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INADEQUACY OF ZERNIKE POLYNOMIALS FOR ACCOUNTING THE VARIABILITY OF WAVEFRONT MEASUREMENTS

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Wavefront measurements have been crucial in vision science and ophthalmology, especially for wavefront-driven corrections like laser refractive surgeries and customized contact lens design. However, the accuracy of these corrections hinges on precise measurements. In clinical practice, multiple measurements are taken from a patient's eye during each session to avoid ambiguous conclusions from a single measurement. Despite these efforts, variations in measurements occur due to aberrometer misalignments, pupil size, lens position, and eye accommodation. These variations directly impact custom vision corrections, leading to errors. However, comprehensive studies on these dynamics are lacking, but understanding them is crucial in vision science. Previous studies have found that the variability in repeated measurements is significant, as indicated by changes in Zernike coefficients. However, these studies have only examined this variability through the Zernike coefficients themselves. In contrast, this study uniquely investigated their variability using the raw local slope data from wavefront measurements. The least squares estimation was implemented to analyse data from patients with astigmatism, myopia, keratoconus, and keratoplasty. Further, measurement noise was simulated using normally distributed random numbers, with signal-to-noise ratios (SNR) varied between 20 dB and 80 dB. The SNRs for individual Zernike coefficients have been determined. The results from patients showed that most Zernike coefficients had SNRs above 10, indicating minimal measurement variation impact. A few Zernike modes had SNRs below 2 for some patients. The study concludes that it is crucial to balance the addition of more Zernike modes with measurement variability to avoid introducing errors in custom vision corrections. Moreover, the results challenge the existing findings and suggest opportunities for deeper analysis and new insights.

Keywords: Least squares estimation, Signal-to-noise ratio, Variability, Wavefronts, Zernike coefficients