EVALUATION OF DYNAMIC WAVEFRONT ABERRATION MEASUREMENT

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Purpose

The eye is in constant motion, but most objective measurements are taken as a single measurement. By recording a sequence of measurements, a better evaluation of the eye condition can be obtained. This is particularly important for correcting aberrated eyes with custom contact lenses, where translation and rotation of the correction directly affects the visual quality. In addition, accommodation may play a significant role in the calculation of refraction from a wavefront measurement.

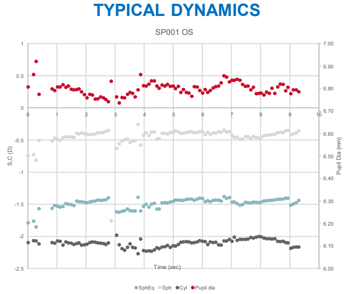
There is often a difference between a subjective manifest refraction and objective measurement.[1,2] Autorefractors and aberrometers both suffer from "instrument accommodation" where the eye accommodates during the measurement process. There are several factors that are important:

- Fixation target
  - Image content
  - Astigmatism correction
  - Fogging
- Eye condition
  - Tear film
  - History
  - Refractive state

These factors make it complicated to determine basic refraction.

Most autorefractors and aberrometers measure the eye with a single snapshot. By recording a dynamic sequence[3], our hypothesis is that we can improve on the objective refraction accuracy.

TYPICAL DYNAMICS

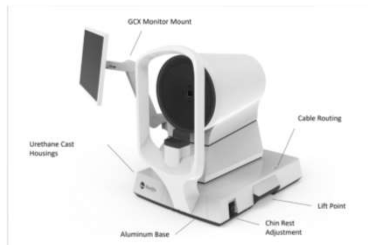


Dynamic refraction parameters

Methods

DYNAMIC ABERROMETER

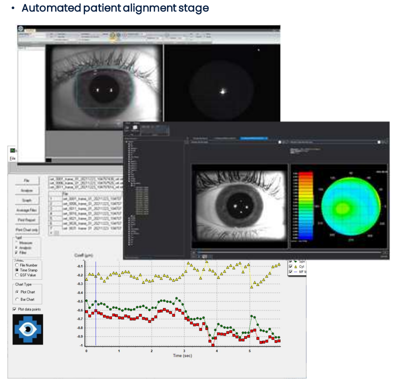
A dynamic wavefront measurement instrument was developed using a high-resolution Shack-Hartmann wavefront sensor. This was combined with a large field of view imaging camera and corneal topographer to provide a platform for dynamic measurement. The system used two synchronized cameras to measure the eye at up to 54 fps. Instrument accommodation was studied by comparing maximum measured sphere to average sphere in a 10 second sequence, for five subjects, ages 22-42. Subjects were measured five times each with three different operators.



Specifications

A multi-function system capable of measuring:

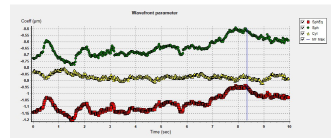
- **Dynamic wavefront aberrometry**
- **Dynamic iris image**
- **Contact lens fit**
- **Refraction**
- **Dynamic corneal topography**
- **Dynamic keratometry**
- **Pupil dynamics**
- **Accommodation range**
- **24 mm horizontal field of view**
- **Measurable range:** sphere and cylinder measurements in 0.01 D increments. Spherical equivalent range (7 mm pupil) -22 to +16 D. Cylinder range (7 mm pupil) 14 D
- **Axis** in 1° increments
- **Maximum wavefront diameter** 8.5 mm
- **Zernike terms** displayed through sixth order
- **Measurement spatial resolution** 116 µm (approximately 2870 measurement points for a 7 mm pupil)
- **Eye image field of view** 24 mm
- **Subjective refinement** with integrated eyechart
- **Live wavefront and refractive displays**
- **Automated patient alignment stage**



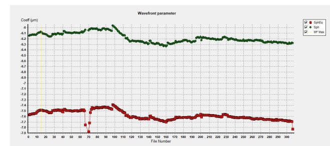
Results and Discussions A

DYNAMIC ABERROMETER

For all subjects, the measured sphere varied during the 10 second measurement sequence. Data was acquired at 10 or 54 fps



Refraction parameters (Seq, Sph and Cyl) as a function of time for a 23 y.o. female subject

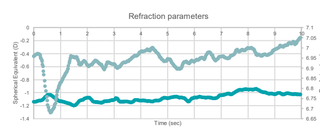


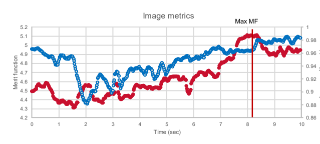
Refraction parameters (Seq, Sph) for a 25 y.o. male subject

FINDING OPTIMUM REFRACTION

- Merit function parameters
  - Seq, pupil size, image quality
  - Find maximum MF in sequence
  - Adjust weights to match clinical data

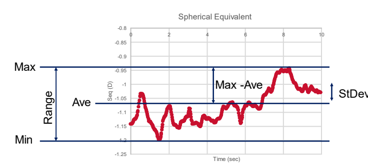
$$MF = W_{SEQ}SEQ + W_P P_D + W_{IQ}IQ$$





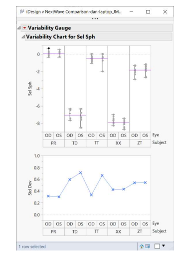
Refractive parameters with merit function calculation. W_{SEQ}=3, W_p=1, W_{IQ}=1. The maximum MF is found with a simple search.

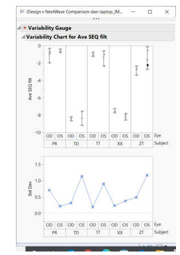
DATA ANALYSIS

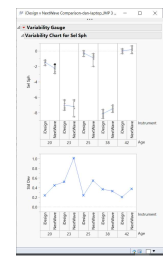


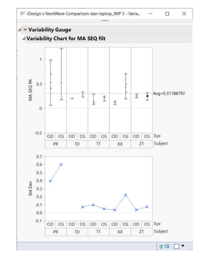
Data filtered to remove outliers and blinks

Results and Discussions B

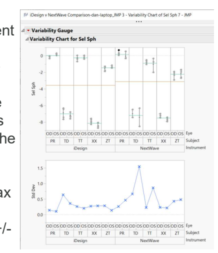








The maximum (most hyperopic) measurement was on average 0.25D more than the average sphere. In the young group (ages 20-25) the average difference was 0.28 +/-0.1 D while in the old group (age 38-42) the difference was 0.21+/-0.07 D. The max sphere values were more myopic by -0.34+/-0.35D compared to a commercial aberrometer.



Conclusions

The MF selection matched closer to iDesign refraction values than the sequence average. Overall, compared to iDesign, the NextWave measurement was slightly myopic in the younger group but hyperopic in the older. This may be due to the very simple fixation target in this early prototype which is planned to be improved in future versions

The merit function approach gave more consistent results with fewer outliers.

References

1. *Bullimore MA, Fusaro RE, Adams CW, "The repeatability of automatic and clinical refraction," Optom Vis Sci 75(8) 617-22 1998.*
2. Charles E. Campbell, T.D. Raymond, C. David Baer,[2] Dan Neal "Comparison of repeatability of manifest refraction and instrument-based refraction," ARVO 2011
3. *Dan Neal, Wei Xiong, TD Raymond, Jason Hoy, Kavita Dhamdhere, Sanjeev Kasthurirangan," Estimation of visual acuity from dynamic wavefront tear film measurement," ARVO 2018*