Wavefront Customized Ablations With the WASCA Asclepion Workstation

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ABSTRACT

PURPOSE: WASCA (Wavefront Aberration Supported Cornea Ablation) is a method for wavefront-guided ablation. This new method records all existing eye aberrations with the Asclepion Wavefront Aberrometer and calculates the customized pattern for laser correction. We measured the low and high order aberrations of eyes before and after PRK and LASIK, as well as before and after flap creation.

METHODS: The Asclepion Shack-Hartmann aberrometer was used to measure wavefront aberrations. Preoperative and postoperative measurements were made following both PRK and LASIK performed with conventional software, modified Aberration-free Profile (AFA) software, and specially designed WASCA software. Surgery was performed with the Meditec MEL-70 G-scan excimer laser. Additionally, measurements were made before and after flap creation only (10 eyes).

RESULTS: There was a significant difference between preoperative and 1-month postoperative high order aberrations, with notable increases following conventional PRK and LASIK and less increase following modified AFA PRK and LASIK. Flap creation only changed the higher order aberrations slightly, and caused a shift toward hyperopia. In the eyes that received WASCA correction with PRK or LASIK, at 3 months postoperative the high order aberrations averaged an increase of 1.3 times for PRK and 1.8 times for LASIK. Both the AFA and WASCA treatments demonstrated improved outcomes in comparison to conventional PRK and LASIK.

CONCLUSION: Wavefront mapping of the eye and wavefront-guided ablation with the Asclepion Aberrometer can be used for optimizing the results and fine-tuning visual performance after laser vision correction. WASCA PRK appeared to result in better outcomes than WASCA LASIK.
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Wavefront technology has been used in our efforts for customized treatments in order to achieve better results after photorefractive keratectomy (PRK) and laser in situ keratomileusis (LASIK). At the University of Crete, we are using the WASCA Workstation with the MEL-70 excimer laser, both from Asclepion Meditec, for a series of clinical trials of wavefront customized corrections.

The Asclepion aberrometer used for the wavefront mapping of the eye is a Shack-Hartmann sensor with a resolution of 210 µm in the corneal plane. An array of microscopic lenses forms the heart of the Shack-Hartmann sensor. This array dissects the incoming light into a large number of subapertures, and then measures the wavefront slope across each subaperture. The sensor information is used to analyze the optical properties of the eye that created the wavefront. Starting at the retina, an ideal wavefront is generated, which passes through the optical path of the eye. As the wavefront exits the eye, it contains a complete map of the eye's aberrations for analysis by the sensor. When the sensor receives the wavefront, a complex series of analyses are performed to provide a "complete" picture of the optical path of the eye. This information may then be visualized and reported in a number of formats, including wavefront error and Zernike polynomials. The information derived from the wavefront analyzer is presented in a color map and one can choose to view only higher order aberrations, or all aberrations, such as spherical, coma, etc. (Figs 1, 2).

PATIENTS AND METHODS

From routine examination of patients, we see that third and fourth order Zernike coefficients can be plus or minus and differ from patient to patient; they are sometimes reduced or increased after surgery. However, when we reviewed many cases, the most remarkable change seemed to be an increase of the middle term of fourth order

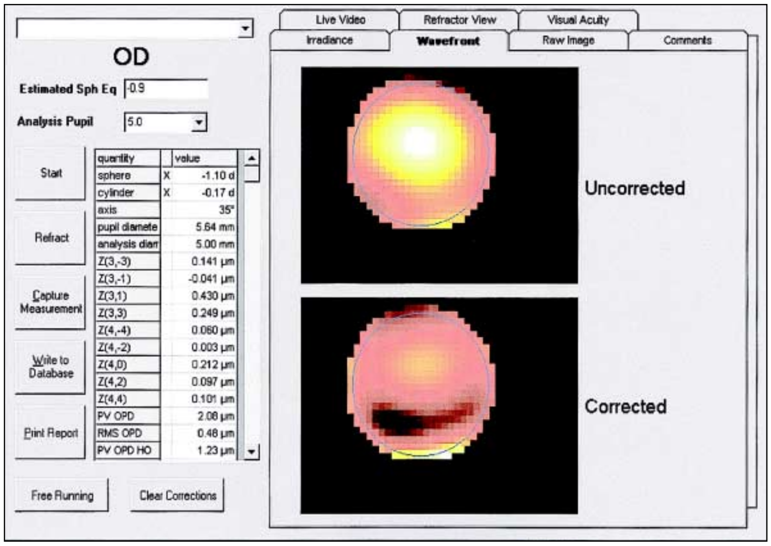

Figure 1. Asclepion Analyzer main screen shows the sphere, cylinder, and the higher order Zernike coefficients up to the fourth order. The total aberration map is on the top and the bottom shows the higher order aberration map.

