Lasers in Surgery and Medicine 36:43–46 (2005)

Histologic Evaluation of the Pulsed Nd:YAG Laser for Laser Lipolysis

Kota Ichikawa, MD,[1]* Muneo Miyasaka, MD,[1] Rica Tanaka, MD,[1] Ryuzaburo Tanino, MD,[1] Kana Mizukami,[2] and Moriaki Wakaki, PhD[2]

[1]*Department of Plastic Surgery, Tokai University School of Medicine, Japan Bohseidai, Isehara-shi, Kanagawa, 259-1193, Japan*

[2]*Tokai University School of Engineering, Japan*

Background and Objectives: Laser lipoplasty with pulsed Nd:YAG laser, widely used in Europe and Latin America, has recently been introduced in Japan and the USA. We report histologic analyses of the effects of the laser on human fat tissue.

Study Design/Materials and Methods: Freshly excised human skin and subcutaneous fat were irradiated with the pulsed Nd:YAG laser (SmartLipo, DEKA, Italy). A 1,064 nm laser at 40 Hz and 150 mJ and 100 microseconds-long pulses were used. Methods of exposure were the same as in the clinical application. In the control group, the specimens were cannulated by the handpiece without irradiation. The tissue was studied by scanning electron microscopy and hematoxylin eosin staining.

Results: Scanning electron microscopy after irradiation showed greater destruction of human adipocytes than in the control. Degenerated cell membrane, vaporization, liquefaction, carbonization, and heat-coagulated collagen fibers were observed.

Conclusions: Our study showed that the SmartLipo appeared to be histologically effective for destruction of human fat tissue. Lasers Surg. Med. 36:43–46, 2005.

Key words: histology; laser lypolysis; pulsed Nd:YAG laser; scanning electron microscopy

INTRODUCTION

Attempts to reduce localized adiposity by diet or exercise alone are often unsuccessful. Over the years, a variety of surgical and medical interventions have been used to remove subcutaneous fat including suction-assisted lipoplasty, ultrasound-assisted liposuction, external ultrasound assistance, power-assisted liposuction, laser-assisted liposuction [1–3], low level laser assisted liposculpture [4,5], carbon dioxide (CO_2) injection, and mesotherapy. The search continues to reduce downtime, operator effort and bleeding, and to achieve skin tightening, fine sculpture, and treatment of fibrous or reoperative areas.

Laser lipoplasty with pulsed neodymium, yttrium, aluminium, garnet (Nd:YAG) laser, also called interstitial laser lipolysis, is widely used in Europe and Latin America, and has recently been introduced in Japan and the United States. We were given an opportunity to test the effect of pulsed Nd:YAG laser therapy on adipocytes in fresh ex vivo human fat tissue. No controlled studies of laser lipolysis including histology with electron microscopy have been reported. The goal of our study was to examine the effects of pulsed Nd:YAG laser on human adipocytes. Fat tissue was evaluated by histology and scanning electron microscopy.

MATERIALS AND METHODS

The tissues were taken from excised excess parts of flaps containing skin and a sufficient amount of subcutaneous fat generated from plastic surgery operations. All subjects gave informed consent for the Tokai University Hospital Institutional Review Board-approved protocol. Six samples of $3\times2\times2$ cm tissue were used. The tissues were irradiated or cannulated immediately after excision.

SmartLipo (DEKA, Italy) is a pulsed Nd:YAG, variable-hertz, variable-Joule, 1,064 nm laser system. The laser light is conveyed through micro-cannulas with a diameter of 1 mm into which an optical fiber of 300 μm is inserted. A 100 microseconds-long pulsed laser at 40 Hz and 150 mJ was used for all subjects.

Methods of exposure were the same as in the clinical application. The cannula was inserted into the target layer of the subcutaneous fat approximately 1 cm below the skin. The laser was applied to the tissue with an extracting motion of 2 cm/second. The laser was applied to the target layers for 1 second each with repeated cannulation, and the total duration of exposure was 3 seconds for each sample. In the control group, samples were processed in the same manner without irradiation. In both groups, suction was not applied to the cannula during passage through the tissue.

To evaluate the area of acute thermal effects in vivo, rat livers of high cellularity were irradiated and examined. The studies and protocols using the animals were approved by the institutional committee. Female Sprague–Dawley rats were anesthetized with intramuscular injection of ketamine (120 mg/kg). The abdomen was opened, the liver

*Correspondence to: Kota Ichikawa, MD, Department of Plastic Surgery, Tokai University School of Medicine, Japan Bohseidai, Isehara-shi, Kanagawa, 259-1193, Japan.
E-mail: ichikota@is.icc.u-tokai.ac.jp

Accepted 28 October 2004
Published online in Wiley InterScience (www.interscience.wiley.com).
DOI 10.1002/lsm.20118

was exposed, a cannula was inserted, and the laser emitted in the same way.

