Preliminary Evaluation of SVOne Autorefractor for Low Order Refractive Errors

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BACKGROUND

Smart Vision Labs has developed a smartphone-based autorefraction technology to measure vision imperfection and generate refraction results on the phone. This new device is (1) mobile, (2) low cost, (3) objective, and (4) can be used by caregivers with basic instructions. It can significantly improve the current refraction workflow and prevent the unnecessary loss of vision for 300 million people around the globe and improve educational readiness for children.

Wavefront aberrometry (Shack-Hartmann) can be used to measure the refractive errors of the eye. The traditional wavefront aberrometer is an expensive desktop laboratory instrument which employs a laser, a scientific-grade camera, and a microlens array. We invented a portable aberrometer to dramatically improve the way people get their vision evaluated. Given recent advancements in smartphone technology, we designed a portable aberrometer to work with the camera of a smartphone, combined with an add-on microlens array. The following figure shows the working principle of wavefront aberrometry: light reflecting off the retina encodes the geometrical representation of the refractive errors of the eye (i.e., myopia, hyperopia and astigmatism), and can be measured through a combination of a microlens array and a light detector (i.e., the camera).

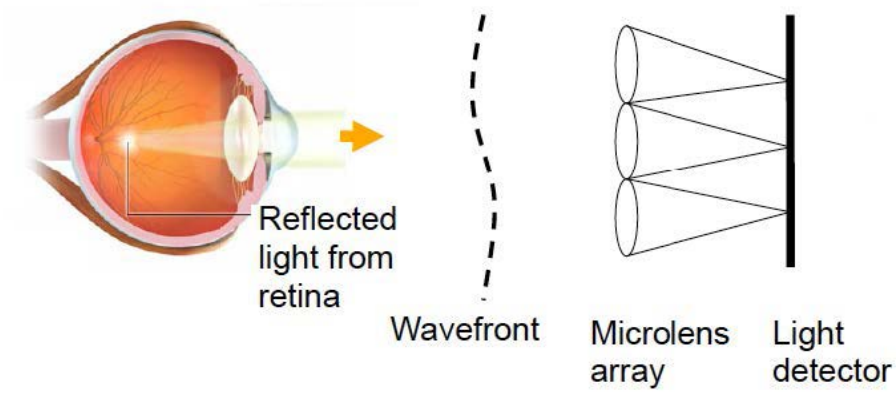


Figure 1. Wavefront aberrometer.

Figure 2 shows the captured raw data from the camera. On the top half of Figure 2, the iPhone camera captures an evenly distributed two-dimensional array of spots with perfect eye optics. On the bottom half of the figure, the iPhone camera captures a distorted two-dimensional array of spots with myopia present. The movement of the spots between the two acquired images represents the slopes of the wavefront coming out of the pupil. With Zernike decomposition, the wavefront aberrometer is able to reconstruct the wavefront and produce the Zernike coefficients for up to 35 terms. The second order Zernike terms can be used to convert to eyeglasses prescriptions. The smartphone-based device is both an aberrometer and an autorefractor.

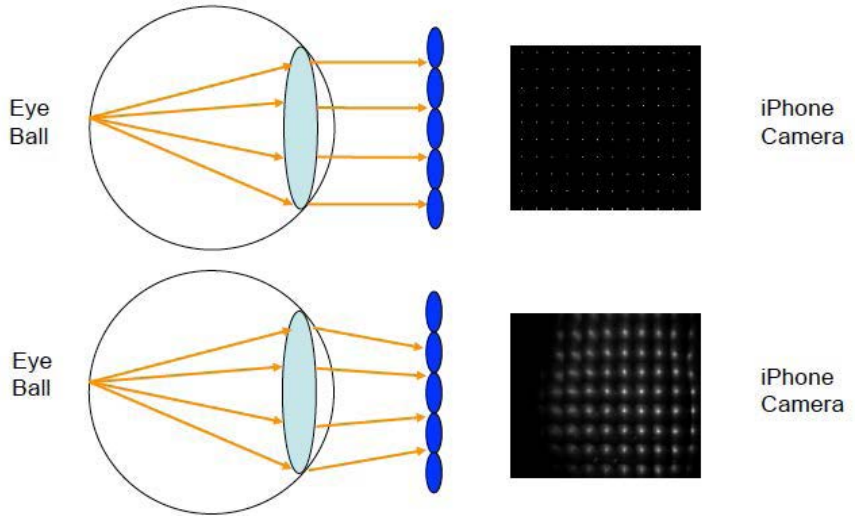


Figure 2. Shack-Hartmann spots.

