.

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Material and Method

A prospective study of 20 myopic eyes was conducted from June 2004 to January 2005 at the Department of Ophthalmology, Siriraj Hospital, Mahidol

University. All eyes had myopia less than -6.00 diopters and astigmatism less than -2.00 diopters. Pupillary dilatation was acquired by using 1% mydriacyl eye drop every 5 minutes for 2 times. Zywave Aberrometer® (Bausch & Lomb, USA) was used to evaluate aberra-tions of the dilated eyes after 15 minutes of pupillary dilatation. The measurements were done by manufac-turing standard method, focus at pupillary plane. Each measurement comprised of 5 automatically consecutive readings, and only the best three readings were chosen by computer software to average the data in to one measurement (Fig. 1). There were three components of the measurement; spherical, astigmatism and higher order aberrations. All components were analyzed at 6 mm pupil diameter. Un-focus measurements also were performed by the same method at 6 other different planes; 5, 10, 15 mm inside and outside pupillary plane respectively. The value of each un-focus measurement was analyzed to correlate for the error by comparing with the focus measurement at the pupillary plane.

Results

The mean age of the subjects was 29 $\pm$ 3.4 years old (range from 18-35) with the mean refractive error (Spherical Equivalent) of -2.40 $\pm$ 3.2 diopters (range from -0.25 to -6.00). The magnitude of error was calculated in the form of root mean square, RMS, at 6 mm pupil. The RMS errors of spherical component at 5, 10, and 15 mm inside and outside the pupillary plane are shown in Fig. 2. The RMS errors of astigmatic component inside and outside the pupillary plane at the same distance are shown in Fig. 3. The RMS errors of higher order aberrations inside and outside the pupillary plane at the same distance are shown in Fig. 4. There was no statistically significant difference between the error of inside and outside pupillary plane and no statistically significant difference between focus measure and all level of un-focus measurements.

Discussion

Customized ablation by wavefront-guided LASIK is proposed to improve the optical properties of the human eye by adding higher-order optical aberrations (HOAs) in to the individual ablation profile calculation[3,4]. Normally, there are two components in the customized laser ablation profile; refraction compo-nent and HOAs component. The refraction component, which included sphere and astigmatism data, is always taken from manifest refraction. On the contrary, the HOAs component is derived from the aberrometer. The error of measurement in refraction component of aberrometer is irrelevant for the treatment. But the error in HOAs component is an issue. The accuracy of the HOAs is very important for the outcome of the treatment. Previous studies showed lateral alignment accuracy should be 0.07 mm or better for 7 mm pupil and 0.2 mm or better for 3.0 mm pupil[1]. The torsional

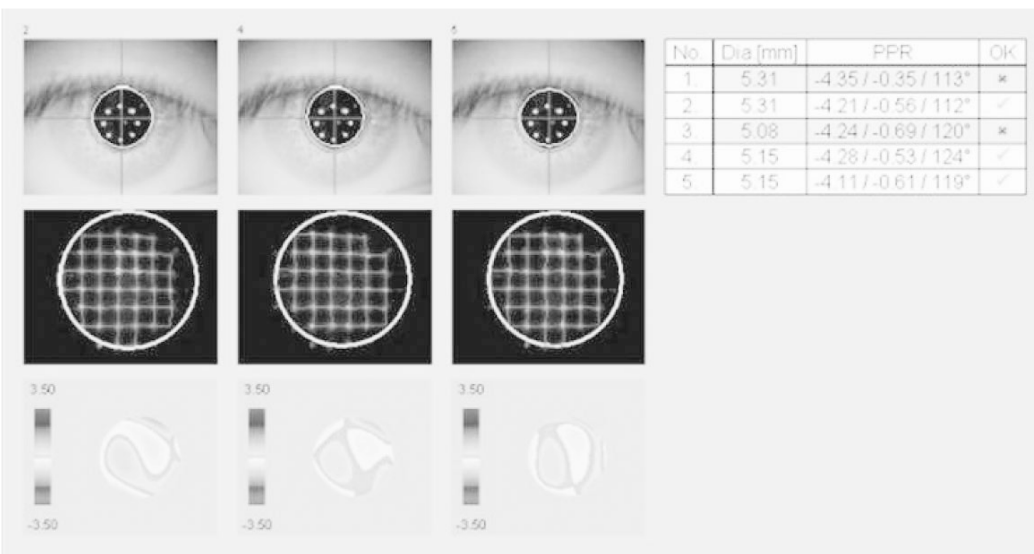

Fig. 1 Shows appearance of the Zywave® aberrometer software. Note that there are 5 consecutive measurements on the right table. Only 3 best readings are chosen for the data acquisition

