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OPTOMETRY AND VISION SCIENCE

GUEST EDITORIAL

Aberrometry: Clinical and Research Applications

Optometry has a history of taking the lead in correcting the optical defects of the eye. While the primary definition of optometry has changed as the profession has expanded its scope of practice, the secondary definition of optometry has remained unchanged. The second definition of optometry is *the use of an optometer*. The definition of optometer is *any of several objective or subjective devices for measuring the refractive state of the eye.* There is no better way of measuring the refractive state of the eye than to measure its wavefront error using state-of-the-art aberrometers. State-of-the-art aberrometry opens doors for new research and clinical applications while creating a new set of issues and opportunities. We will briefly discuss a few in this editorial.

An Opportunity

State-of-the-art aberrometry provides detailed analysis of the optical performance of refractive corrections. That is, it provides a sensitive tool for measuring how optical aberrations of the correcting devices combine with the subject's own aberrations. For example: What are the sources of optical aberrations in progressive spectacles, and soft and rigid contact lenses? What amount of optical degradation is induced or reduced by different types of corneal and intraocular surgeries? The answer to these questions provided by aberrometry will lead to an optimization of a variety of correcting devices and procedures and to a better customization of the individual correction.

An Issue

Aberrometry is rapidly making its way into the clinic, yet there are many technical issues still being carefully looked at in the laboratory. While the Hartmann-Shack aberrometer has been the most widely adopted, other approaches are being used both in the laboratory and in commercially available instruments. Are all aberrometers equivalent? Are there particular types of aberrometers that are more appropriate for a particular application? What is the ideal pupil sampling configuration? Are measurements affected by defocus or by wavelength? Aberrometry measures the contribution of only one source of degradation (aberrations). How do we incorporate the effects of scattering into the optical quality, and what is the best method to measure its contribution? Aberrometry itself is not a closed technology. New research and new technology will continue to contribute to a better understanding of the measurement and a more complete set of tools.

An Opportunity

State-of-the-art aberrometry provides necessary data for designing ideal corrections for the eye. Receiving less attention is the fact that the same aberroscopic data allow for a noninvasive microscopic view into the living eye. Said differently, the optical aberrations of the eye limit the view into the eye. If the eye's aberrations can be reduced, the view through a dilated pupil will be improved. The confocal adaptive optics scanning laser ophthalmoscope developed by researchers under the leadership of Dr. Austin Roorda at the University of Houston's College of Optometry is providing the first noninvasive real-time microscopic views of individual optical sections of a patient's retina (layer by layer). With this device it is possible to see white corpuscles flowing in 7 micrometer capillaries. Noninvasively sectioning a little deeper using a confocal sectioning technique, individual photoreceptors on the order of 2 micrometers in cross section can be readily visualized. Imagine the opportunities to noninvasively study the living structure of the eye at the cellular level in its healthy and pathological states! We will soon be monitoring, photographing, and evaluating on a microscopic level new medical therapy designed to alter the natural history of diseases that affect the retina, including diabetes and high blood pressure. As the technology becomes standardized and the components decrease in price, such devices will quickly work their way into numerous research and clinical environments. This new instrumentation will significantly increase the probability of developing therapy that prevents or significantly alters the natural history of diabetic retinopathy and ocular hypertension, as well as other blinding eye diseases.

The Issue of Calibration

If the calibration of an aberrometer is incorrect, correction designs based on the measurement or any comparison to other measurements from other clinics and laboratories will also be incorrect. ANSI standards need to be developed and approved. This includes recommendations for a set of calibrated schematic eyes to be used to help ensure that each aberrometer is calibrated in a consistent and accurate manner. Manufacturers need to provide to the end user a calibration set of schematic eyes with an appropriate adapter to properly align the schematic eyes to their particular instrument. We are pleased to report that an ANSI Standards Committee has been formed and has been charged with developing standards for reporting the optical aberrations of the eye and proposing recommended methods of calibration. These issues will be put to rest, hopefully within the near future. In the mean time it is wise to question results from clinics and labs that do not provide calibration data to insure that their aberrometer was properly calibrated.

