

Ablation Efficiency Measurements for Laser-Assisted Lipolysis Using Optical Coherence Tomography

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Abstract

The aim of this study was to evaluate ablation efficiency of 3 different laser wavelengths— $\lambda = 1064$ nm, 1320 nm, and 1444 nm—for laser-assisted lipolysis. Ablation efficiency was determined by measuring crater size and the amount of mass removed after laser irradiation using optical coherence tomography and a microanalytical balance system, respectively. The results demonstrate that crater size and mass removal after laser irradiation are wavelength dependent, and the largest crater size and the greatest amount of mass removal are achieved at $\lambda = 1444$ nm, followed by, in order, $\lambda = 1320$ nm and 1064 nm. This study demonstrated that ablation using $\lambda = 1444$ nm provided the largest crater size and maximum mass removal at the same radiant exposure for all 3 wavelengths.

1. Introduction

Recently, laser-assisted lipolysis using a laser fiber inside a standard liposuction cannula to eliminate unwanted body fat has become increasingly popular [1-6]. In conventional liposuction procedures, the adipocytes in fat tissue are mechanically removed from the subdermal tissue. This procedure causes many adverse effects, such as excessive blood loss and slow postoperative recovery time [1-3]. Owing to these adverse effects, an alternative method, laser-assisted lipolysis, was introduced that dissolves unwanted fat using laser irradiation [1-3]. Laser-assisted lipolysis causes less bleeding, bruising, and swelling, resulting in a faster recovery than conventional liposuction procedures [2-6]. Many medical laser companies have developed a number of lasers with various wavelengths for laser-assisted lipolysis. Among them are 2 Nd:YAG lasers that are widely used in the clinical setting with wavelengths of $\lambda = 1064$ nm (Smartlipo™, Cynosure, Inc., Westford, MA; LipoLite™, Syneron Inc., Irvine, CA) and 1320 nm (CoolLipo™, CoolTouch Corp., Roseville, CA). In this study, ablation efficiency measurements were performed using 2 popular laser wavelengths in the market, $\lambda = 1064$ nm and 1320

nm, and the recently introduced novel laser wavelength, $\lambda = 1444$ nm (AccuSculpt™, Lutronic Corp., South Korea).

Optical coherence tomography (OCT) is a noninvasive imaging technology that uses light reflected from within tissue to generate 2-dimensional sectional images of the tissue structure in a manner similar to, but with higher resolution than is obtained with, ultrasound. OCT is reported to provide images that have good correlation with histology at a sufficient resolution to identify morphologic changes within the tissue [7-10]. In this study, wavelength-dependent measurements of the laser lipolysis effect were performed at 3 different laser wavelengths that are currently used in the clinical setting— $\lambda = 1064$ nm, 1320 nm, and 1444 nm—using OCT and a microanalytical balance system. The quantitative results from the ablation efficiency measurements may help to determine the effective wavelength as a function of the fat mass to be removed.

2. Materials and Methods

2.1 Fat tissue harvest

Fresh porcine skin with fat tissue was obtained from a local abattoir. The fat tissue was extracted before the experiment 2 hours postmortem. The prepared porcine tissue was placed on an operating table and explored for an incision line. The skin was removed using a scalpel, and the fat tissue specimens were cut into squares measuring approximately $3 \times 3 \times 3$ cm³. The specimens were then stored in a physiologic saline solution just prior to the experiment.

2.2 Experimental Methods

Three different lasers, with wavelengths of $\lambda = 1064$ nm, 1320 nm (protocol lasers provided by Lutronic Corp., South Korea), and 1444 nm (AccuSculpt™, Lutronic Corp., South Korea), delivered by a 600-mm silica multimode fiber, were applied to the porcine fat tissue, with radiant exposure set at 5 to 8 W. To investigate the crater depth and width of the fat tissue after laser irradiation, a spectral domain OCT system was used (Figure 1).

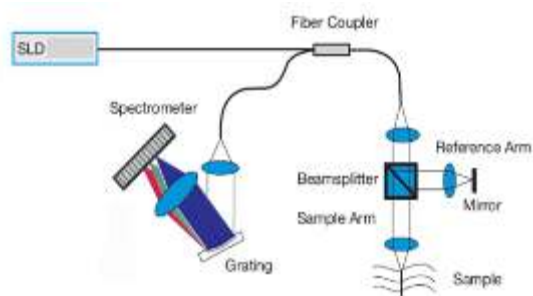


Figure 1. Spectral radar Optical Coherence Tomography

Low-coherence light having a center wavelength of $\lambda = 840$ nm with a full-width half-maximum bandwidth of 50 nm was coupled into the source arm of a fiber-based Michelson interferometer. Back-reflected lights from the reference and sample arms were guided into a spectrometer. The detected signal was then image processed by a computer. In our system, an imaging depth was 3.2 mm in air, and the acquired OCT images from the sample were 6×1.6 mm. The OCT images of the craters after each laser irradiation of 5 to 8 W were explored and taken at the deepest position in the crater region.

For mass removal measurements, a microanalytical balance (XS204, Mettler-Toledo GmbH, Greifensee, Switzerland) with a resolution of 10 mg was used to measure the amount of mass after laser irradiation at the 3 different laser wavelengths. The microanalytical balance was connected through a serial port to record the mass loss during laser irradiation in real time.

The radiant exposure was set at 5 to 8 W, with the same parameters used for all 3 laser wavelengths (beam diameter = 600 μm , repetition rate = 40 Hz) (Table 1).