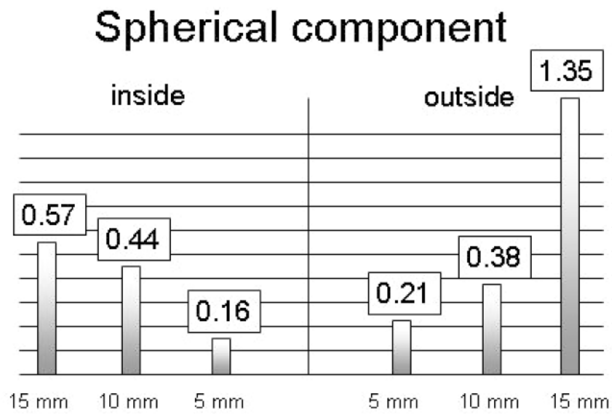

Fig. 2 Shows the magnitude of errors of spherical component at different un-focus planes. Note that the tendency of the error was more toward the outside pupillary plane (outward defocus)

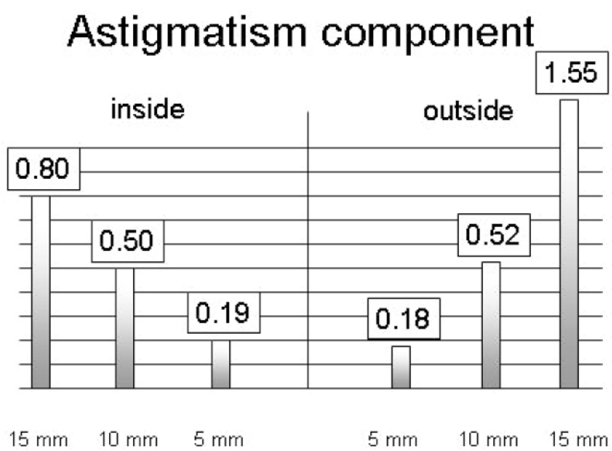

Fig. 3 Shows the magnitude of errors of astigmatism component at different un-focus planes. Note that the tendency of the error was more toward the outside pupillary plane (outward defocus)

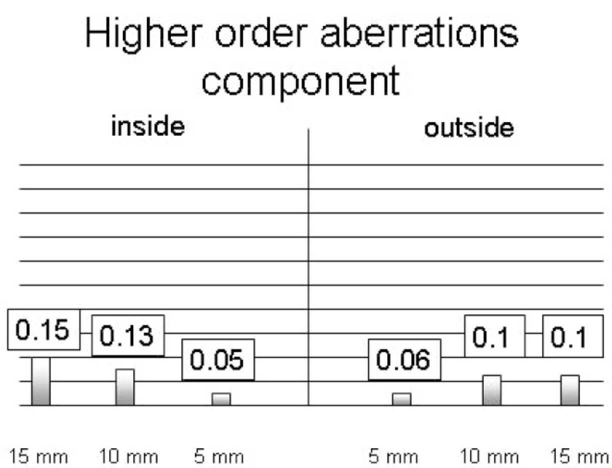

Fig. 4 Shows the magnitude of errors of higher order aberrations component at different un-focus planes. Note that the tendency of the error was similar in both inside (inward defocus) and outside pupillary plane (outward defocus)

alignment accuracy should be 4.0 degrees for 7.0 mm pupil[2]. The present study was conducted to find the defocus accuracy by using Zywave aberrometer®, which was based on Hartmann-Shack principle. The accuracy and reproducibility of Zywave aberrometer® had also been studied previously with a recommendation of several measurements and excluding the outliers as was done in this automatic calculation of the software[5,6].

From the present study, simply the more the defocus, the more the errors of ocular aberrations. The most sensitive component to the defocus was astigmatism, followed by sphere, and HOAs component. Even though there was no statistically significant difference due to the small sample size, the trend could be predicted. The errors were more in the outward than the inward defocus. The authors' explanation to this finding is the angulations effect of the ray of light. Basically, the principle of Hartmann Shack aberrometer is to focus the wave that travels throughout the eye by using lens array. If there is no aberration, the focusing spot of the wave will be symmetrical and regular. If there are some aberrations, the focusing spot will be displaced from the ideal location and the amount of displacement can be used to calculate the amount of aberrations as in Fig. 5[7]. In the defocus measurement, the spot will never be sharply focused because of the fixed focal length of the lens array. Therefore, the average central location of the spot will be used. The displacement of the average central location of the spot will have more effect on the outward defocus compared to the inward defocus due to the angulation's effect of the ray of light as shown in Fig. 6. The present study supported this theory by showing more trends of the errors in the outward than inward defocus measurement.