An Opportunity

Wavefront sensing provides the fundamental information used in the design of a variety of ideal corrections (e.g., contact lenses, intraocular lenses, corneal refractive surgery, inlays, etc.) and to evaluate the success of each design in minimizing the wavefront error of the eye. This incredible promise is the high octane fuel that shapes, molds, and guides an expanding billion dollar industry. Yet there are unanswered general questions that apply across approaches and numerous specific questions for each approach. Here we list a few of the general questions needing attention.

- Aberrometers measure the monochromatic aberrations of the eye, yet the eye operates in a polychromatic world. How do we use the monochromatic wavefront error to best optimize polychromatic performance?
- What should our goal be? Is it really to minimize all aberrations or only selected aberrations?
- Given that it is impossible to eliminate all of the optical aberrations of the eye, can we create an optimized set? If so, what is the optimized set?
- What criterion determines the optimal far-point for any given set of aberrations?
- How do aberrations change as the crystalline lens changes in the accommodation process?
- How do aberrations change with reading?
- Are aberrations involved in the emmetropization process (both in humans and animal models)?
- How do aberrations change across the visual field?

An Issue

Will a patient's neural system be able to capitalize on the increased contrast and spatial detail contained in an optimized retinal image? It is well known that if the visual system is deprived of good retinal imagery, the deprived eye will become amblyopic. Further, there is a critical period early in life over which good retinal imagery allows the visual system to optimize its' performance. This fact poses several interesting questions including:

- Will we need to provide an ideal correction early in life to achieve the maximum optimization of visual performance?
- How age dependent are the visual gains?
- If retinal image quality is optimized late in life, will vision improve?
- If so, how much and how long will it take?
- Are there significant advantages to having an optimal set of aberrations such as an increased depth of focus?
- How good is good enough? Can good enough be defined?

An Issue

Assuming we can achieve ideal corrections that minimize the aberrations of the eye, do such corrections create a new and adverse set of problems? That is, what risks do ideal corrections pose? For example:

- Will flash bulbs become photo-coagulators?
- Will the dot matrix of newsprint provide unacceptable resolution?
- Will the TV dot matrix provide unacceptable resolution?
- Will photo-reactive retinal disease be increased?
- Will aliasing due to photoreceptor under-sampling be a intolerable?

An Opportunity

Knowing the wavefront error of any optical system fundamentally defines the optical quality of the system. Once known, wavefront error can be used to calculate numerous other metrics of optical quality each having advantages and disadvantages. The recommended standard for specifying the wavefront error of the eye is to fit the error with a normalized Zernike expansion.[1] The normalized Zernike expansion parcels the error into unique building blocks (prism, astigmatism, defocus, coma, spherical aberration, etc.). A distinct advantage of the normalized Zernike expansion is that coefficients for each Zernike mode specify its relative contribution to the total RMS error. However, RMS wavefront error is not highly correlated to visual performance, which is highly dependent upon the distribution of the wavefront error across the pupil. Wavefront error can be used to calculate other metrics of optical quality that better correlate with visual performance. Many old and new metrics are currently being investigated by several groups. It is likely that some will be very predictive of certain visual tasks and not as predictive of other visual tasks. It is also likely that several will be statistically equivalent. What is needed is a set of metrics that are predictive of a wide range of visual performance measures.

An Issue

What are the clinically viable methods for evaluating visual performance with increased or decreased amounts of aberrations (induced or reduced by surgery or other non-optimal corrections)? Which of the viable methods is best suited for a busy practice? Given that high contrast visual acuity is reasonably insensitive to subtle changes in optical quality, are there other methods of evaluating visual performance as efficient to administer in the clinic (as high contrast acuity), yet more sensitive to subtle changes in optical quality? Does the Pelli-Robson Chart or the Regan Chart meet this need? Does low contrast logMAR letter acuity meet this need? Are these metrics or others that we might create more predictive of visual satisfaction in life than high contrast acuity? Or are we chasing an illusion?

Clinically viable aberrometry presents numerous opportunities for basic and clinical research, the results of which are already improving the vision of our patients, our view into the eye, and will soon be improving therapy designed to alter the natural history of blinding eye disease. It is an exciting time for visual optics.

REFERENCE

1. Thibos LN, Applegate RA, Schwiegerling JT, Webb R. Standards for reporting the optical aberrations of eyes. J Refract Surg 2002;18: S652–60.

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