Soft Tissue Cutting with CO_2, Diode Lasers

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For The Educational Series

The cutting and ablation of soft tissue by CO_2 and diode lasers have been extensively studied and reported[1-3]. This article illustrates the easily observed practical differences between CO_2 and diode lasers with respect to their soft tissue cutting and ablation abilities.

Water Absorption Spectrum

Wavelength-dependent laser light's interaction with water (the dominant component of soft tissue) is the key to understanding how the laser light cuts soft tissue. See Figure 1.

The absorption/penetration depth in water for the CO_2 laser wavelength (10,600 nm) is 0.01 mm, which explains the very thin sub-100 µm thermal damage zone on the margins of the incision in soft tissue[1]. Such short penetration depth enables high precision in removing the tissue, and provides for sufficient hemostasis for sub-0.5 mm diameter blood vessels.

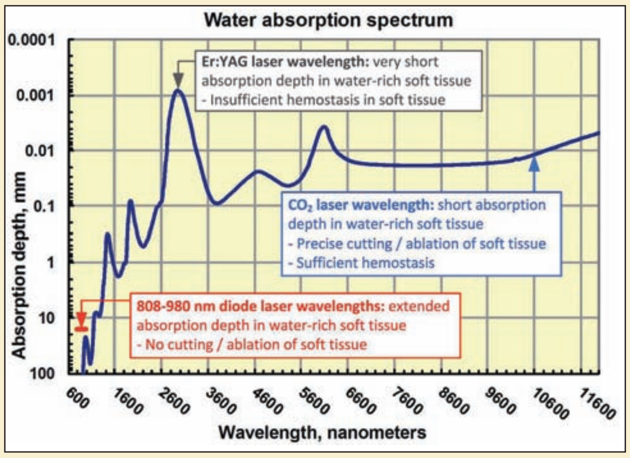

Figure 1

The absorption/penetration depth in water for the diode laser wavelengths in the 800-1,000 nm range is a thousand times greater than for the CO_2 laser wavelength. While hemoglobin and melanin do strongly absorb light in the 800-1,000 nm range, their relatively low concentrations in soft tissue result in a widely spread thermal damage zone of up to 8 millimeters[2,3].

Such deep subdermal penetration of diode laser light enables many useful non-surgical applications such as hair removal, spider vein reduction, biostimulation, etc.

CO_2 Laser-tissue Interaction

Figures 2 and 3 illustrate the interaction of CO_2 laser light at 10,600 nm with fresh poultry muscle tissue. The CO_2 laser beam from an Aesculight AE-3020 laser, focused to 0.25 mm spot size (Aesculight Tipless Handpiece) at 7 watt continuous wave in SuperPulse mode, produces a clean incision with char-free (carbon-free with no evidence of burning) margins with minimal thermal damage; see Figure 2.

The same laser with a larger spot size (Aesculight Wide Ablation Tip) at similar average power (6 watt; mode A14 SuperPulse at 20 watt with 30 percent duty cycle) to the tissue produces a 3 mm wide sub-mm deep ablation path—see Figure 3—a useful modality for tumor debulking, scar removal, wound cleaning and a variety of dermatological applications, etc. The CO_2 laser-tissue interaction is always predictable and is based on laser beam spot size, and laser beam power.

Diode Laser-tissue Interaction

Figures 4-7 illustrate the use of diode laser at 810 nm with the same tissue sample, the same average laser power (7 watts continuous wave) and similar spot size (0.3 mm) as used for CO_2 laser cutting settings presented in Figure 2. Diode laser use in "non-contact" mode is represented in Figure 4A (laser beam on) and Figure 4B (laser beam off); no tissue is removed regardless of exposure time while sub-surface thermal necrosis may extend for up to 8 mm deep[2].

Diode laser use in "contact" mode with a fresh and clean distal glass fiber tip firmly pressed against the soft tissue surface is presented in Figure 5A (laser beam on) and Figure 5B (post-lasing). Just as with "non-contact" mode, no tissue is removed regardless of exposure time while sub-surface thermal damage may be very wide spread and extensive[2].

The key to soft tissue removal with the diode laser is the carbon-rich black ink or char deposited on the diode laser's fiber glass tip in order to initiate or activate it—see Figure 6A. The char absorbs the diode laser light and blocks it inside the glass tip. The glass tip then heats up where it can burn the soft tissue upon contact; see Figure 6B.

Such thermal tissue removal is a slow heat-conduction process that depends on how charred and how hot the glass tip is. Slow tissue removal induced thermal necrosis of up to 6 mm deep[3] is manifested by extensive char left at the margins of incision, and by white "seared" discoloration outside of the charred margins of incision, seen in Figure 6B. An often overlooked aspect of using a hot charred glass tip for soft tissue removal is the thermal stress induced fracture of the fiber and loss of the broken tip inside the tissue; see Figure 7.

Summery

Diode laser light does not ablate soft tissue; it is used indirectly to heat up the optically "black" char on the tip of glass fiber; then the hot charred glass tip cuts the tissue by burning it away upon contact. Excessive char and thermal necrosis along with the possibility of a thermal stress-induced fracture of the glass tip inside the surgical site make the diode laser a "What you don't see can hurt you" tool for soft tissue surgery.

