A comparative study of two intraoral laser techniques for soft tissue surgery

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Abstract

Historically, 810nm has been the predominant wavelength used for intraoral surgery, when diode lasers have been discussed, due to their large numbers in the market place. The techniques used intraorally with the 810nm diode have been relatively similar in most cases. Low powers, 1 or 2 watts, using continuous wave, are employed.

The purpose of this study is to compare the thermal damage of the technique of using continuous wave at low powers, to using higher powers with a pulse mode and water for coolant, with the 980nm diode wavelength. During the study the laser fiber was held immobile eliminating surgical manipulation as an error.

The resultant histology proves, the volume of vaporization dramatically increases with the higher fluence, thus giving the clinician the ability to reduce the time for destructive conduction of excess heat for a given procedure and the amount of coagulation actually decreases in width and depth. As an added benefit charring, which has been implicated in delayed healing is virtually eliminated. This evidence, coupled with excellent clinical results, lends validity to the use of pulsed higher powers and water coolant for the 980nm diode laser.

Keywords: 980nm diode, high fluence technique, intraoral laser surgery.

Introduction

Historically, the 810nm wavelength has been the predominant diode wavelength used for intraoral laser surgery, due to the wavelength's initial positioning and predominance in the market place. The techniques used with the 810nm diode have been relatively similar in all cases. Low powers, less than 1 and up to 2 watts, continuous wave, using articulating paper or a tongue blade, to activate the fiber are employed. This technique utilizes a hot tip for the predominance of its photothermal effects. This technique is utilized due to the low water absorbtion and high scattering of the 810nm wavelength and other NIR wavelengths. The predominant process of optical propagation for the 810nm and the other wavelength lasers that comprise the NIR portion of the spectrum is elastic scattering. Scattering, however, does lengthen the pathway that the photons travel and increases the probability for absorption, thus increasing that effect, when it occurs, but causing it to be more diffuse. The resultant effect, of this technique, in intraoral use is desiccated tissue that exhibits charring, unless very low power is applied. The application of very low power, however leads to an additional adverse effect when delivered over a period of time to connective tissue. This effect is a crème brulee like surface to the ablated connective tissue which resists any additional vaporization and lends itself to charring (figure 1).

Recently the 980nm wavelength has entered the arena for intraoral surgery. The 980nm wavelength is positioned at an absorption peak in the water absorption spectrum giving it 8 times higher water absorption than the 810nm wavelength and 3 times more water absorption than 1064nm. The 980nm wavelength was initially utilized with a technique similar to the 810nm wavelength, 1 or 2 watts, continuous wave, with

moderate activation on the fiber tip. The laser produced similar results clinically when these parameters are employed due to the use of a hot tip effect.

An alternative technique, the high fluence technique, which better utilizes the subtle but significant difference in the 980nm wavelength, has been investigated. Using higher powers, a pulsed mode, a lightly activated fiber and water for cooling, dramatically better tissue results can be obtained (figure 2). Charring can be eliminated as well as the crusty coagulation, crème brulee effect of the connective tissue.

The rationale for the technique began to be developed from a case presentation the author had given at the ASLMS meeting in 1999. The case presented was accomplished using a low power technique as the author had been instructed. The case in question (figure 1) exhibited charring and dried connective tissue, the crème brulee effect, as had seemingly been the standard in the industry at the time as this was the only tissue effects the author had seen. . Having taken the Laser Biophysics and Safety course provided by Gregory Absten the authors thoughts were changed. In this manual Gregory Absten states, "the higher fluence will be more precise thermally in its tissue effects. This is very important as it relates to pulsing of laser energy. By pulsing the energy to very high peak powers, but for very short periods of time, any unwanted heat conduction to adjacent tissue is minimized or eliminated."[1] Also stated is," The longer the laser is left in place, even at low power; the more extensive is the thermal conduction to adjacent tissues. It is important to visualize this spread of heat during any laser procedure."[2] The first statement supports the reasoning behind using super pulse, free running pulse and Q switched laser energy for exacting thermal effects. The second statement supports completing laser treatment in an expeditious manner.