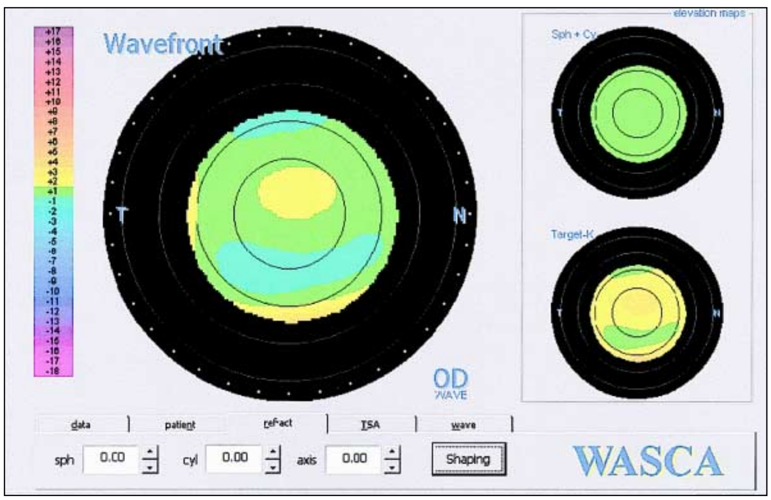

Figure 2. The WASCA program shows the middle of the wavefront map of the eye to be treated, and the calculated ablation map (below right).

Figure 3. Zernike coefficients of third and fourth order of one individual for different pupil sizes.

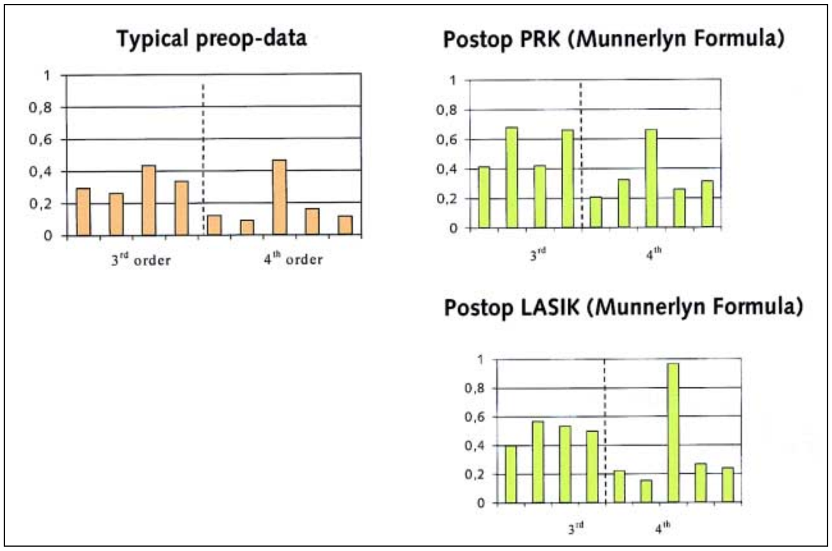

Figure 4. Mean values of Zernike coefficients third order (four terms), and fourth order (five terms). On the left are the preoperative data and on the right, the data from the 3-month postoperative examination patients who underwent PRK or LASIK.

