



Histologic Evaluation of Laser Lipolysis: Pulsed 1064-nm Nd:YAG Laser Versus CW 980-nm Diode Laser

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Background: The use of the laser as an auxiliary tool has refined the traditional technique for lipoplasty. During laser lipolysis, the interaction between the laser and the fat produced direct cellular destruction before the suction, reduced bleeding, and promoted skin tightening.

Objective: This study sought to perform a comparative histologic evaluation of laser lipolysis with the pulsed 1064-nm Nd:YAG laser versus a continuous 980-nm diode laser.

Methods: A pulsed 1064-nm Nd:YAG (Smart-Lipo; Deka, Italy) and a CW 980-nm diode laser (Pharaon, Osyris, France) were evaluated at different energy settings for lipolysis on the thighs of a fresh cadaver. The lasers were coupled to a 600- μ m optical fiber inserted in a 1-mm diameter cannula. Biopsy specimens were taken on irradiated and non-irradiated areas. Hematoxylin-erythrosin-safran staining and immunostaining (anti-PS100 polyclonal antibody) were performed to identify fat tissue damage.

Results: In the absence of laser exposures (control specimens), cavities created by cannulation were seen; adipocytes were round in appearance and not deflated. At low energy settings, tumescent adipocytes were observed. At higher energy settings, cytoplasmic retraction, disruption of membranes, and heat-coagulated collagen fibers were noted; coagulated blood cells were also present. For the highest energy settings, carbonization of fat tissue involving fibers and membranes was clearly seen. For equivalent energy settings, 1064-nm and 980-nm wavelengths gave similar histologic results.

Conclusions: Laser lipolysis is a relatively new technique that is still under development. Our histologic findings suggest several positive benefits of the laser, including skin retraction and a reduction in intraoperative bleeding. The interaction of the laser with the tissue is similar at 980 nm and 1064 nm with the same energy settings. Because higher volumes of fat are removed with higher total energy, a high-power 980-nm diode laser could offer an interesting alternative to the 1064-nm Nd:YAG laser. (Aesthetic Surg J 2007;27:263–268.)

Lipoplasty has become increasingly popular over the last decade and is now the most popular body sculpting procedure. This increasing popularity is associated with the evolution of techniques and equipment for fat removal and body reshaping. In addition to the traditional suction-assisted lipoplasty, other options include ultrasound-assisted and external ultrasound-assisted lipoplasty, power-assisted lipoplasty, and laser lipolysis. This search for alternative techniques and new tools is mainly directed toward reducing downtime, decreasing operator effort for the surgeon and assistant, reducing bleeding, and promoting skin tightening,

Laser lipolysis, also called *laser lipoplasty*, is widely used in Europe and Latin America and has recently been introduced in Japan and the United States. Laser lipolysis with a pulsed 1064-nm Nd:YAG laser has been proven to be a safe and effective method. After adequate infiltration of an anesthetic solution, a flexible fiber optic delivered through a small-caliber cannula is inserted inside the fat tissue. The positioning of the 1-mm cannula is highlighted via transillumination from a red guiding beam. The laser energy is transmitted to the adipocytes, which absorb the energy, expand their volume, and rupture.¹ Histologic analyses of the effects of the pulsed

Nd:YAG laser on human fat tissue have shown areas of reversible cellular damage (tumefaction), irreversible tissue damage (lysis), and a reduced intensity of bleeding, as compared with the results of conventional lipoplasty.

The mechanisms leading to laser lipolysis are temperature dependent. First, for low energy and consequently low temperature, only tumefaction of the adipocytes is observed.² With higher energy, the histologic assessment carried out by Goldman¹ on tissues removed immediately after the procedure showed not only the rupture of adipocytes but also the coagulation of small vessels in the fatty tissue. Because heat is confined inside the adipocyte, it leads to rupture of its membrane. The effect is not only thermal but also thermomechanical.

More importantly, the degree of tumefaction and lysis varied proportionally with the intensity of energy accumulated to the target. Badin et al² showed that conventional lipoplasty produces less reversible damage (tumefaction) than laser lipolysis with 1000 J of energy. Using energy ranging from 1000 J up to 12,000 J, Kim and Geronemus³ observed that the higher the energy, the greater the volume reduction. Typically, a 5-cm³ reduction of fat volume is observed with 3000 J. A 20 cm³ volume reduction is obtained with 12,000 J.

