Fourier algorithms hold promise for wavefront treatment of aberrated eyes

Dermot McGrath
in Paris

FOURIER algorithms offer a promising new technique to drive wavefront-guided laser corrections that may prove more effective than Zernike polynomials in treating highly aberrated eyes, according to a number of researchers.

John Vukich MD and Julian Stevens FRCS told delegates here at the XXII Congress of the ESCRS that the two-dimensional Fourier algorithm represented another important step towards improving the precision of wavefront-guided laser ablations and reducing the aberrations typically induced by LASIK.

"Zernike polynomials have served us very well but their limitations are clear when it comes to treating complex visual systems. The Fourier algorithm, by contrast, represents a new way of calculating wavefront-driven shapes that uses all the data from the Hartmann-Shack aberrometer and allows for more accurate ablations and improved visual outcomes," said Dr Vukich, Madison, Wisconsin, US.

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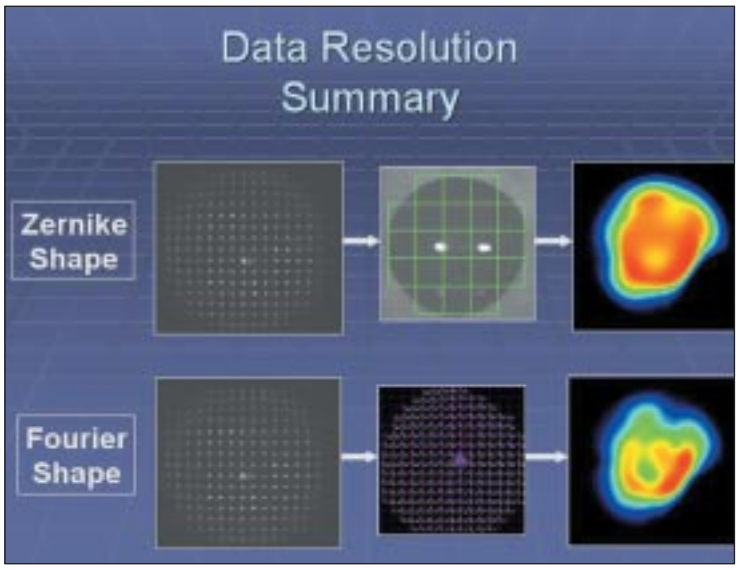
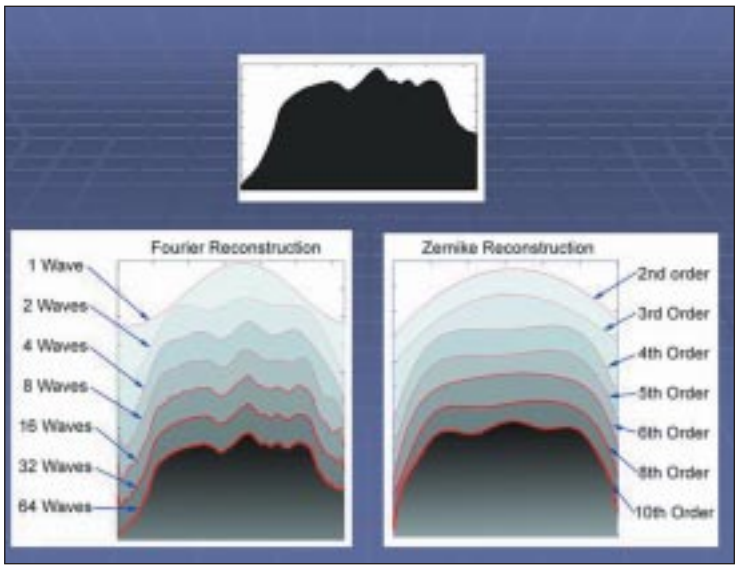
>
> *John Vukich MD*

Fourier analysis is a mathematical tool named after the French physicist Jean Baptiste Joseph Fourier (1768-1830), noted Dr Vukich. He explained that Fourier configurations are widely used in solving optical, astronomy, and quantum physics problems.

Using all the spots

The benefit of using Fourier analysis in refractive surgery is that it can be used to fully map Hartmann-Shack data to derive a precise ablation shape. Unlike Zernike polynomials, which take a subset of Hartmann-Shack lenslets as the raw data for generating the wavefront, Fourier uses all of the approximately 240 Hartmann-Shack spots in a 7.0 mm pupil to define the wavefront pattern.





The result, said Dr Vukich, is an image of greater fidelity because there are more data points available for interpretation and the derived wavefront shape is a much better characterisation of the actual wavefront that exits the patient's eye.