Table 1. Laser specifications used in the measurements

	1064 nm	1320nm	1444 nm
Maximum Pulse rate (Hz)	40	40	40
Maximum Pulse Energy (mJ)	300	400	200
Maximum Power (W)	12	16	8
Beam diameter (μm)	600	600	600

3. Results and Discussion

Figure 2 presents OCT images from the ablated crater of fat tissue at a radiant exposure of 6 W for the 3 laser wavelengths; $\lambda = 1444$ nm revealed the largest crater size, followed by, in order, $\lambda = 1320$ nm and 1064 nm.

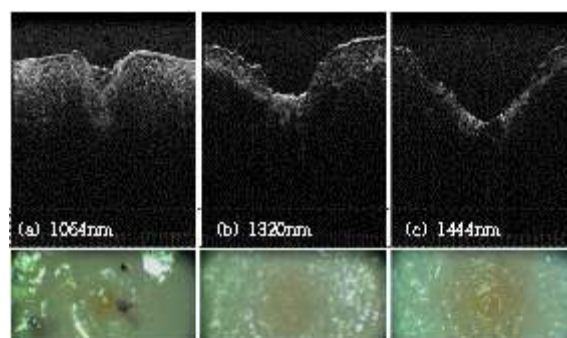


Figure 2. OCT images and gross images of a crater in fat tissue after the laser irradiation at different wavelengths

For quantitative analysis of the OCT images taken at the deepest region at each radiant exposure for the 3 different laser wavelengths, the crater depth and width were measured from 5 to 8 W (Figure 3). As seen in Figure 3A, crater depth at $\lambda = 1444$ nm is monotonically increased as the incident radiant exposure increases. On the other hand, crater depth at $\lambda = 1064$ nm and 1320 nm seems to reach the maximum at around 8 W and tends to plateau there (Figure 3B)

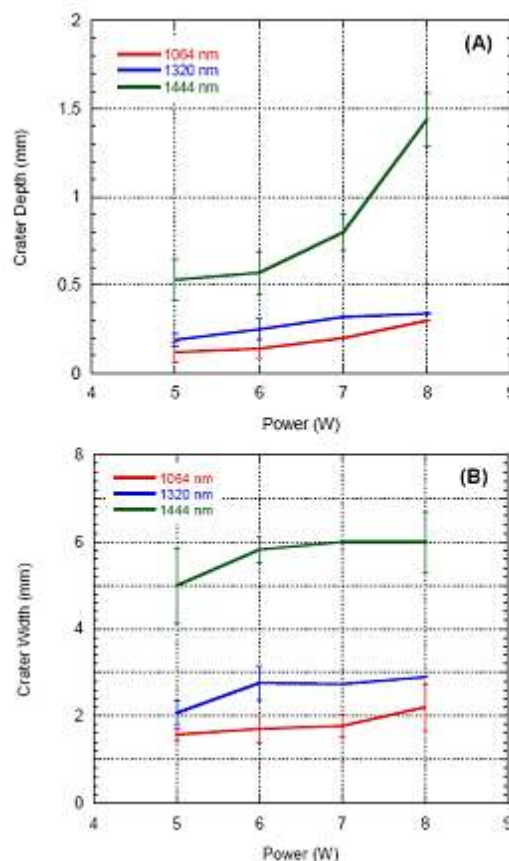


Figure 3. Crater size measurements after laser Irradiation at 3 different wavelengths, with 10 tissue samples each; (A) Crater depth measurements, and (B) Crater width measurements.

Figure 4 shows the measured mass loss for 3 different laser wavelengths at a radiant exposure of 28.3 kJ/cm^2 . The highest mass removal for fat tissue ablation was achieved at $\lambda = 1444 \text{ nm}$, followed by, in order, $\lambda = 1320$ and 1064 nm . As seen in Table 2, the 1064-nm wavelength needs 3 times more energy than the 1444-nm wavelength to remove the same amount of fat tissue.

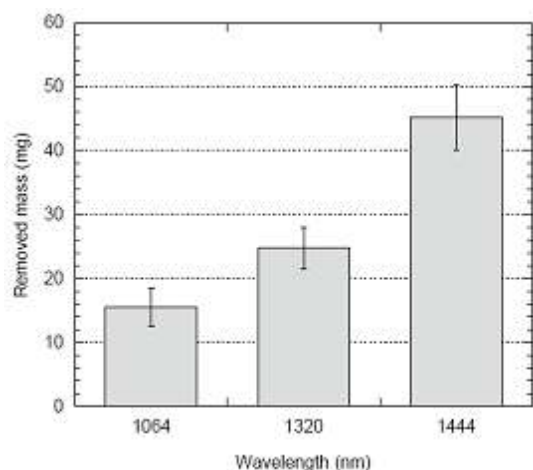


Figure 4. Amount of removed mass after laser irradiation at 28.3 kJ/cm^2 for 3 different laser wavelengths ($E = 80 \text{ J}$, 10 seconds , $D = 600 \mu\text{m}$)

Table 2. Quantitative values of removed mass from Figure 4

	1064nm	1320nm	1444nm
Average mass (mg)	15.46±2.92	24.78±3.24	45.19±5.07
Energy per gram (kJ/g)	5.17	3.23	1.77

4. Conclusion

This study shows that fat ablation is wavelength dependent, with $\lambda = 1444 \text{ nm}$ providing the largest craters and greatest amount of mass removed at all radiant exposures. Therefore, $\lambda = 1444 \text{ nm}$ provided the highest ablation efficiency as compared with the other 2 laser wavelengths, $\lambda = 1064 \text{ nm}$ and 1320 nm .

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