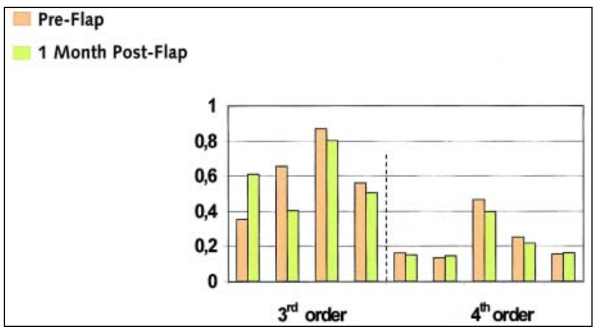

Figure 5. Mean values of Zernike coefficients of third and fourth order before, and 1 month after flap creation.

aberrations—spherical aberration. This is not surprising; it indicates that our treatment diameters were not the optimum size. An optimum size, which might have a minimal increase in spherical aberration, would be a diameter 2 mm larger than the pupil diameter under scotopic conditions. This is not possible for eyes with a scotopic pupil diameter more than 6.5-mm because the treatment diameter is limited by the corneal diameter as well as the ablation depth, and in case of LASIK, the flap dimensions.

Another characteristic of these coefficients is that they depend strongly on pupil size during measurement.

Figure 3 shows one case where the coefficients were measured for three different pupil sizes. Changing the pupil size from 5 to 6 mm means roughly doubling the coefficients.

All patient data for the higher (third and fourth order) Zernike coefficients were measured and calculated using the same pupil size—preoperatively as well postoperatively—in order to make an appropriate comparison. All the values for the Zernike coefficients presented in this study are the absolute values of the measured coefficients that were plus or minus.

If we want to correct all the aberrations of an eye in our effort to achieve better vision for patients, we must study all parameters involved with LASIK or other refractive procedures. The correction of lower order aberrations (defocus, astigmatism) are not enough to create an optical system without aberrations. With the new wavefront technology, we can measure all aberrations of the eye: lower order aberrations such as defocus and astigmatism, and higher order aberrations such as spherical aberration and coma.

RESULTS

Conventional PRK and LASIK

We studied wavefront measurements from patients preoperatively and compared them to postoperative measurements (Fig 4). We studied two groups of patients, one with photorefractive keratectomy (PRK) and a second with laser in situ keratomileusis (LASIK) for myopia. For both groups, the attempted correction was a mean -5.75 ± 1.00 diopters (D). We measured wavefront aberrations for the same pupil diameter preoperatively and postoperatively, and each coefficient presents a mean value from 20 cases (Fig 4).

Postoperatively, higher order aberrations increased in both groups, but more so in the LASIK

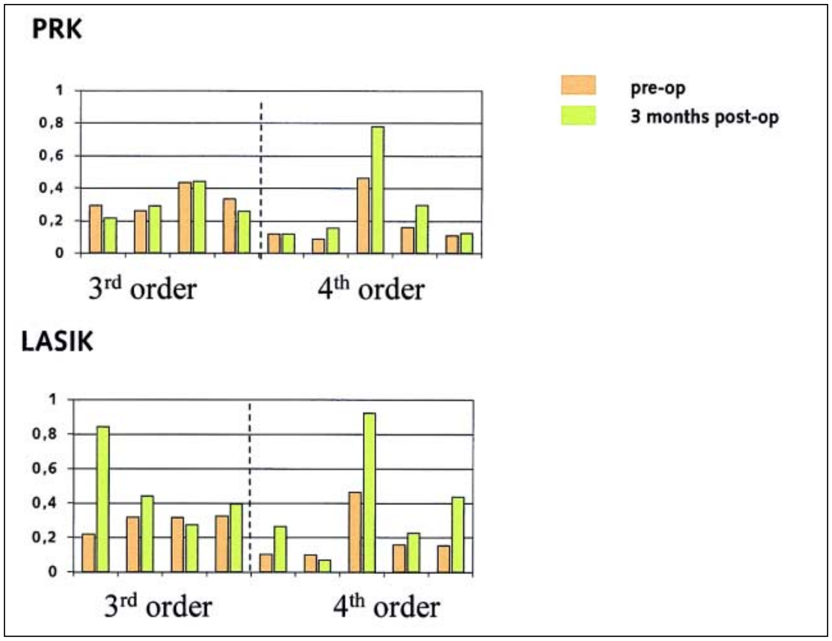

Figure 6. Zernike coefficients from third and fourth order using the AFA profile and WASCA higher order aberration correction.