There is also an issue of how many errors one can accept for the laser treatment. Generally, the normal

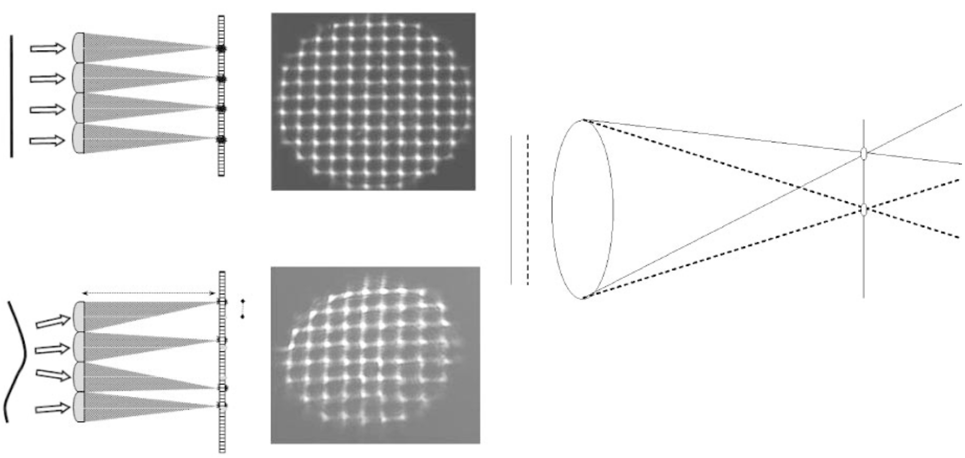

Fig. 5 Shows the principle of Hartmann Shack aberrometer. The distance from A to B is used to calculate the aberration

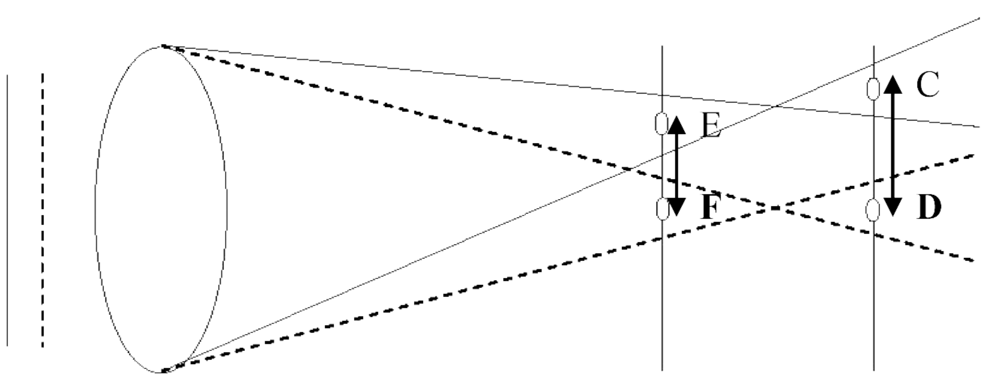

Fig. 6 Shows more displacement effect of outward defocus (C to D) than inward defocus (E to F) due to angulation's effect

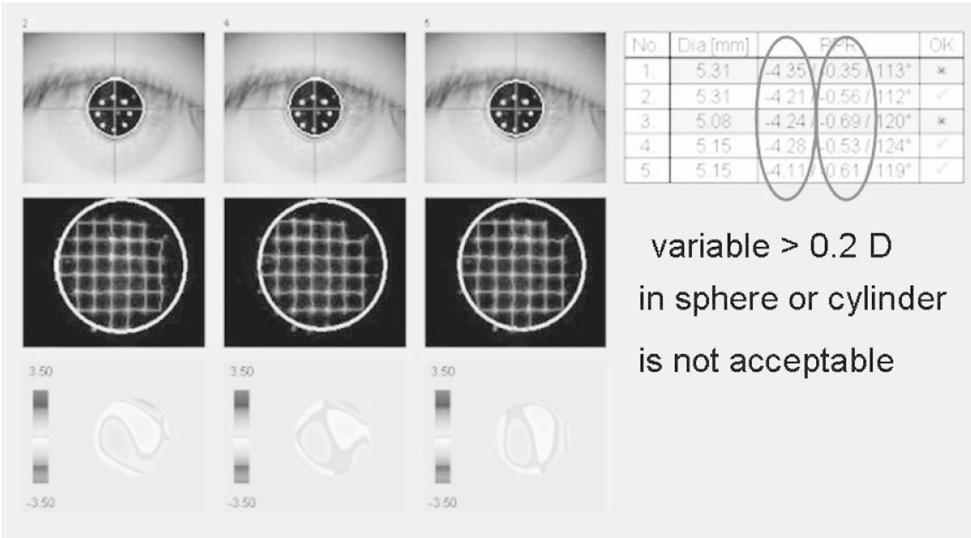

Fig. 7 Shows the result screen of the Zywave® aberrometer software. Note the value of sphere and cylinder on the right table