A diode's fiber hot glass tip is best used surgically where the use of CO_2 lasers is limited (fluid filled surgical site or with flexible endoscopes), while diode laser light has a number of non-surgical applications such as biostimulation, etc.

CO_2 laser light's ability to ablate and cut the water-rich soft-tissue with maximum precision and minimal collateral thermal effects[1] makes it a true "What you see is what you get" surgical laser with a short learning curve and a great variety of uses in general surgery. The sub-100 µm deep thermal effects on the margins of the incision are sufficient for sealing the blood vessels, lymphatics, and nerve endings, while the 10,600 nm laser light efficiently sterilizes the margins of incision by destroying surface bacteria. ●

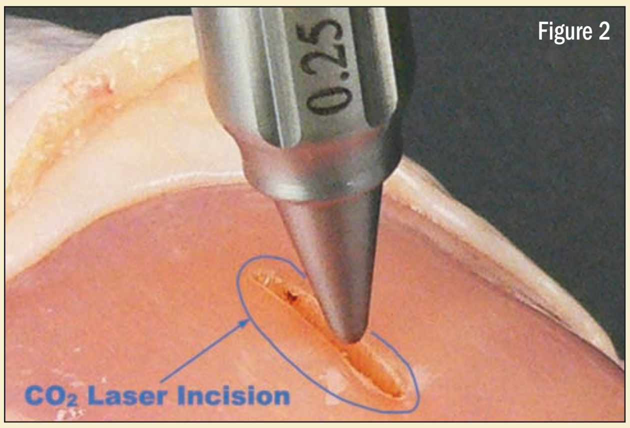

Figure 2

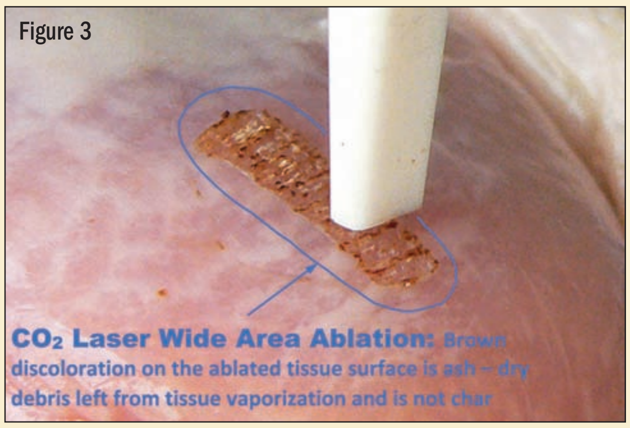

Figure 3

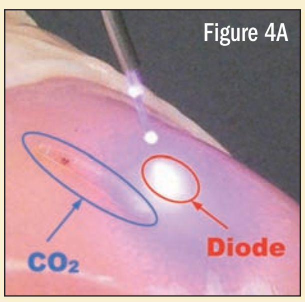

Figure 4A

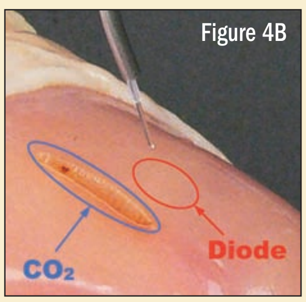

Figure 4B

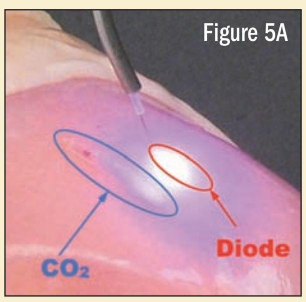

Figure 5A

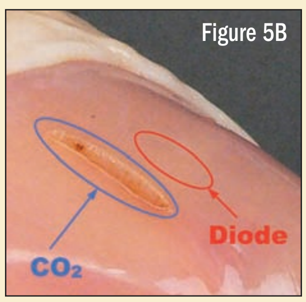

Figure 5B

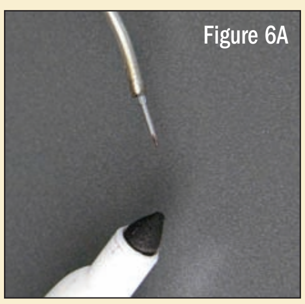

Figure 6A

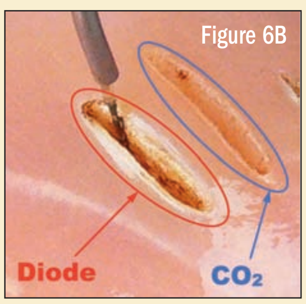

Figure 6B

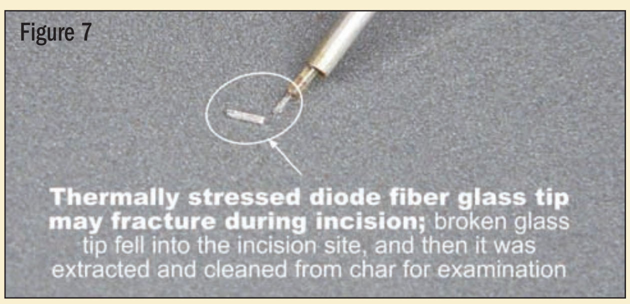

Figure 7

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This Education Series story was underwritten by Aesculight LLC of Woodinville, Wash., manufacturer of the only American-made CO_2 laser.