Tissues were fixed immediately after irradiation or cannulation in formalin and stained with hematoxilin and eosin. Samples were also fixed in glutaraldehyde and osmium for scanning electron microscopy.

RESULTS

In scanning microscopy of human specimens after laser irradiation, destructive changes were evident (Fig. 1). Hollows of about 300 μm, equal to the diameter of the fiber, and heat-coagulated collagen fibers were seen in a low-power field. Degenerated cell membrane and dispersed lipids were apparent. Heat-coagulated collagen fibers were observed. In the absence of laser exposure, cavities created by cannulation were seen, but adipocytes were round in appearance and not deflated (Fig. 2).

Photomicrography of human fat after laser therapy showed hollows with denatured cell membranes (Fig. 3), but this could not be accurately specified in comparison with control specimens (Fig. 4) because there appeared to be artifactual destruction of cell membranes. Carbonization of human fat tissue caused by laser exposure was observed (Fig. 5).

Liver tissue in the center of the field displayed hemorrhage, vaporization, cavitation, heat necrosis, and coagulation (Fig. 6). The diameter of the condensed necrotic zone was about 1 mm, suggesting scattering and thermal conduction from the point of beam contact.

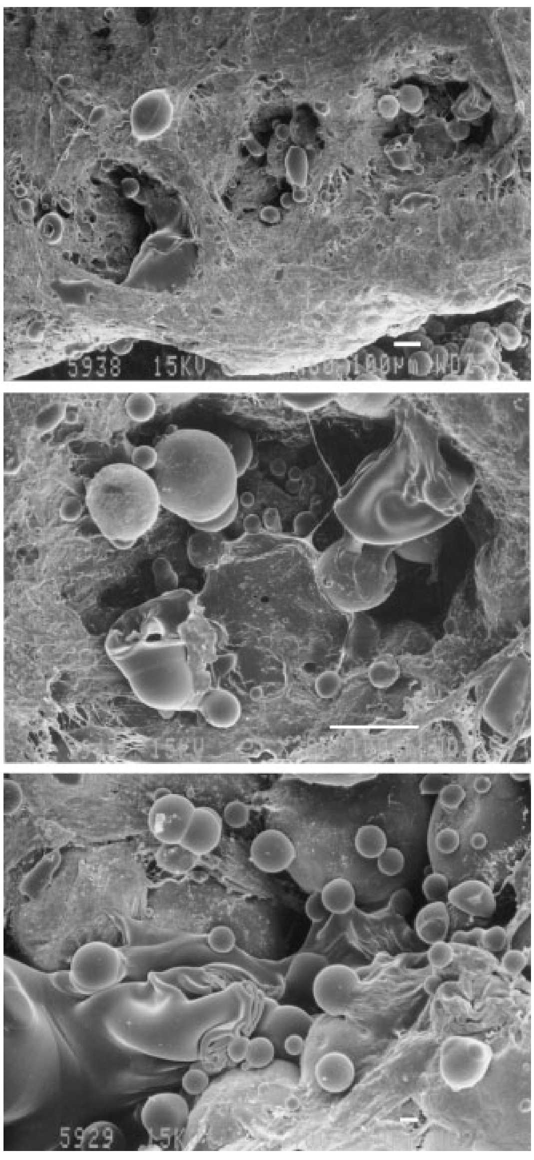

Fig. 1. Scanning microscopy of human specimen after laser irradiation showed destructive changes. Hollows of about 300 μm, equal to the diameter of the fiber, and heat-coagulated collagen fibers were seen (**above**). Degenerated cell membrane and dispersed lipids were apparent (**center** and **below**). Scale bar = above and center 100 μm, below 10 μm. (Original magnification: above ×60; center ×200; below ×400).