All these studies, performed with a pulsed Nd:YAG laser, show clearly that two parameters must be considered for laser lipolysis. The first parameter is the wavelength, since the interaction of the laser with the tissue is achieved by the absorption of laser energy by the receptive chromophores, thus producing sufficient heat to cause the desired thermal damage. The heat acts on the fatty cell and the extracellular matrix to produce both reversible and irreversible cellular damage, which facilitates lipoplasty by lessening trauma and bleeding. The second parameter is the energy, since a dose-response relationship exists.^{3,4}

Up to now, laser lipolysis was performed with a low-power flash-lamp-pumped Nd:YAG laser (maximum 6 W). Because of the technology of the 1064-nm Nd:YAG laser, the flash lamp pump yields a total efficiency on the order of only a few percent.⁵ In many medical laser applications, (for example, endovenous laser treatment), diode lasers have replaced Nd:YAG lasers. Their much better efficiency (usually 30%), high power (25 W or more), reduced sizes, and low weight are among their main advantages. These diode lasers could offer an alternative to the 1064-nm Nd:YAG laser; in particular, the 980-nm diode laser has a wavelength that is very close to that of the 1064-nm

Nd:YAG laser. In this study, we compared a pulsed 1064-nm Nd:YAG laser usually used for laser lipolysis with a continuous 980-nm diode laser.

Materials and Methods

Laser lipolysis of the subcutaneous fat layer in the thigh was performed on a fresh female cadaver less than 8 hours postmortem. A pulsed 1064-nm Nd:YAG (Smart-Lipo; Deka, Florence, Italy) was evaluated on the left thigh with the following parameters: 100 μ pulse, 150 mJ per pulse, 40 Hz (peak power: 1.5 KW, average power: 6 W). These parameters are those usually reported in the literature.

A 980-nm diode laser (Pharaon, Osyris, Hellemmes, France) was evaluated on the right thigh with the following parameters: continuous emission; for 3 different power settings: 6 W, 10 W, and 15 W. The association of these two lasers with an He:Ne source allows precise visualization of the region where the energy acted, because of transcutaneous illumination.

These 2 lasers were coupled to a 600- μ m optical fiber inserted in a 1-mm diameter cannula. The cannula was inserted into the subcutaneous fat layer of the thigh approximately 1 cm below the skin. The laser was applied to the tissue at several locations with a total duration of exposure varying from 1 to 3 seconds.

Histologic study

Biopsy specimens were taken on irradiated and non-irradiated areas. Samples devoted to the histologic study were fixed for 24 hours in a 10% formaldehyde-buffered solution (pH 7.2, NaCl 133 mmol/L). They were then progressively dehydrated in alcohol, embedded in paraffin, and sectioned at 4 μ m. Sections were stained with hematoxylin-erythrosin-safran (HES).

To clearly identify the adipocyte membrane, anti-PS100 polyclonal antibody (N 1573; Dako Corporation, Trappes, France) was used at a 1:500 dilution. Immunohistochemical assays were performed with the Universal DakoCytomation LSAB combined with the LSAB kit HRP K06909 (Dako Corporation). The slides were examined at different magnifications ($\times 20$, $\times 40$, $\times 60$, and $\times 100$).

Results

In the absence of laser exposures (control specimens), cavities created by cannulation and channels induced by the laser fiber were seen, but adipocytes were round in appearance and not deflated (Figure 1). On irradiated samples, hollows of about 300 μ m were also observed.