When lasers are used with the "hot tip effect," conductive energy is nearly the sole source of heat to the tissues. Excessive carbonization of a non contact fiber, used with no cooling, as is recommended with 810nm diode lasers and as is performed by some clinicians with free running pulse Nd:YAG lasers turns the lasers into instruments strictly using conductive energy, rather than instruments using radiant energy. The end result is to greatly reduce penetration but to increase lateral coagulation and increase charring.

This author speculated that even though water absorption in the NIR wavelengths is low, and high peak power microsecond pulses with milliseconds of thermal relaxation time could not be achieved at this time with a diode laser, the water absorption difference and penetration difference between 810nm 1064nm and 980nm, as stated by Cecchetti et al.[3] might be able to be exploited. Possibly a combination of minimal conductive energy from a hot tip and the use of radiant energy might be utilized to achieve more satisfactory tissue effects.

2. Methodology

Freshly butchered pig tongues were obtained from a local slaughterhouse. The tongues, ventral surfaces only, were cut into $1cm^3$ blocks x 30 and placed into room temperature normal saline. The blocks were kept in the normal saline prior to lasing. Only blocks bordering the midline were used. A stabilization device for the laser handpiece and fiber was previously constructed. Its purpose was to immobilize the fiber and eliminate surgical manipulation as a variable in the study. The pig tongue samples were precisely placed in light contact under the immobile laser fiber using a surgical operating microscope at 10x power for similar placement. Ten samples were prepared at each power setting.

Fiber preparation was identical in all of the 2 and 4 watt samples. A 400um silica/silica fiber was used for all samples. Most laser manufacturers suggest initiation of the laser fiber by firing the laser on a piece of dental articulating paper. The fibers for all of the samples were freshly cleaved, the cleaved fibers checked by evaluating the accuracy of the aiming beam on a non reflective surface for throughput and circularity of the beam. They were then initiated on dental articulating paper.

Fiber preparation for the 10 watt samples was accomplished in a similar manner, except the fiber initiation was accomplished by firing on the black ink of a business card rather than the articulating paper. The reason for the variation is to restrict the heat generated by the silica fiber to a minimum. When the diode laser fiber is initiated on articulating paper and fired in the air at 10 watts the fiber gets hot enough to melt. Initiating the fiber on a business card generates minimal fiber heat. This type of fiber initiation does not generate that level of fiber heat as when the fiber is fired in the air it doesn't even glow let alone melt. The reason for initiating the fiber is that some conductive energy will be used to reach vaporization threshold.

The 2 watt samples were individually placed in light contact with the laser fiber and the laser was set at 2 watts for a 5 second pulse, the computer in the laser therefore controlled the exposure to 2 watts continuous wave for 5 seconds. High speed dental evacuation was employed for possible biohazard evacuation and standardized cooling. The samples were immediately transferred to a biopsy bottle containing 10% neutral buffered formalin and appropriately marked. The total energy delivered to each sample being 10 joules.

The 4 watt samples were handled similarly with the exception that the laser was set on 4 watts for a 5 second pulse prior to placement of the samples in the biopsy bottles. The total energy delivered to each sample being 20 joules.

The 10 watt samples were placed similarly with the aid of the surgical operating microscope. The difference being threefold as indicated by the high fluence technique:

1. The power was set at 10 watts pulsed at a 50% duty cycle .05 seconds on and .05 seconds off or 10 hertz. A peak power of 10 watts and average power of 5 watts was delivered.
2. The pulse counter on the laser was set to deliver 50 pulses or exactly 5 seconds of total exposure time.
3. Water was used for cooling through the prototype cooling handpiece, from bioLitec. The water was delivered coaxially with the laser fiber through a 20 gauge cannula, with a flow rate of 7cc/min.

The samples were placed immediately after lasing in the appropriately marked biopsy bottles. The total energy delivered in this case to each sample being 25 joules. The major difference being the 25 joules were delivered in 2.5 seconds with 2.5 seconds of cooling.

The collected (oral) tissue was sent to Mass Histology Services. At the histology laboratory the individual tissues were retrieved from their shipping bottles, any excess tissue trimmed, and then placed on their long side in tissue holders (cassette) with the mucosal surface at 90 degrees to bottom of cassette. Tissues were then processed through a series of alcohol baths to dehydrate and fix them after which they were embedded in paraffin wax molds to hold their shape. Tissues were then trimmed from the wax molds using a standard microtome into 5-micron sections with the mucosal surface parallel to line of cut so that the depth and width of the laser penetration points (lesions) were visible. Cut tissues were then stained with standard Hematoxylin (stains nuclear DNA and RNA blue) and Eosin (stains cytoplasmic structures red) stains. The stained tissues on glass slides were then cover slipped to preserve them, numbered by group and sent to the pathologist for microscopic evaluation.