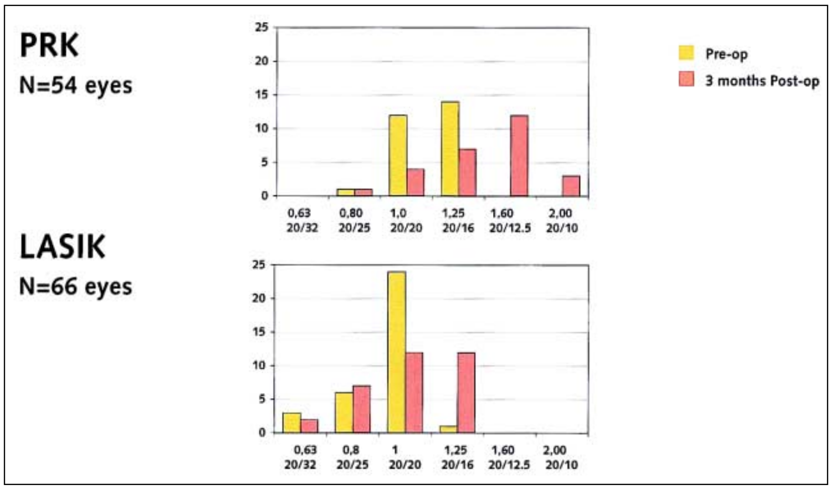

Figure 7. Best spectacle-corrected visual acuity for PRK and LASIK eyes, preoperative and 3 months postoperative.

group. Hence, we began to modify the laser algorithm for corrections that would result in as little higher order aberration as possible. We named the new profile, AFA (Aberration-free Profile); it is the Munnerlyn profile with more ablation in the midperiphery of the ablation area, and leads to a partially prolate cornea inside the treatment zone.

Modified AFA PRK and LASIK

With the AFA profile, we performed PRK (N=44) and LASIK (N=52) for myopia and astigmatism. Our results showed that the high order aberrations measured postoperatively were less than when we used the simple Munnerlyn profile in both PRK and LASIK groups. Of course, there was still some increase in higher order aberrations postoperatively. They were greater in the LASIK group, and we speculate that creation of the flap may affect these high order aberrations.

Flap Only Measurements

We also studied higher order aberrations in 10 eyes with flap creation only. One month after flap creation, we measured the wavefront aberrations. A comparison before surgery to 1 month after flap creation revealed that the higher order aberrations were changed (Fig 5). Creation of the flap had a hyperopic effect, so myopia was slightly decreased. These results are under consideration for publication.

WASCA PRK and LASIK

For the correction of higher order aberration, our procedure was as follows:

For PRK patients, we measured preoperative wavefront aberrations and with special software (WASCA, Fig 2), we corrected not only the lower order but also the higher order aberrations.

For LASIK patients, we did not employ preoperative wavefront calculations for correcting the higher order aberrations, because we saw that the aberrations were changed with the flap creation. For LASIK patients, we used a two-step technique. First, we created the flap, and 1 month afterward obtained values from the new wavefront aberration map. Second, we planned our corrections for lower (defocus, astigmatism) as well as higher order aberrations; eyes received wavefront-based customized ablation (WASCA correction, Fig 2), using the wavefront data from the examination 1 month after flap creation.

The results for PRK (Drs Pallikaris and Dausch) and LASIK (Dr Pallikaris) patients are presented in the Figures 6 and 7. Some of the coefficients were increased with the wavefront correction, but some were not. The results for PRK patients were good; best spectacle-corrected visual acuity improved postoperatively and in some cases up to 20/10. For the LASIK group, best spectacle-corrected visual acuity also improved postoperatively; most eyes gained two lines of visual acuity.

DISCUSSION

Based on our results, wavefront technology offers advantages for refractive surgery. We believe it is advisable to continue correction of lower order aberrations, as this currently yields safe and reproducible results. However, from our study we postulate that is preferable to use higher order wavefront correction as a second step to improve vision, especially in LASIK procedures. All aberrations, and more importantly, higher order aberrations change continuously during the aging process, and during everyday vision. Wavefront mapping of an eye can be useful to select the most suitable operation and the exact correction to optimize the outcome. This study has demonstrated our early utility in achieving this kind of precision, and in the future will allow us to fine-tune visual performance based on wavefront measurements of dynamic vision.

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