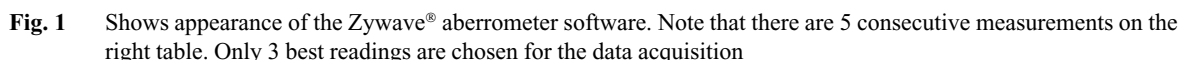




and 15 mm inside and outside the pupillary plane are shown in Fig. 2. The RMS errors of astigmatic component inside and outside the pupillary plane at the same distance are shown in Fig. 3. The RMS errors of higher order aberrations inside and outside the pupillary plane at the same distance are shown 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.

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<sup>(3,4)</sup>. Normally, there are two components in the customized laser ablation profile; refraction component 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<sup>(1)</sup>. The torsional

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,



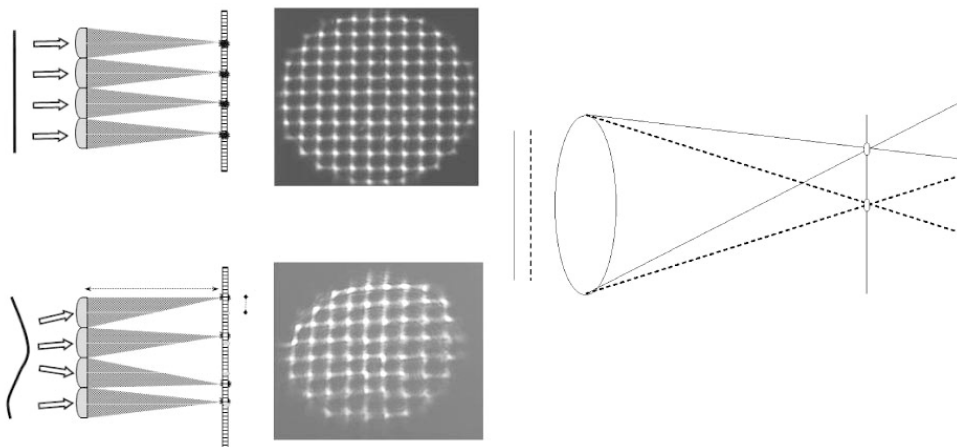


alignment accuracy should be 4.0 degrees for 7.0 mm pupil<sup>(2)</sup>. The present study was conducted to find the defocus accuracy by using Zywave aberrometer®, which was based on Hartmann-Shack principle. The accuracy and reproducibility of Zywave aberrometer® had also been studied previously with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

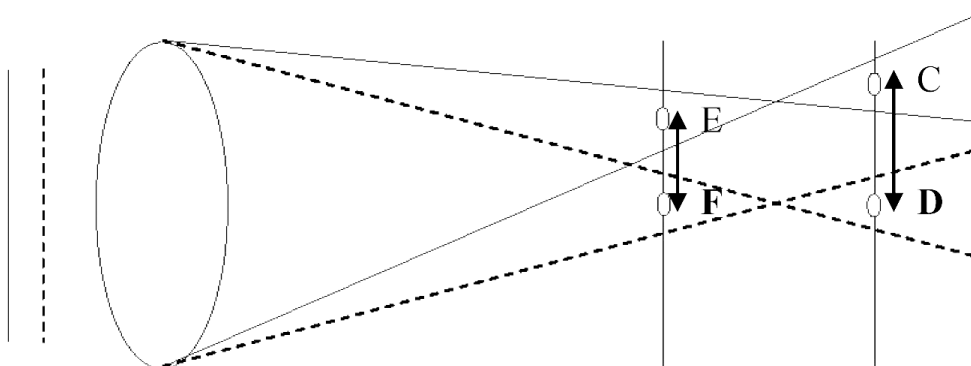
From the present study, simply the more the defocus, the more the errors of ocular aberrations. The most sensitive component to the defocus was astigmatism, followed by sphere, and HOAs component. Even though there was no statistically significant difference due to the small sample size, the trend could 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<sup>(7)</sup>. 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.