Dr. Vukich underscored the difference between the algorithms using shapes such as a human face and the Lincoln head penny to illustrate how the law of diminishing returns applied to the Zernike images beyond the 6th order while Fourier maintained high fidelity to the 10th order and beyond.

"When we look at the Fourier transformation where each spot is sampled individually, there is no need to go back to a centre spot and in fact all of the spots are summated to produce the shapes of the available information. If we translate these findings to aberrated eyes, then the new algorithm offers greater potential for restoring excellent quality of vision," he said

Discussing whether there was actually a real need to find an alternative to Zernike polynomials, Dr Vukich said that while Zernike works very well in telescopes and optical lenses it has inherent limitations in defining the complexity of the human eye.

"There are peer reviewed studies demonstrating that Zernike polynomials may not represent all of the known aberrations especially in significantly aberrated eyes, for example those with keratoconus or irregular astigmatism or other either induced or naturally occurring aberrations," he said.

He added that another inherent problem with Zernike, unlike Fourier, is that linear defects cannot be characterised by polynomials and aberrations are smoothed out as a pattern becomes more complex, so Zernike loses fidelity in mapping a highly aberrated eye.

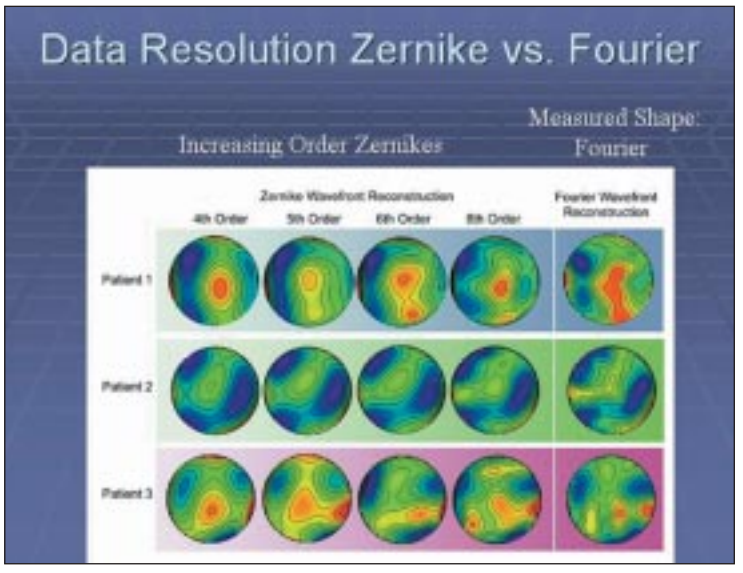
Clinical results

In a separate presentation, Julian Stevens MD, of Moorfields Eye Hospital, London, said that he had achieved extremely promising clinical results using Fourier algorithms with the Visx CustomVue platform for re-treatments after previous refractive surgery or for the treatment of highly aberrated eyes. While acknowledging the usefulness of obtaining a more accurate wavefront profile for such patients, he also stressed the importance of factors such as surgical technique and proper follow-up care in order to achieve predictable and stable visual outcomes.

"The application of what is really a high-fidelity reconstruction still depends on us to translate that fidelity into the surgery itself and also in terms of managing the healing effect, particularly with highly aberrated eyes," he said.

He also emphasised the importance of ensuring that the raw wavefront data to be interpreted by the Fourier algorithm is not unduly distorted by irregularities with the tear film.

"If you have an eye where the tear film is very irregular and you have dry spots and basically the cornea is so irregular that you're experiencing fast break-up time, then really one has to consider a manual PTK smoothing. We must remember that whatever reconstruction of the wavefront we end up with, it can only be as good as the data that has been inputted in the first place."



Courtesy of John Vukich MD

In treating a number of aberrated eyes with the Fourier-driven CustomVue system, Dr Stevens said the results had been very encouraging, with a consistent reduction of higher order aberrations, improved contrast sensitivity and night vision and significantly less visual symptoms. He said, however, that it was still too early to determine statistical significance for this group of patients or to determine if the likely advantages of Fourier algorithms would carry over into routine care patients as well.

"It is still not clear whether the higher fidelity images will be translated into better ablations for routine care. But it certainly holds promise for more complex optical shapes and therapeutic applications and I think will be worth watching in the future," he said.

John Vukich MD
javukich@facstaff.wisc.edu

Julian Stevens FRCS, FRCOphth
julianstevens@compuserve.com