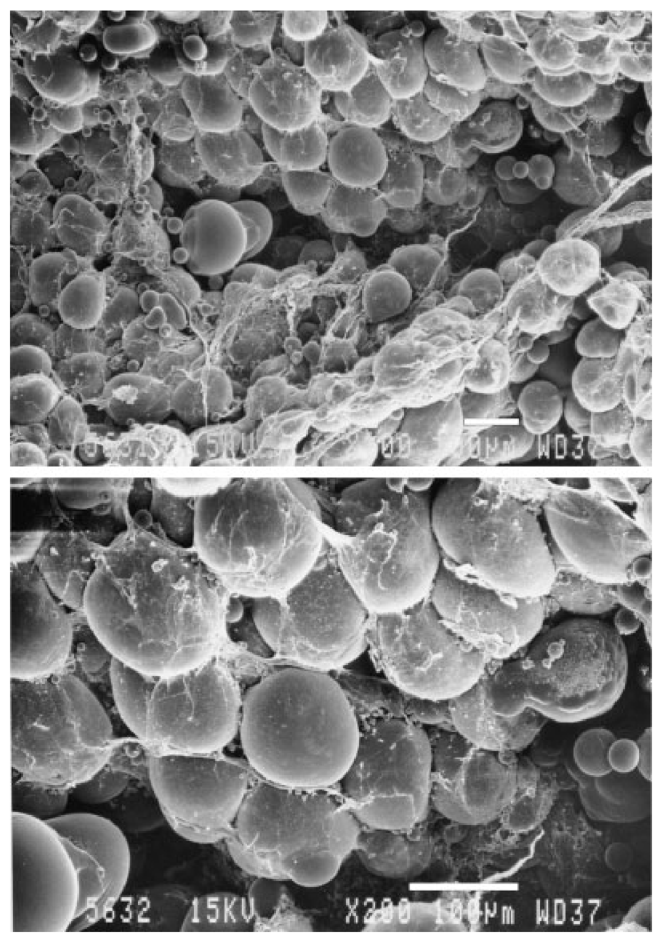

Fig. 2. Scanning electron microscopy of human specimens after cannulation without laser irradiation (control). No major structural changes were observed in adipocytes. Scale bar = 100 μm. (Original magnification: **above** ×100; **below** ×200).

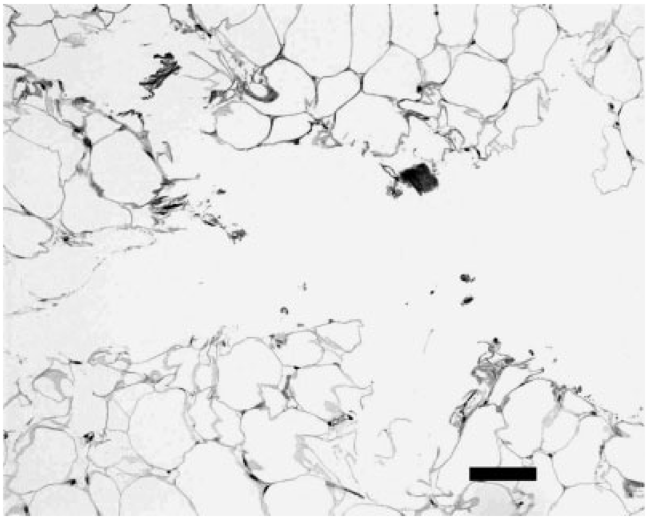

Fig. 3. Photomicrograph of human fat in a laser-treated specimen showing hollows with denatured cell membranes. Scale bar = 100 μm. (Hematoxylin eosin, original magnification: ×200).

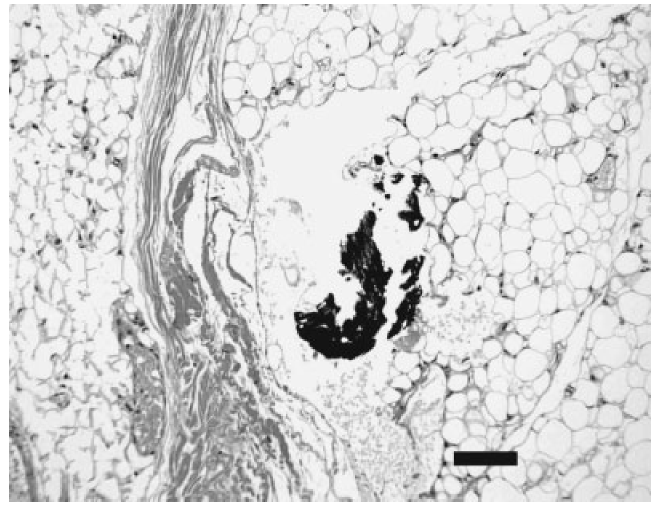

Fig. 5. Carbonized region in human fat tissue, involving fibers and membranes. Scale bar = 100 μm. (Hematoxylin eosin, original magnification: ×200).