The microscopic pathology evaluation included assessments to insure: that the exact same board part of the lesion was present in each mucosal section submitted; that the accessory dermal structures outside the immediate penetration point were or were not involved in spread; and that morphological measurements of the width and depth of spread were done in the same manner for each section using a standard Leitz 2mm microscopic slide micrometer. All measurements and observations were then recorded in computer-based tables using Microsoft word 2000. Finalized data was then sent to researcher for analysis and incorporation into final report.

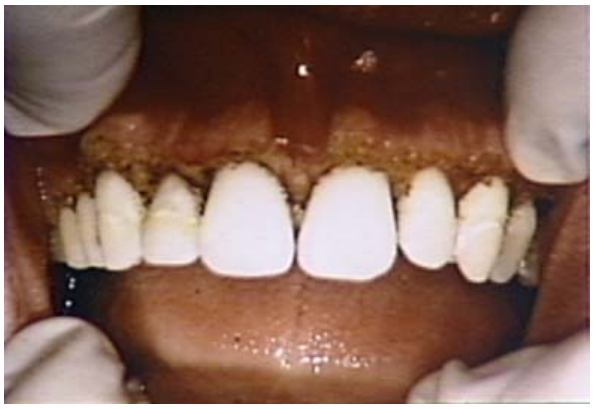

Figure 1.

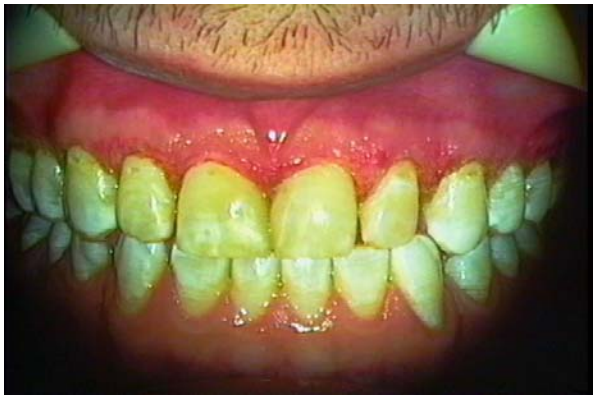

Figure 2.

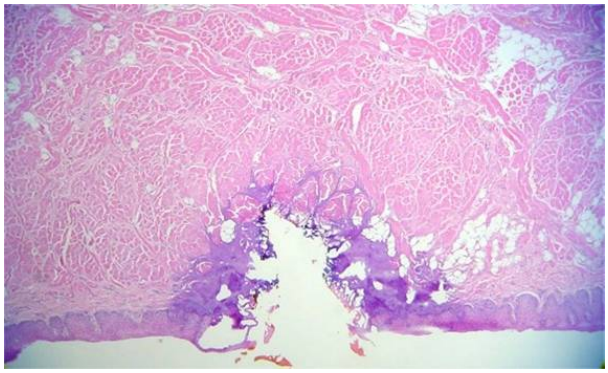

Figure 3. 2 watts.