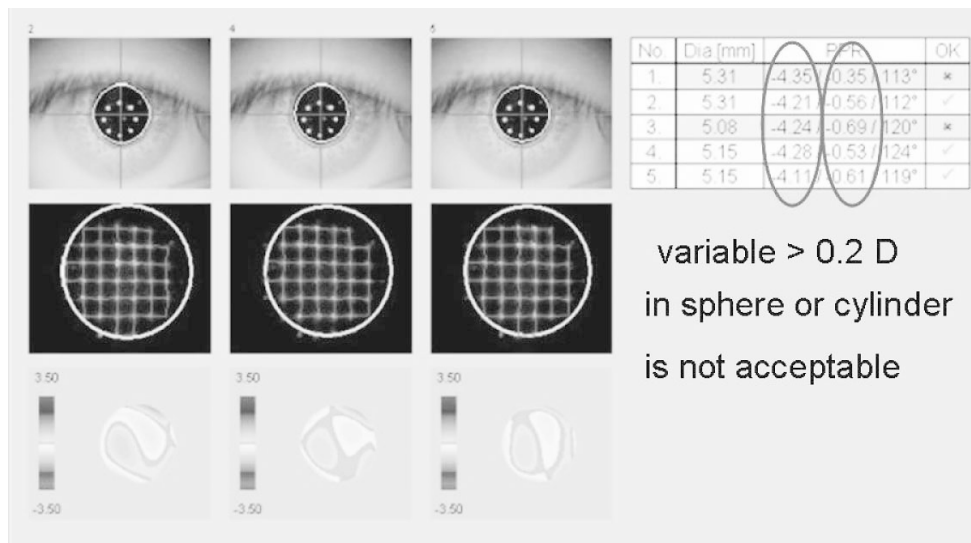
There is also an issue of how many errors one can accept for the laser treatment. Generally, the normal



**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  $\mu\text{m}$  of HOAs component<sup>(8)</sup>. In the present study, 10 mm of defocus produced 0.1  $\mu\text{m}$  errors of HOAs or approximately 25% of the HOAs magnitude in the normal population and 5 mm of defocus measurement produced 0.05  $\mu\text{m}$  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 ศรีวรรณบุรณ์, นริศรา อตุลพันธุ์

**วัตถุประสงค์:** เพื่อหาผลของความคลาดเคลื่อนของการวัดที่ไม่โฟกัสต่อค่าของการกระจายตัวของแสงชนิด Aberrations

**วัสดุและวิธีการ:** การศึกษานี้ทำในผู้ที่มีสายตาสั้นน้อยกว่า -6.00 diopters และสายตาเอียงน้อยกว่า -2.00 diopters จำนวน 20 คนที่ภาควิชาจักษุวิทยา คณะแพทยศาสตร์ศิริราชพยาบาล โดยทำการตรวจวัดการกระจายตัวของแสงชนิด Aberrations ด้วยเครื่อง Zywave Aberrometer® (Bausch & Lomb, USA) ซึ่งจะทำการวัดที่จุดโฟกัสของเครื่อง (ระดับม่านตา) และวัดที่ไม่โฟกัส (5, 10, 15 มิลลิเมตร ที่ระยะในและนอกต่อระดับม่านตา) และนำค่าที่วัดได้ไปคำนวณหาความสัมพันธ์ทางสถิติ

**ผลการศึกษา:** ค่าความคลาดเคลื่อนของการวัดที่ไม่โฟกัสที่ระยะ 5, 10, 15 มิลลิเมตร ที่ระยะในและนอกต่อ ระดับม่านตา (รวม 6 ระยะ) โดยคำนวณเป็น root mean square (RMS) พบว่าในส่วนของคุณค่าสายตาสั้นมีค่า 0.16, 0.44, 0.57 และ 0.21, 0.38, 1.35 D ตามลำดับ ในส่วนของคุณค่าสายตาเอียงมีค่า 0.19, 0.50, 0.80 และ 0.18, 0.52, 1.55 D ตามลำดับ และในส่วนของคุณค่า 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

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