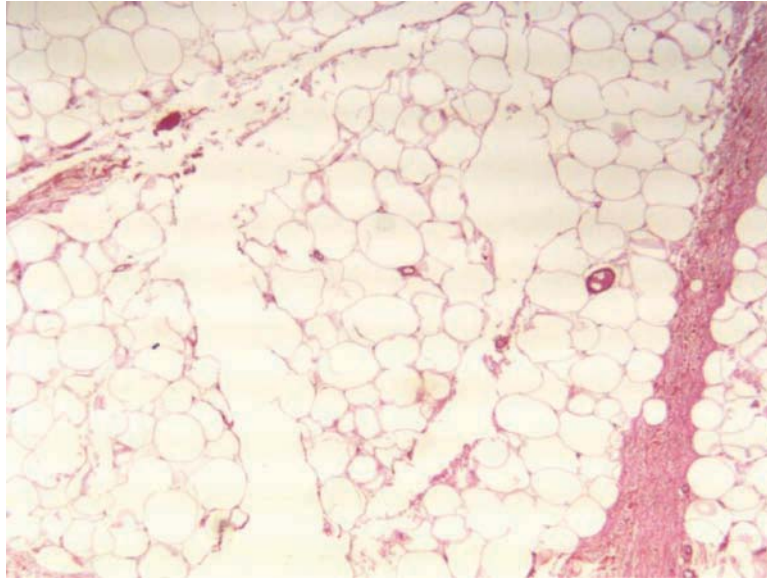


Figure 1. Photomicrograph of human fat, showing a channel produced by the fiber without laser irradiation (HES stain; original magnification $\times 40$).

When using the Nd:YAG laser (1 second), tumescent adipocytes were observed. The diameter of the adipocytes was increased, and their round shape was altered. Instead of round-shaped adipocytes with a maximum diameter of $75\ \mu\text{m}$ (range $30\text{-}75\ \mu\text{m}$), adipocytes were deformed, and their diameter reached $110\ \mu\text{m}$ (Figure 2).

For a 2-second exposure, degenerated cell membranes were apparent. Heat-coagulated collagen fibers were only observed when using 3-second exposure; significant irreversible damage (cytoplasmic retraction and disruption of membranes) was noted. Coagulated blood cells were also present. Using the same power (6 W) and same exposure times, samples irradiated with the 980-diode laser displayed similar results (Figure 3). When using the 980-diode laser with higher power (10 W and 15 W), most adipocyte membranes were ruptured; collagen fibers and small vessels were coagulated. For the highest energy setting (45 J), carbonization of fat tissue involving fibers and membranes was clearly seen with immunoreactivity for PS 100 (Figure 4).

Discussion

Laser lipolysis is a new technique still under development. The main objectives of this technique are faster

recovery, less operator effort, and skin tightening.⁴ The use of the Nd:YAG laser as an auxiliary tool has refined the traditional lipoplasty technique. Badin et al⁶ reported its utility in the upper abdomen and periumbilical region. The Nd:YAG laser was proposed first for use in laser lipolysis because of the penetration depth of its wavelength (1064 nm). However, diode lasers, which can typically emit at 810, 940, and 980 nm, could offer an alternative. Their wavelengths are in the same spectral region, and they offer the advantages of higher efficiency (usually 30%) and higher power (25 W or more). The absorption spectrum of mammalian fat obtained by van Veen et al⁷ using three independent methods show that the absorption coefficient obtained with a wavelength of 980 nm ($0.02\ \text{cm}^{-1}$) is very similar to that obtained with a wavelength of 1064 nm ($0.04\ \text{cm}^{-1}$). Similarly, coefficients of human fatty tissue reported by Altshuler et al⁸ were found to be very similar. Moreover, Conway et al,⁹ using a new method for the estimation of body composition in human beings, reported a similar optical absorption coefficient in the 900- to 1100-nm spectral band.

The interaction of the laser with the tissue is achieved through the absorption of the laser energy by the receptive chromophores, thus producing sufficient

