

A Comparative, Controlled Study of the CO₂ Laser WaveGuide and FreeBeam Tissue Effects

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BACKGROUND

The use of carbon dioxide (CO₂) lasers in surgery has been in existence for over 2 decades. The wavelength of the laser and its beam characteristics provide an efficient source of energy for cutting and ablating tissue with high water content. This efficiency is coupled with a residual thermal component that is ideal for hemostasis of blood vessels less than 0.5 mm in diameter thus combining surgical precision with minimized bleeding during surgery.

The CO₂ laser wavelength has been primarily delivered as a Free Beam (FB) to the target tissue through an articulated arm and rigid delivery devices of fixed focal length. These delivery devices require the ability to provide direct line of sight between the laser and the target tissue. Specially designed laser accessories of varying shape and length are used to enable access of the FB to anatomical areas such as the oral pharynx, nasal cavities, larynx, trachea, cervix, peritoneum, etc. The limitations imposed by direct line of site energy delivery can inhibit access at times, as well as eliminate the ability to deliver the energy through small lumen devices or flexible endoscopes.

The CO₂ laser wavelength cannot be transmitted efficiently through commonly used glass (or silica) core fibers, thus the use of flexible fibers was, until recently, not an available option. Lumenis has developed a flexible hollow, air core fiber (waveguide) that can efficiently transmit the CO₂ 10,600nm wavelength. The availability of the FiberLase CO₂ laser waveguide technology and the AcuPulse WaveGuide (WG) laser system allows delivery of energy directly to the tissue through the small fiber, around corners, with bendable handpieces and flexible endoscopes.

STUDY OBJECTIVE

The objective of this study was to compare in an in-vivo model the tissue effects of the AcuPulse CO₂ laser emitted via the WG versus the FB.

METHODS

Animal model:

Tissue effects were assessed on tissues of interest for the ENT specialty, namely tongue and lymphoid tissue, in a porcine model. Due to the small size of the porcine laryngeal lymph nodes, intestinal porcine lymph nodes were chosen for this study.

EQUIPMENT

CO₂ laser energy was delivered via an AcuPulse FB laser with an articulated arm and and AcuPulse WG laser through the FiberLase CO₂ fiber. In order to ensure delivery of the same power density to tissue, both delivery devices were standardized to deliver a 0.7mm spot. A commercially available handpiece for the FB with a focal length of 260mm (Figure 1) and a custom made handpiece for the WG (Figure 2) were used to maintain a constant distance of 5mm from tissue. The handpieces also limited the tremor effect thus enhancing the delivery motion consistency.



Figure 1 - FB handpiece on tissue



Figure 2 - WG handpiece on tissue

Testing was performed using Continuous Wave (CW) and Super Pulse (SP) modes with power on tissue set to 5, 10 and 15 Watts and 5 and 10 Watts, respectively. Power was measured as it exited the delivery device to ensure that the energy output was compensated for the waveguide power attenuation.

METHOD OF INCISION

Linear incisions in the target tissue were made at a speed of ~ 1cm/2sec. Contact of the handpiece to the tissue was ensured assuring both a constant focal length as well as stabilization.

Duplicate incisions for each laser delivery device were performed in parallel on the right and left sides on the dorsal surface of the tongue moving from medial to lateral. This provided normalization for tongue thickness and vascularization, etc. Paired incisions were made in lymph nodes, with sizes and orientations dependant on the shape of the lymph nodes.

Immediately after completion of the surgical procedure, the animal was euthanized and the tongue and lymph nodes were excised. The tongue was fixed on a foamed plastic board with hypodermic needles to prevent mechanical deformation and placed in a container for fixation in formalin for routine histopathology. Three cross sections were prepared at equal distances along the surgical cut, for each sample, and stained with Hematoxylin and Eosin.

DATA ANALYSIS

Comparison of the tissue effect was performed based on the following key comparative parameters:

1. Cutting depth
2. Collateral thermal damage

Review of the histologies was performed by a professional histopathologist. Cutting depth was assessed by measuring the depth of each incision from the surface level of the intact margins. Measurements were taken from each section and averaged to compensate for variability in cutting rate along each incision line.