Figure 3. SVOne Autorefractor.

STUDY OBJECTIVE

The objective of the study is to validate the feasibility of using the SVOne prototype in a clinical setting and to compare the measurement results to subjective refraction.

METHODS

Subjects To evaluate the preliminary performance of the SVOne for low order refraction errors (i.e., sphere, cylinder, and axis), we recruited 20 adult volunteers at Drs. Farkas, Kassalow, Resnick & Associates. We tested both eyes of each subject. The testing subjects have a large range of refractive errors:

1. Spherical refractive errors: between -11.5 diopters and 1.75 diopters (D)
2. Astigmatism: between 0 and -2.5 D

Procedures
1. Autorefraction: SVOne (1 measurement)
2. Autorefraction: Nidek Tonoref II (4 measurements)
3. Subjective refraction (1 measurement)

Data To compare measurement results to subjective refraction, we convert sphere (S), cylinder (C) and axis (θ) to power vector [1], using the equations 1-3. This is necessary since one cannot compare astigmatisms directly without the same axes.

$$J_{45} = (-C/2)\sin(2\theta) \quad (1)$$
$$M = S + C/2 \quad (2)$$
$$J_{180} = (-C/2)\cos(2\theta) \quad (3)$$

Out of the 20 patients, one patient has refraction errors (subjective refraction OD: -11.5, -1.25, 20; OS: -11, -1.75, 170; SVOne refraction OD: -9.75, -0.25, 53, OS: -9.25, -1.25, 1) that surpass the measurement range of SVOne (sphere range: between -10D and 10D, cylinder range: between -5D and 5D). The following data analysis excludes this patient's measurement results.