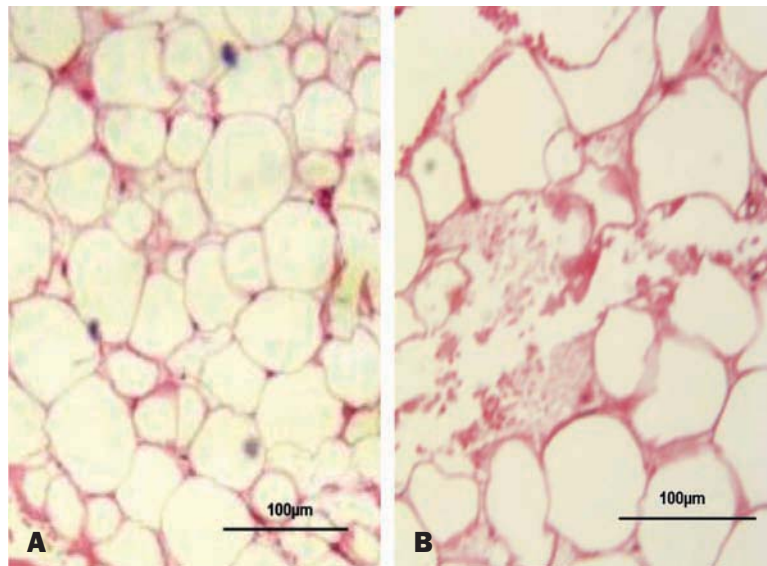


Figure 2. **A**, Normal adipocytes. Round-shaped adipocytes with a maximum diameter of $75\ \mu\text{m}$ (range $30\text{--}75\ \mu\text{m}$). **B**, Tumescent adipocytes observed after irradiation with an Nd:YAG laser (6 J). The diameter of the adipocytes was increased, and their round shape was altered (up to $100\ \mu\text{m}$). The channel produced by the fiber is seen at the center.

heat to cause the desired thermal damage. The heat acts on the fatty cell and the extracellular matrix to produce both reversible and irreversible cellular damage. In our study, for low-energy settings and at both 980 nm and 1064 nm, reversible damage was confirmed by the tumefaction of the adipocytes and an increase in their diameter of up to $100\ \mu\text{m}$. The heat generated by the laser would alter the balance of sodium and potassium of the cellular membrane, allowing the free transport of extracellular liquid to the intracellular atmosphere. This observation is in agreement with those of Badin et al.² Using an Nd:YAG laser, they observed that the average adipocyte diameter was $95.69\ \mu\text{m}$, as compared with an average diameter of $73.48\ \mu\text{m}$ for adipocytes in their normal state, and a diameter of $85.54\ \mu\text{m}$ for adipocytes after conventional lipoplasty.

For higher energy settings (1064 nm, 18 J–980 nm, 18 J up to 45 J), rupture of adipocytes and coagulation of collagen fiber and small vessels were observed. These observations are in accordance with the histologic assessment carried out by Goldman¹ on tissues removed immediately after the procedure and on biopsy specimens taken approximately 40 days after the procedures. These biopsy specimens showed the coagulation of small vessels

in the fatty tissue, the rupture of adipocytes, the appearance of small channels produced by laser action, reorganization of the reticular dermis, and coagulation of collagen in the fat tissue. Because of the rupture of the membrane, lipases liberated by the adipocyte are responsible for the liquefaction of the tissue, which further facilitates the subsequent aspiration. Through the liquefactive effect of the laser, the fat is loosened without the abrupt and repetitive back-and-forth motion of the cannula as performed with the conventional technique. The fact that heat also induces coagulation of small vessels in the fat tissue is very important because this phenomenon will facilitate lipoplasty by lessening trauma and bleeding. Lipoplasty removes significant amounts of fat, serum, and blood. In cases wherein large amounts of fatty tissue are to be removed, a physiologically significant loss of blood can provoke metabolic alterations. In this way, laser-assisted lipoplasty offers the advantage of removing larger volumes of fat without hemodynamic repercussions.²

Our observations are also similar to those made by Ichikawa et al.⁴ After irradiation of freshly excised human skin and subcutaneous fat with a 1064-nm laser, scanning electron microscopy showed greater destruction of human adipocytes than in the control.

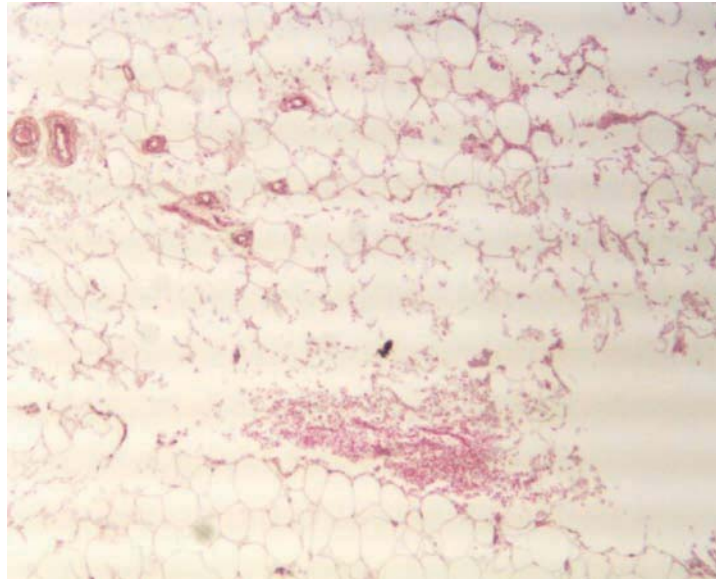


Figure 3. Photomicrograph of human fat in a laser-treated area (980-nm diode laser: 30 J) shows disruption of adipocyte membranes, coagulated collagen fibers, and blood vessel coagulation. (HES stain; original magnification $\times 40$.)