Thermal damage is defined as a layer of cells exhibiting thermal cellular necrosis, i.e., loss of nucleus, denaturated cytoplasmic protein, and membrane disruption. The thermal damage was measured at three different incision depths (superficial, middle and deep).

RESULTS

Cutting depth

Calculated averages (\pm SE) of incision depths performed for each laser power and delivery method for the FB and WG are presented below. Figure 3 demonstrates very similar depths achieved at equal power to tongue tissue for both the FB and WG at all power settings. None of the differences between the different delivery methods were statistically significant. Increase of power in both the CW and SP modes led to an increase in depth achieved. (Figure 4 presents two examples of side by side comparative histologies of the FB and WG at low CW and high SP modes demonstrating the depth of penetration in parallel settings). The effect on lymph tissue was not as uniform with a slightly better depth achieved with the FB (Figure 5).

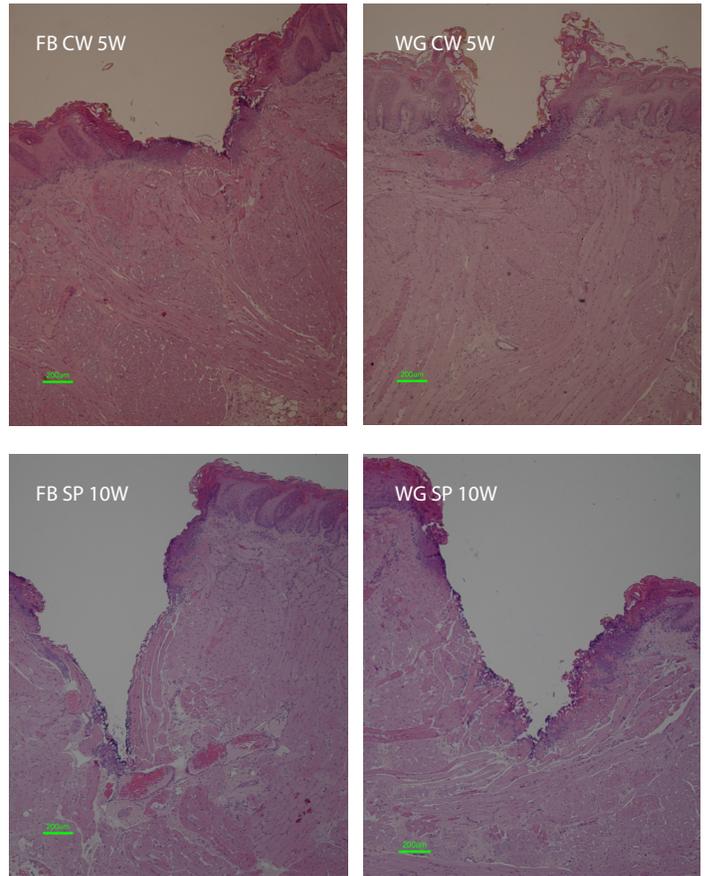


Figure 4 - Example side by side comparative histologies of tongue tissue cut with the FB and WG at low CW and high SP modes (x500M)