population has about 0.4 µm of HOAs component[8]. In the present study, 10 mm of defocus produced 0.1 µm errors of HOAs or approximately 25% of the HOAs magnitude in the normal population and 5 mm of defocus measurement produced 0.05 µm errors of HOAs or approximately 12.5% of the HOAs magnitude in the normal population. Normally, the permissible errors of medical errors should be less than 10%. Therefore, from the present study, the permissible defocus should be less than 5 mm. The reason the authors could not obtain the exact mm of permissible defocus was, more refined interval of the defocused distance was not performed.

The authors finding may help surgeons who currently work with Zywave Aberrometer®. As mentioned earlier, the measurement will be done automatically 5 times at approximately 5-6 seconds and only 3 repeatable measurements will be selected. Surgeons will not be able to see the patient's eye during that period and all the errors could happen. Lateral decentration is very easy to identify by looking at the position of the pupil in the result screen as shown in Fig. 1. Defocus can be a question depending on the resolution of the image. As in the authors' finding, defocus within 5 mm distance will produce approximately 0.2 diopters of sphere and astigmatism. By looking at the result screen, the difference of sphere and astigmatism in 3 selected measurements should be less than 0.2 diopters, which referred to the less than 5 mm of defocus (Fig. 7). If the difference was more than 0.2 D, the repeated measurement should be done.

In conclusion, for the Zywave II aberrometer, the permissible defocus should be limited within 5 mm distance for 6 mm pupil. For the more accurate permissible defocus, the larger sample size and more refined interval of the defocused distance should be evaluated in further studies.

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ผลของความคลาดเคลื่อนของการวัดที่ไม่โฟกัสต่อค่าของการกระจายตัวของแสงชนิด Aberrations

สบง ศรีวรรณบูรณ์, นริศรา อตุลพันธุ์

วัตถุประสงค์: *เพื่อหาผลของความคลาดเคลื่อนของการวัดที่ไม่โฟกัสต่อค่าของการกระจายตัวของแสงชนิด Aberrations*
วัสดุและวิธีการ*: การศึกษานี้ทำในผู้ที่มีสายตาสั้นน้อยกว่า -6.00 diopters และสายตาเอียงน้อยกว่า -2.00 diopters จำนวน 20 ตาที่ภาควิชาจักษุวิทยา คณะแพทยศาสตร์ศิริราชพยาบาล โดยทำการตรวจวัดการกระจายตัวของแสงชนิด Aberrations ด้วยเครื่อง Zywave Aberrometer® (Bausch & Lomb, USA) ซึ่งจะทำการวัดที่จุดโฟกัสของเครื่อง (ระดับม่านตา) และวัดที่ไม่โฟกัส (5, 10, 15 มิลลิเมตร ที่ระยะในและนอกต่อระดับม่านตา) และนำค่าที่วัดได้ไปคำนวนหาความสัมพันธ์ทางสถิติ*
ผลการศึกษา: *ค่าความคลาดเคลื่อนของการวัดที่ไม่โฟกัสที่ระยะ 5, 10, 15 มิลลิเมตร ที่ระยะในและนอกต่อ ระดับม่านตา (รวม 6 ระยะ) โดยคำนวณเป็น root mean square (RMS) พบว่าในส่วนของค่าสายตาสั้นมีค่า 0.16, 0.44, 0.57 และ 0.21, 0.38, 1.35 D ตามลำดับ ในส่วนของค่าสายตาเอียงมีค่า 0.19, 0.50, 0.80 และ 0.18, 0.52, 1.55 D ตามลำดับ และในส่วนของ higher order aberrations มีค่า 0.05, 0.13, 0.15 และ 0.06, 0.1, 0.1 ไมครอน ตามลำดับ*
สรุป: *การศึกษานี้พบว่าค่าความคลาดเคลื่อนของการวัดที่ไม่โฟกัสจะมีผลมากกว่าที่ระยะนอกต่อระดับม่านตาเมื่อเทียบกับที่ระยะในต่อระดับม่านตา โดยมีค่าความคลาดเคลื่อนอยู่ที่ 10-12% ภายในระยะ 5 มิลลิเมตรที่ไม่โฟกัส*
