ABSTRACT

PURPOSE: To perform a quantitative evaluation of smoothness of ablation on polymethylmethacrylate (PMMA) using four scanning excimer lasers available commercially for photorefractive surgery.

METHODS: Ablations were done on PMMA plates with dimensions 100 x 50 x 1 mm. Four scanning excimer lasers were used, two with flying spot technology (Zeiss-Meditec MEL-70, and a Russian-made unit, Microscan) and two Nidek models with scanning slit delivery systems and an expanding iris diaphragm (EC-5000 and EC-5000 CX). Forty PMMA plates were ablated with standard -3.00-D settings using an ablation zone of 6 mm; each laser ablated 10 plates. Measurements were made in the center of each plate with the Zygo microscope, based on the principle of white light interferometry. Smoothness of ablation was characterized by three surface parameters (RMS, Ra, PV). RMS was considered the most significant parameter.

RESULTS: The smoothest surface was obtained in samples produced by Zeiss-Meditec MEL-70 unit (RMS=112±23 nm), followed by the Nidek EC-5000 CX (RMS=153±12 nm), and the Microscan (RMS=181±11 nm). The smoothness of ablation produced by the Nidek EC-5000 unit (RMS=329±39 nm) was significantly less than the other three lasers (P<.01).

CONCLUSIONS: Scanning excimer lasers based on flying spot technology—Zeiss-Meditec MEL-70 and Microscan, as well as the Nidek EC-5000 CX with FlexScan—created smoother ablations on PMMA plates compared to the older Nidek EC-5000 unit. [J Refract Surg 2004;20(suppl):S730-S733]

Creating a smooth ablation surface is one of the major advantages of excimer lasers.1,2 The quality of the surface determines both the regeneration and re-epithelialization speed, and presumably may influence the probability of stromal haze and scar formation. Construction of the delivery system, laser beam shape, and the scanning algorithm(s) are the main factors that influence smoothness of ablation. A useful and informative method to measure smoothness of the ablated surface is scanning white light interferometry with the Zygo microscope.3,4 We used this method to quantitatively compare the smoothness of ablation produced on polymethylmethacrylate (PMMA) plates with four scanning excimer lasers.

MATERIALS AND METHODS

Ablations were performed on PMMA plates with dimensions of 100 x 50 x 1 mm. We used four excimer lasers to perform -3.00-diopter (D) ablations with a 6-mm ablation zone. Two lasers had scanning spot delivery systems, the Zeiss-Meditec MEL-70 (Jena, Germany) and the Microscan (Physics Instrumentation Center, Troitsk, Russia). Two models of Nidek (Gamagori, Japan) had scanning slit delivery systems and an expanding iris diaphragm (EC-5000 and the FlexScan EC-5000 CX).

The Zeiss-Meditec MEL-70 uses a flying spot with a Gaussian profile, spot size of 1.8 mm at full width half maximum (FWHM), spot size at the ablation threshold of 2.97 mm, fluence of 80 mJ/cm², pulse energy of 5 mJ, and a repetition rate of 35 pulses per second (pps). The Microscan laser has a flying spot with a truncated Gaussian profile, spot size of 1.1 mm both at FWHM and at the ablation threshold, fluence of 120 mJ/cm², pulse energy of 1.2 mJ, and a repetition rate of 100 pps. The Nidek EC-5000 has a scanning slit delivery system and an...
Figure 1. Zygo microscopy, three-dimensional color-coded display of the ablated surface of the Zeiss-Meditec MEL-70 laser.

Figure 2. Zygo microscopy, three-dimensional color-coded display of the ablated surface of the Nidek EC-5000 CX with FlexScan.

Figure 3. Zygo microscopy, three-dimensional color-coded display of the ablated surface of the Microscan laser.
expanding iris diaphragm, slit size of 1x7 mm, fluence of 130 mJ/cm², pulse energy of 29 mJ, and a repetition rate of 20 to 40 pps. The Nidek EC-5000 CX is the current FlexScan-equipped version of the original Nidek EC-5000 laser.

Ten samples were ablated with each laser and measured in the center of each plate with the Zygo microscope (New View 5000, Zygo Corp, Middlefield, CT). Examples of microscopy of the surfaces by all four excimer lasers are presented in Figures 1 to 4.

Smoothness of ablation was characterized by the root-mean-square (RMS) deviation of surface points relative to the average height of the entire area of study, the average deviation of surface points from the median surface (Ra), and the distance between the highest and lowest points in the measured area (PV). RMS was considered the most significant parameter.

RESULTS

The Table shows the smoothness parameters of the ablated PMMA plates measured by the Zygo microscope for all four excimer lasers. The Zeiss-Meditec MEL-70 laser had better ablation smoothness than the other lasers (difference with each of the other lasers was statistically significant for RMS and Ra, \( P < .001 \); for PV the difference was not significant). PMMA plates ablated by the Nidek EC-5000 CX and Microscan lasers also had relatively low values of RMS and Ra, and variance of all parameters for these two lasers was significantly less (\( P < .05 \)) than for the other two lasers. All analyzed parameters for the older Nidek EC-5000 laser were lower than with the other three lasers, with both mean and variance for all parameters significantly increased, compared to the other three lasers.

DISCUSSION

We examined smoothness on PMMA plates of a -3.00-D ablation, which we consider typical. For the tested lasers, all with flying spot technology, the Zeiss-Meditec MEL-70, followed by the Microscan, and then the Nidek EC-5000 CX with FlexScan created the smoothest ablation surface, compared to the older Nidek EC-5000 unit.

Some authors report advantages of flying spot technology over slit ablation in achieving a smoother surface. Our data suggest that slit ablation can produce a surface with comparable smoothness with the recently developed Nidek EC-5000 CX FlexScan system. This new slit scanning ablation profile was developed by Nidek in order to reduce ablation volume and improve accuracy of refractive correction.
Repeatability of smoothness is characterized by variance of the measured parameters. The Zeiss-Meditec MEL-70 showed better measures of ablation smoothness but greater variance between them compared to the Microscan and the Nidek EC-5000 CX. One possible explanation might be in the characteristics of the laser spot and scanning algorithm of the MEL-70—a relatively large size and Gaussian profile laser spot provide better smoothness of ablation. At the same time, a spot of such size has relatively high energy in each pulse. With such a high level of energy, the scanning pattern should have fewer pulses, hence resulting in a larger variance in smoothness.

The Microscan laser also has flying spot technology. Compared to the MEL-70, its ablation was less smooth due to the truncated Gaussian profile of the laser spot, but variance of smoothness was better due to the smaller spot size and greater number of pulses with smaller energy in each pulse. With these assumptions, we suggest that to achieve maximal and repeatable smoothness of ablation, one should use a small-size spot with a Gaussian profile. A recent publication6 confirms this by showing good smoothness produced by an excimer laser that has a small spot size with a Gaussian profile.

REFERENCES