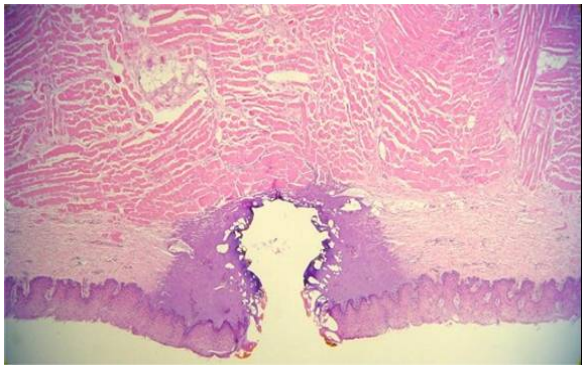

Figure 4. 4 watts

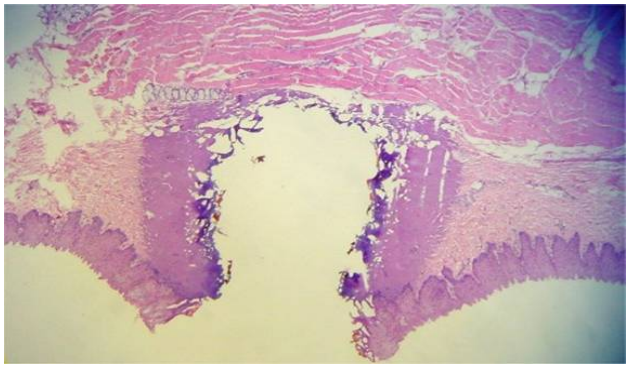

Figure 5. 10 watts

3. Data

Laser Techniques Histology chart

	Widest Spread	Ablated Width	Lateral coagulation	Total depth of ablation	Vertical coagulation
GROUP 1					
2W 5 sec #1	1.55 mm	0.75 mm	0.40mm	0.85 mm	0.25mm
2W 5 sec #2	1.75 mm	1.35 mm	0.20 mm	0.75 mm	0.20 mm
2W 5 sec #3	1.90 mm	0.90 mm	0.50 mm	0.70 mm	0.25 mm
2W 5 sec #4	1.90 mm	0.80 mm	0.55 mm	0.76 mm	0.19 mm
2W 5 sec #5	1.60 mm	0.60 mm	0.50 mm	0.70 mm	0.10 mm
2W 5 sec #6	1.50 mm	0.50 mm	0.50 mm	0.65 mm	0.10 mm
2W 5 sec #7	2.00 mm	0.80 mm	0.60 mm	0.80 mm	0.20 mm
2W 5 sec #8	1.50 mm	0.50 mm	0.50 mm	0.50 mm	0.20 mm
2W 5 sec #9	1.70 mm	0.80 mm	0.45 mm	1.00 mm	0.25mm
2W 5 sec #10	1.70 mm	0.90 mm	0.40 mm	0.65 mm	0.15 mm
Average	**1.76 mm**	**0.79mm**	**0.46 mm**	**0.74 mm**	**0.19 mm**
GROUP 2					
4W 5 sec #1	1.85 mm	0.85 mm	0.50 mm	0.75 mm	0.15 mm
4W 5 sec# 2	2.10 mm	0.80 mm	0.65 mm	1.40 mm	0.20 mm
4W 5 sec# 3	1.95 mm	0.35 mm	0.80 mm	1.30 mm	0.10 mm
4W 5 sec #4	1.90 mm	0.60 mm	0.65 mm	1.30 mm	0.30 mm
4W 5 sec #5	2.30 mm	1.00 mm	0.65 mm	0.80 mm	0.35 mm
4W 5 sec #6	2.00 mm	1.00 mm	0.50 mm	1.65 mm	0.35 mm
4W 5 sec #7	2.20 mm	1.10 mm	0.55 mm	0.80 mm	0.10 mm
4W 5 sec #8	2.10 mm	0.90 mm	0.60 mm	1.10 mm	0,35 mm
4W 5 sec #9	1.70 mm	0.70 mm	0.50 mm	0.70 mm	0,40 mm
4W5 sec #10	1.70 mm	0.60 mm	0.55 mm	1.52 mm	0.22 mm
Average	**1.92 mm**	**0.79 mm**	**0.59 mm**	**1.13 mm**	**0.25 mm**
GROUP 3					
10 Watt#1	1.55 mm	0.95 mm	.30 mm	1.25 mm	0.15 mm
10 Watt#2	1.65 mm	0.95 mm	.35 mm	1.40 mm	0.10 mm
10 Watt#3	1.00 mm	0.80 mm	.10 mm	1.10 mm	0.25 mm
10 Watt#4	1.80 mm	1.10 mm	.35 mm	1.25 mm	0.20 mm
10 Watt#5	1.70 mm	1.10 mm	.30 mm	1.40 mm	0.25 mm
10 Watt #6	1.50 mm	1.20 mm	.15 mm	1.25 mm	0.10 mm
10 Watt#7	1.45 mm	1.05 mm	.20 mm	1.05 mm	0.20 mm
10 Watt#8	1.20 mm	0.70 mm	.25 mm	1.25 mm	0.05 mm
10 Watt#9	1.75 mm	1.25 mm	.25.mm	1.30 mm	0.25 mm
10 Watt#10	1.90 mm	1.60 mm	.15mm	1.10 mm	0.25 mm
Average	**1.58 mm**	**1.07 mm**	**.25 mm**	**1.24 mm**	**0.18 mm**

4. Results

The data was evaluated and the Volume of Ablated Tissue was calculated. Representative slides were photographed. (See figures 3-4-5.)