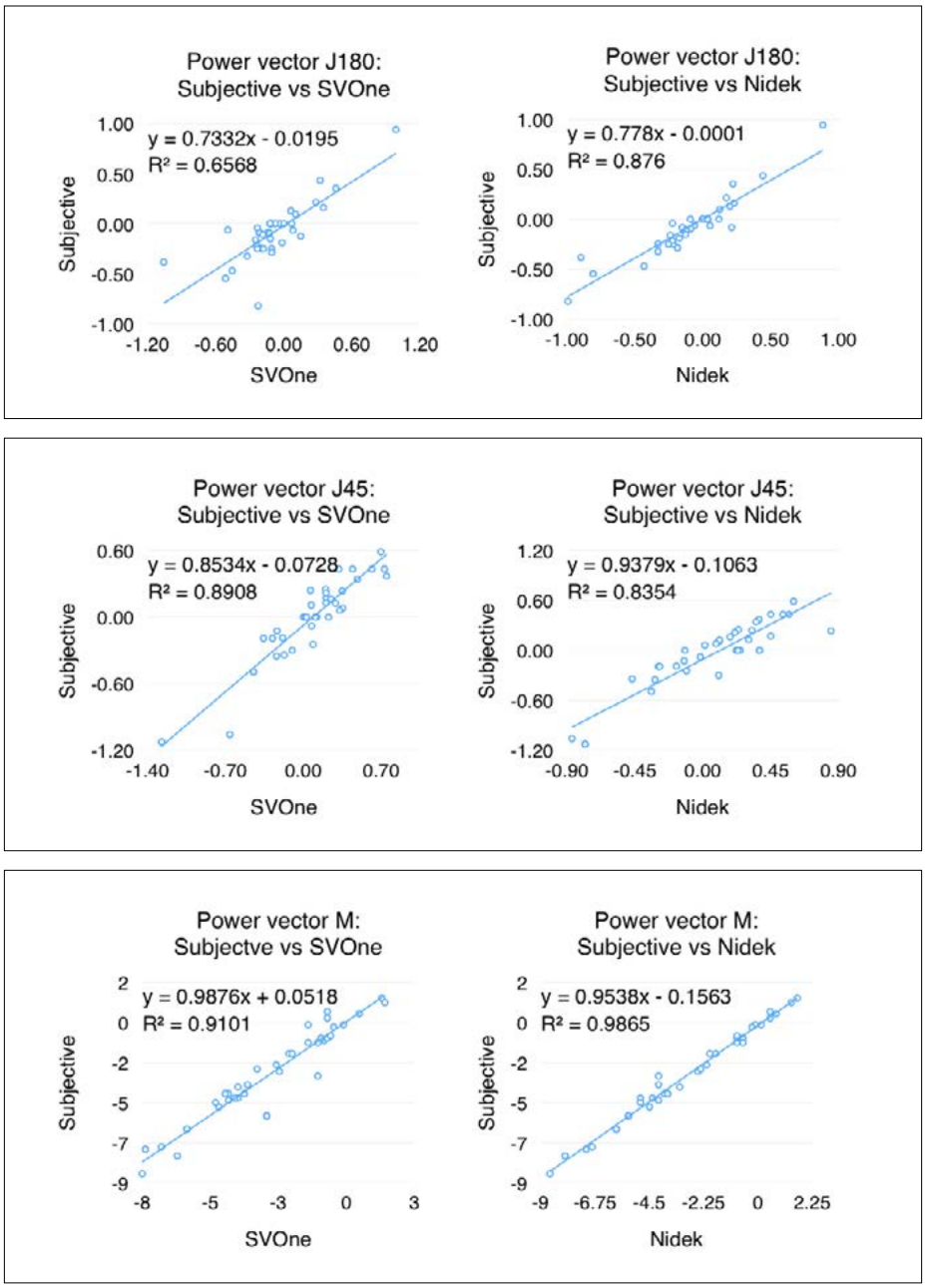
To illustrate the performance of the SVOne, we plot the derived power vectors J_{45}, M, and J_{180} from the SVOne and subjective refraction, and from the Nidek autorefractor and subjective refraction. To demonstrate the data set similarity, a linear regression line is fitted to each plot. Both the first order equation and R^2 value are derived from the regression line.

Accuracy From the linear regression line fitting, the first order coefficient (A) and the offset (B)

$$Y = AX + B$$

indicate the similarity of the X and Y data sets. When A=1 and B=0, Y=X. In this case, Y is the subjective refraction, and X is either the SVOne measurement result or the Nidek measurement result. For power vector M, both SVOne and Nidek show good matching results to subjective refraction, with A=0.99 and 0.95 and B= 0.05 and -0.16, respectively. For power vectors J_{45} and J_{180}, both SVOne and Nidek show moderate deviation from subjective results. This is due to the range limitation of the data sets. The majority of the test subjects have minor astigmatism and the data distribution is limited. To develop an accurate regression fitting, a larger range of astigmatism measurement is desired.

One also notices that SVOne has more outliers than that of the Nidek. This could be due to two factors: alignment and single data point. During testing, we took only a single measurement with the SVOne on each patient using a R&D version of the software. With the commercial release of the software, the device will automatically take 5 measurements on each patient. The multiple data points will improve accuracy and reduce data uncertainty due to eye movement, misalignment, and measurement variation.



SUMMARY

The preliminary testing shows that SVOne has the ability to compete with much more expensive autorefractors. We will conduct more detailed testings to address quantified performance in the very near future.

REFERENCE

[1] Thomas Salmon and Corina van de Pol, Evaluation of a clinical aberrometer for lower-order accuracy and repeatability, high-order repeatability, and instrument myopia, Optometry- Journal of American Optometric Association, Volume 76, Issue 8, August 2005, Pages 461-472.