DISCUSSION

A variety of devices have been used clinically to assist lipoplasty. They include suction, ultrasound, vibration, and lasers [1–5]. Methods of power-delivery are classified into two categories: internal and external.

Laser liposculpture is a relatively new technique and still under development. The main objectives are faster recovery, less operator effort, and skin tightening. Basic research continues on the laser effect of catabolic activation, softening and liquefying fat. Although penetration of cell membrane, cavitation, destruction, and vaporization may be achieved with high-power lasers, the cost of the equipment and responsibility for use of non-approved devices should be taken into account.

Ultrapulse CO_2 laser application to vaporize subcutaneous fat was reported by Cook et al. [6] and Park et al. [7]. Instead of good tightening, they needed to incise and dissect

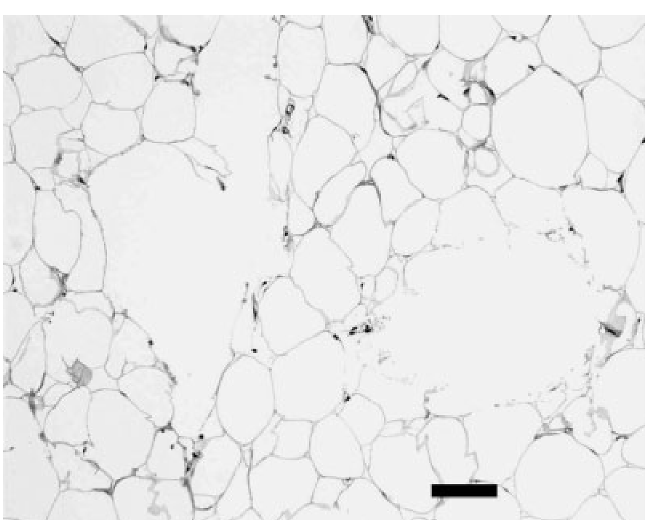

Fig. 4. Photomicrograph of human fat after cannulation without laser irradiation (control) showing hollows created by mechanical cannulation. Scale bar = 100 μm. (Hematoxylin eosin, original magnification: ×200).

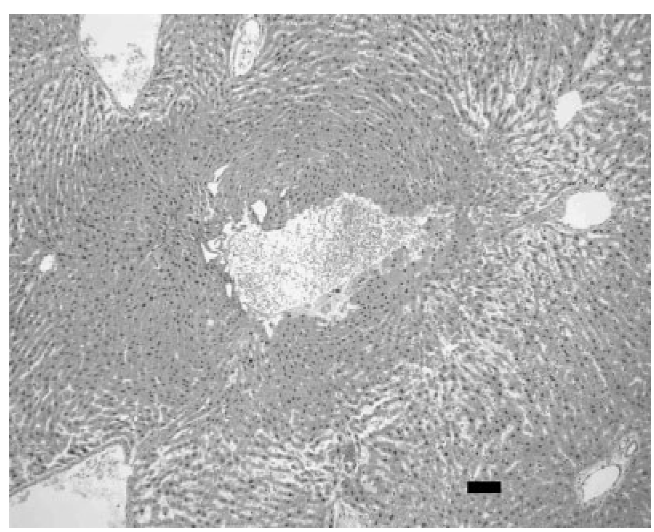

Fig. 6. Photomicrograph of rat liver after irradiation showing heat necrosis, coagulation, hemorrhage, and cavitation. The diameter of the condensed zone was about 1 mm, suggesting scattering and thermal conduction from the point of beam contact. Scale bar = 100 μm. (Hematoxylin eosin, original magnification: ×100).

the skin for laser exposure because of the large handpiece. The Er (Erbium):YAG laser has been reported to be effective for facial rejuvenation with shorter downtime, but no reports on lipoplasty with the Er:YAG laser have been published. Apfelberg [1–3] reported laser-assisted liposuction with the YAG laser beam enclosed in a cannula, but clear benefits over standard liposuction could not be demonstrated. Recently, low-level laser therapy has been enthusiastically reported as an adjunct to clinical aspirative lipoplasty by Neira et al. [4,5]. They stated that 99% of the fat was released from the adipocyte after 6 minutes of 635 nm, 10 mW diode laser exposure. They also reported 700 cases treated with external low-level laser-assisted lipoplasty. However, in contrast, Brown et al. [8] reported that no adipocyte structural differences were observed between low-level laser therapy and non-irradiated samples in their studies using the same methodology as that of Neira et al. [4,5].