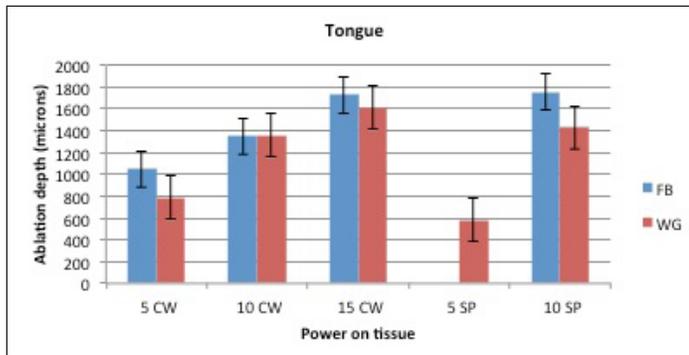


Figure 3 - Depth of ablation on tongue tissue

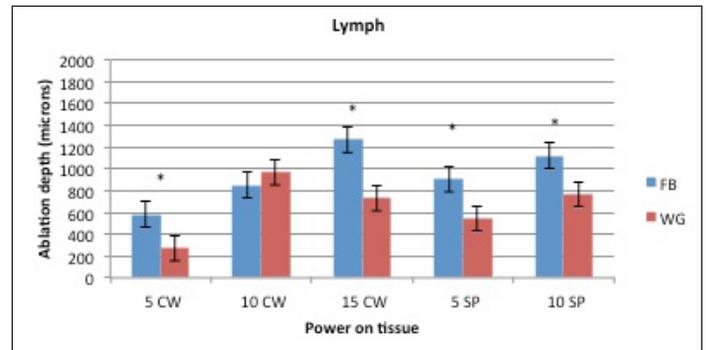


Figure 5 - Depth of ablation on Lymph tissue

COAGULATION

Thermal effect was reviewed at three depths for each laser power and delivery mode. Averages of the thermal effect demonstrated uniform lateral heating along the incision depth. Averages of the thermal effect at all depths demonstrate a very uniform effect for both the FB and WG. The uniform lateral heating can be seen for both the tongue and lymph tissue as well as for the different power settings (Figures 6 and 7).

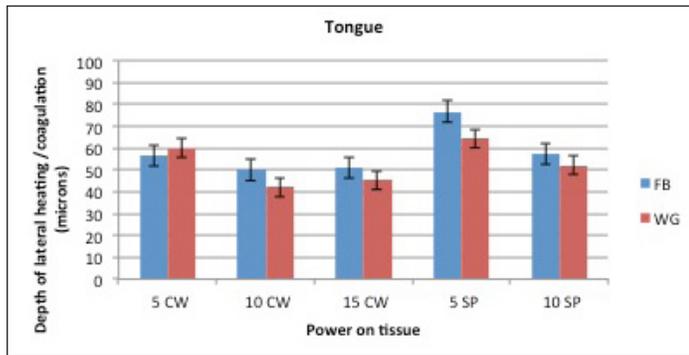


Figure 6 - Lateral heating on tongue tissue

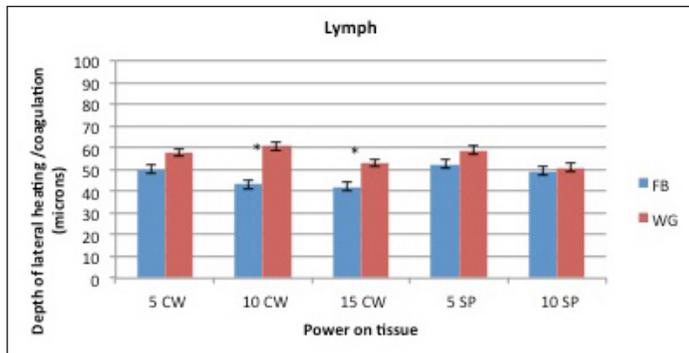


Figure 7 - Lateral heating on Lymph tissue

* statistically significant difference

DISCUSSION

Results demonstrate that the tissue affect of the FB and WG is similar for both the cutting capabilities and coagulation. Differences between the observed impact on the tongue and the lymph nodes can be attributed to the tissue variability of the lymph versus the uniform tongue structure and incision method.

Another phenomenon observed for both delivery devices (FB and WG) at both pulse modalities (CW or SP) is the increased depth of ablation versus the reduction in coagulation with the increase in power, reflecting a better ablation/coagulation ratio with increased power. This phenomenon is more prominent in the tongue, due to the above mentioned uniformity.

This comparative, histological analysis of the FB and WG in CW and SP laser modes, further demonstrates the applicability of the WG in ENT procedures, thus maintaining the desirable tissue thermal characteristics of the FB while enhancing the flexibility and accessibility.