Since the shape of the 2 watt sample was conical in nature the formula used was:
$V= \frac{1}{2}h\pi r^2$
Where h= the ablated depth
And r=Ablated width/2

Since the shape of the vaporized tissue in the 4 and 10 watt samples were not conical or cylindrical, the formula for volume calculation was altered to accommodate the U shape of the ablated tissue.

The formula used was: $V= \frac{3}{4}h\pi r^2$
Where h= the ablated depth
And r=Ablated width/2

Group1 $V= (.5)\ (.74mm)\ (3.14)\ (.79mm/2)^2$
$= (.37mm)\ (3.14)\ (.4)^2$
$= (1.16mm)\ (.16)$
$= .19\ mm^3$

Group 2 $V= (.75)(1.13mm)\ (3.14)\ (.79mm/2)^2$
$= (.85mm)\ (3.14)\ (.4)^2$
$= (2.67mm)\ (.16)$
$=.43\ mm^3$

Group 3 $V= (.75)\ (1.24\ mm)\ (3.14)\ (1.07mm/2)^2$
$= (.93mm)\ (3.14)\ (.54)^2$
$= (2.92)\ (.29)$
$=.85\ mm^3$

The 10 watt sample exhibited nearly twice as much ablated volume as the 4 watt sample and 4 times as much ablated volume as the 2 watt sample. The 10 watt sample also exhibited the least amount of total lateral effect but least amount of lateral coagulation, almost 2x less than 2 watts Continuous wave. The ablated depth was slightly greater in the 10 watt sample but the depth of coagulation was similar or slightly less.

5. Conclusions

Intra oral laser techniques for 810nm diode lasers have historically used low power, continuous wave settings and a hot tip for control of thermal effects. These lasers have been typically implicated in deep and wide thermal effects. This is due to the low water absorption and high scattering effects of the NIR wavelengths. Pulsed laser technology has been introduced to off set the thermal scattering effect of the NIR. In pulsed laser technology; free running, Q switching and Mode locking is employed to provide higher peak powers and low average powers to limit the thermal conduction to the surrounding tissues, thus limiting or eliminating thermal damage. Very high peak powers and short duration pulses are available. Diode Laser technology as it exists today does not make available to the clinician 100 microsecond pulses in high peak powers, due to the availability of only gated pulses and no laser cavity for amplification of the pulse.

The author believes that in the 980nm wavelength the increase in water absorption seems to lend itself to a technique using less conductive energy from a hot tip to the use of more radiant energy for ablation. This is

substantiated by a comparison of hot tip techniques at 2 and 4 watts to a technique using 10 watts pulsed and water for cooling. In the high fluence technique for the 980nm diode laser two major differences occur. Pulsing is employed enabling the use of higher peak powers to be applied (for thermal precision and use of radiant energy for ablation) and water is used for cooling of the laser fiber and tissue. The water initially reduces the heat conduction from the laser fiber to the surrounding tissue and secondly reduces the conduction of excess heat through the tissue caused by a typically long laser pulse thus reducing excess thermal damage.

This study, however limited, shows that 10 watts using the High Fluence Technique produces less thermal damage than the standard technique with a greater amount of vaporization, when using the 980nm diode laser. Maximum controllable vaporization with adequate coagulation should be the goal of the general dentist. If either vaporization or coagulation is not sufficient excessive lasing time on the tissue will be required with the resultant increase in thermal damage due to excessive conduction.

More complete studies need to be performed in order to precisely elucidate the effects of the 980nm diode laser and its use in intraoral surgery. The advantage of the 980nm wavelength has already been shown for implant uncovery and decontamination, Ramanos[4]. Nearly 200 dentists world wide are now using the 980nm diode and "The High Fluence Technique" with no reports of adverse effects. More clinical cases will be seen published, in the near future, with this wavelength.

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