Degenerated cell membranes, vaporization, liquefaction, carbonization, and heat-coagulated collagen fibers were observed, with a dose-dependent relationship.⁴

In a recent study performed by Kim and Geronemus,³ in a series of 10 patients, they observed that the thermal damage produced by the Nd:YAG laser in the adipose tissue promoted better hemostasis, better wound healing, and less surgical trauma than conventional lipoplasty. In addition to the anatomic pathologic evidence, the clinical evaluation showed improved postoperative recovery resulting in more rapid return to daily activities with an excellent aesthetic result. Among the 10 patients who underwent magnetic resonance imaging before the procedure and 3 months after the procedure, there was an average 17% reduction in fat volume. Looking at the specific sites, the submentum, with a baseline average volume of 20 cm³, had a greater reduction (25%) compared with other, larger treatment sites, suggesting a dose-response relationship.^{3,4}

Kim and Geronemus³ performed laser lipolysis after infiltration of 1000 cm³ of anesthetic tumescent fluid. They have obtained good and reproducible results with a dose-response relationship. The higher the total energy

delivered, the higher the percent change in fat.³ Similarly, Goldman¹ used subcutaneous infiltration of fluid before laser lipolysis. This fluid does not seem to affect the effectiveness of laser lipolysis. The histologic findings and postoperative clinical outcomes of subjects who underwent laser lipolysis of the submental area, neck, and jowl have proven the safety and effectiveness of this procedure. One explanation could be a low absorption of the fluid compared with that of the subcutaneous fat.

Conclusion

Laser lipolysis is a relatively new technique and still under development. Our histologic findings, in accordance with those already published by several teams, suggest several positive benefits of the laser, including skin retraction and a reduction in transoperative bleeding. The interaction of the laser with the tissue is similar at 980 nm and 1064 nm with the same energy settings. Since higher volumes of fat are removed with higher total energy, high-power 980-nm diode lasers could offer an interesting alternative to the 1064-nm Nd:YAG laser. Further clinical evaluations and long-term analysis with and without aspiration are required to determine optimal treatment parameters. ■

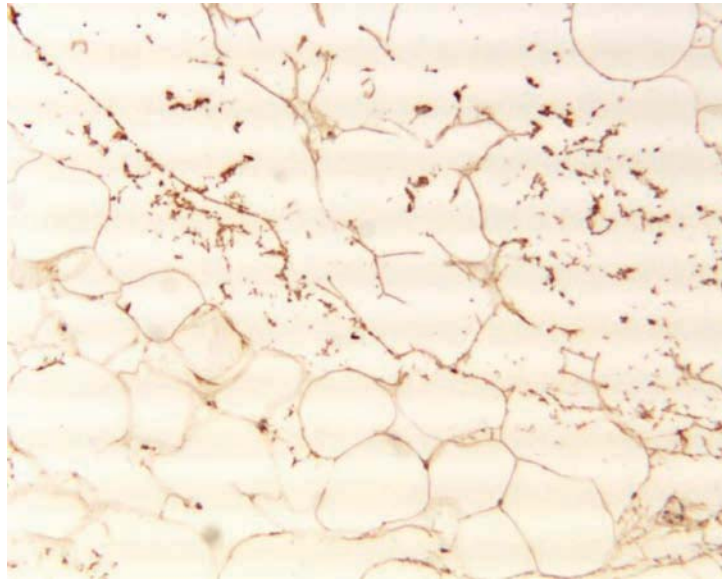


Figure 4. Photomicrograph of human fat in a laser-treated area (980-nm diode laser: 45 J) shows carbonization of fat tissue involving fibers and membranes. (Immunoreactivity for PS 100; original magnification $\times 60$.)

Mr. Wassman and Dr. Ringot are employed by Osyris SA, Hellemmes, France; Dr. Ringot is also a stockholder in this company. Drs. Mordon and Eymard-Maurin have no disclosures with respect to products mentioned in this article. Osyris SA paid the histology laboratory costs for this article.

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