Laser lipoplasty with pulsed Nd:YAG laser, also called interstitial laser lipolysis, has been reported to be widely used in Europe and Latin America [9,10], where the possibility of laser lipoplasty without liposuction was also reported. The system has recently been introduced in Japan and the United States. However, English references are few and there is no report of a controlled study or evaluation with scanning electron microscopy.

Histologically, we observed that human adipocytes were effectively destroyed with laser irradiation. This system is designed to utilize features of the Nd:YAG laser that is conveyed through a small fiber, has tissue permeability, and permits irradiation of the target directly using a skin-penetrating cannula.

The laser shockwave also appears to be effective in removing fat tissue. The high-density energy in short pulses has an explosive effect on atoms within the target tissue. Electrons are inelastically scattered from the atoms and form a plasma shield that helps to screen deeper structures from the beam. After the pulse, released electrons are recaptured, giving off the energy which they gained from the photon pulse [11]. This micro-discharge of energy creates a shockwave and this technique is often employed in ophthalmologic surgery for penetrating and incising the non-pigmented structures such as the cornea and lens, suggesting efficacy in lipoplasty. Although Kuwahara et al. [12] recently discussed rapture of fat cells using laser-generated ultra short stress waves, few basic investigations exploring optimal wave-lengths or pulse-lengths for fat destruction have been reported.

The trend in cosmetic medicine is non-invasiveness. Many patients prefer shorter downtime to volume of fat removal. They choose repeated minor procedures instead of one major surgery. Laser lipoplasty without liposuction is expected to meet this demand. However, the SmartLipo has not been the subject of any controlled clinical studies and has not been approved by the Japanese government. Adequate evaluation of the new modality before marketing for clinical use is important for progress of laser lipoplasty.

Our study showed that the SmartLipo appeared to be histologically effective for destruction of human fat tissue. However, quantitative studies of the tissue effect of the laser lipolysis are required to compare with suction-assisted lipoplasty or to assess the efficacy in combination usage with suction. Further investigations are required for clinical evaluation and long-term analyses.

REFERENCES

1. Apfelberg DB. Results of multicenter study of laser-assisted liposuction. Clin Plast Surg 1996;23(4):713–719.
2. Apfelberg DB, Rosenthal S, Hunstad JP, Achauer B, Fodor PB. Progress report on multicenter study of laser-assisted liposuction. Aesthetic Plast Surg 1994;18(3):259–264.
3. Apfelberg DB. Laser-assisted liposuction may benefit surgeons, patients. Clin Laser Mon 1992;10(12):193–194.
4. Neira R, Ortiz-Neira C. Low level laser assisted liposculpture: Clinical report in 700 cases. Aesthetic Surg J 2002;22: 451.
5. Neira R, Arroyave J, Ramirez H, Ortiz CL, Solarte E, Sequeda F, Gutierrez MI. Fat liquefaction: Effect of low-level laser energy on adipose tissue. Plast Reconstr Surg 2002; 110(3):912–922; discussion 923–915.
6. Cook WR, Jr. Laser neck and jowl liposculpture including platysma laser resurfacing, dermal laser resurfacing, and vaporization of subcutaneous fat. Dermatol Surg 1997;23(12): 1143–1148.
7. Park YJ, Shin MS. What is the best method for treating osmidrosis? Ann Plast Surg 2001;47(3):303–309.
8. Brown SA, Rohrich RJ, Kenkel J, Young L, Hoopman J, Coimbra M. Effect of low-level laser therapy on abdominal adipocytes before lipoplasty procedures. Plast Reconstr Surg 2004;113(6):1796.
9. Badin AZ, Moraes LM, Gondek L, Chiaratti MG, Canta L. Laser lipolysis: Flaccidity under control. Aesthetic Plast Surg 2002;26(5):335–339.
10. Goldman A, Schavelon DE, Blugerman GS. Laser lipolysis: Liposuction using Nd-YAG laser. Rev Soc Bras Cir Plast 2002;17(1):17–26.
11. Brackett KA. Tissue Interactions of Nd:YAG Lasers. In: Joffe SN, Oguro Y, editors. Advances in Nd:YAG Laser Surgery. Berlin: Springer-Verlag; 1988. pp 336–343.
12. Kuwahara K, Gladstone HB, Gupta V, Kireev V, Neel V, Moy RL. Rupture of fat cells using laser-generated ultra short stress waves. Lasers Surg Med 2003;32(4):279–285.