The Alcon/Summit/Autonomous Perspective on Fixed vs. Variable Spot Ablation

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APPROACH

The LADARVision system utilizes a small, fixed diameter excimer laser beam to reshape corneal tissue. The laser beam has a Gaussian fluence distribution and a full-width-half-maximum beam diameter of approximately 0.75 mm. Each pulse of the laser removes about 0.4 nanoliters of tissue, and typical treatments require several hundred to a few thousand pulses. Pulses are delivered to the eye in a specific pattern that is calculated prior to treatment and covers both the central treatment zone as well as the peripheral blend region. For wavefront-based corrections, both the optical and blend zones are customized to provide the greatest accuracy and smoothest possible treated surface.

ACCURACY AND TREATMENT CAPABILITY

Our wavefront device is capable of measuring eighth-order aberrations (and beyond if necessary). We have done extensive simulation and experimentation to ensure that our treatment device can deliver such complex higher order corrections. As an example, simulated treatment of the Z_8^8 Zernike aberration is shown in the figure. This high-order aberration represents a significant challenge to any excimer sculpting device. By incorporating a customized blend region around the optical zone, the LADARVision system is able to reduce the root mean square (RMS) error by 64%.

Note also over most of the optical zone in part D of the figure that the surface is essentially monochromatic, indicating an extremely smooth ablated surface. This is due to the deliberate maximal partial overlap of many Gaussian pulses in our treatment pattern.

PERCEIVED SPEED ADVANTAGE OF VARIABLE SPOT ABLATION

Using a larger beam to effect most of a customized treatment is often touted as providing shorter surgery times. However, we believe LADARVision treatment is quite competitive in this area. A one-diopter myopic correction over a 6-mm optical zone requires 8 to 9 seconds with our device. In customized surgery, we deliver all pulses of the predetermined pattern, which includes the blend zone, in one continuous stream at a rate of approximately 60 Hz. We do not have to pause the treatment to alter either the hardware or software.

POTENTIAL PROBLEMS WITH VARIABLE SPOT ABLATIONS

The variable spot approach uses a larger diameter (eg, several millimeters) beam for much of the treatment. Large beam diameters have been linked with the formation of "central islands," unintended irregularities on the treated corneal surface. The precise etiology of this is unknown, although irregular corneal hydration and non-uniform plume dynamics with large-beam systems have been identified as possible causes.[1,2] Such an imperfection could substantially impact customized treatments in a detrimental fashion. We have not seen central islands with LADARVision treatments[3], perhaps in part because we use a small fixed diameter beam that achieves consistent ablation with every shot.

EYE TRACKING SYSTEM

The LADARVision system employs an infrared laser tracking system that measures eye position at 4000 Hz and tracks eye position in a closed-loop manner. The tracker is able to follow even fast saccades with high fidelity. Perhaps equally important in customized surgery, our tracker provides a "space-stabilized" view of the eye to the surgeon as

From Alcon Summit Autonomous, Orlando, FL.

Presented at the 2nd International Congress of Wavefront Sensing and Aberration-free Refractive Correction, in Monterey, CA, on February 9-10, 2001.

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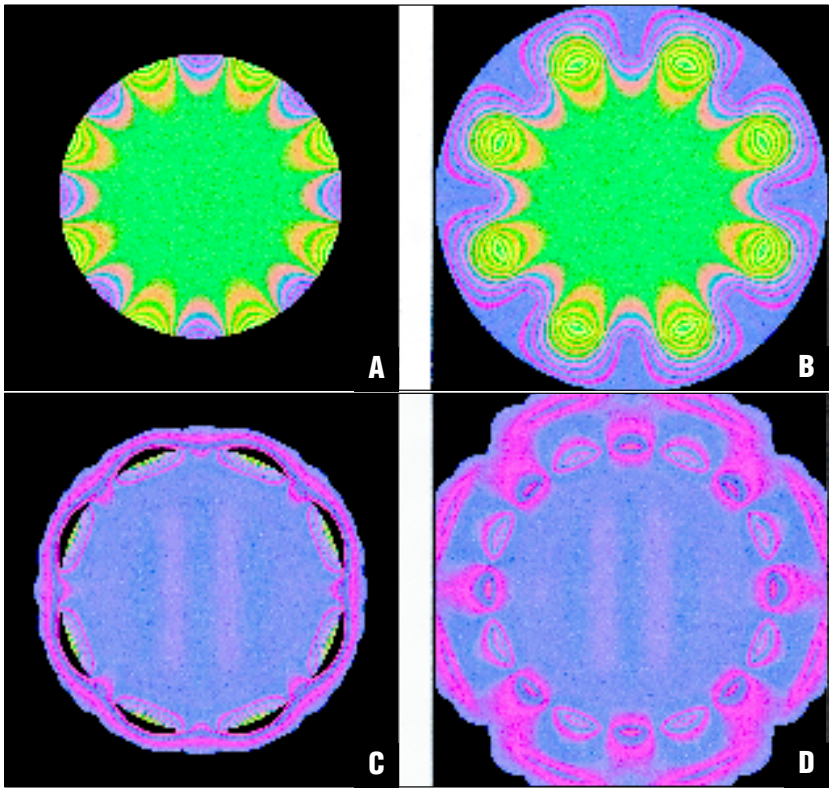

Figure. Simulated ablation of the Z_8^8 aberration by the LADARVision system. **A)** A pseudocolor profile of the aberration over a 6.5-mm-diameter optical zone. **B)** The same profile with the addition of a 1.25-mm wide blend zone. **C)** Residual error after ablation of the profile in A (with no blend zone). **D)** The result after ablation of the profile in B. The root mean square (RMS) error within the optical zone was reduced by 30% in the case without a blend zone, and by 64% in the case where a customized blend was included.

part of the graphical user interface. The eye appears stationary in this "tracked" view. The surgeon is able to register the custom ablation profile to the cornea, accurately using on-screen software reticles in this display; this includes both translational and rotational alignment. Accurate registration of the customized treatment pattern is crucial in order to address both high- and low-order aberrations effectively.

Summary

The LADARVision system utilizes a small fixed diameter excimer laser beam coupled with a high fidelity eye tracking system to perform wavefront-guided refractive surgery. The fixed small beam provides a consistent ablation per pulse. By delivering many identical pulses in a predetermined pattern, which includes an optimized custom blend zone, the laser is able to ablate complex (higher order) corneal shapes accurately. The closed loop eye tracking system ensures that accurate ablation is delivered to the right place on the eye.

REFERENCES

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