Clinical

PRACTICE

The Use of Lasers for Periodontal Debridement: Marketing Tool or Proven Therapy?

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ABSTRACT

The use of lasers in dentistry has recently received much attention, in both clinical practice and research; their unique properties produce favourable clinical results in some cases and encourage patient acceptance. Various types of lasers have been investigated as an adjunct to periodontal therapy; these include carbon dioxide (CO2), diode, neodymium:yttrium–aluminium–garnet (Nd:YAG) and erbium:yttrium–aluminium–garnet (Er:YAG) lasers. However, adverse results have been associated with each type, including thermal damage to root surfaces, increases in pulpal temperature and the production of toxic by-products. The Er:YAG laser has produced the most promising results, as it can ablate effectively with minimal adverse effects. More research is needed to determine the ideal settings and methods for using the laser safely and effectively in clinical practice.

MeSH Key Words: debridement/methods; laser surgery/methods; periodontal diseases

© *J Can Dent Assoc* 2005; 71(9):653–8
This article has been peer reviewed.

The concept of lasers dates back to 1917 with Einstein's theory of stimulated emission, but it was not until 1960 that the first working laser was created by Theodore Maiman.[1] Lasers are currently used in a wide range of medical and cosmetic procedures including cataract surgery[2] and hair removal.[3] However, they have only recently received attention in clinical dental settings. Lasers are being recognized for their ability to ablate hard tissues with minimal anesthesia,[4,5] reduce bacteria counts in root canals[6,7] and even provide hemostasis of soft tissues during their use.[8] The aim of this article is to review various studies of lasers used in periodontal debridement.

Lasers and Clinical Dentistry

The word "laser" is an acronym for "light amplification by stimulated emission of radiation." Lasers are categorized according to the medium used to provide atoms to the emitting system. Each type of atom can absorb photons of only certain wavelengths; therefore, each medium will produce a laser beam with a specific range of wavelengths.[9] Light of different wavelengths will interact differently with tissue and has different adsorption qualities. Lasers used in dentistry emit wavelengths between 377 nm and 10.6 µm. The most common types are carbon dioxide (CO_2), diode, neodymium:yttrium–aluminium–garnet (Nd:YAG) and erbium:yttrium–aluminium–garnet (Er:YAG) lasers. They are currently used for cavity preparation,[4] tooth whitening,[10] gingival incisions[11] and other applications. In periodontics, lasers have been investigated for use in promoting periodontal attachment,[12] elimination of bacteria from periodontal pockets,[6] debridement of root surfaces[13] and treatment of dentinal hypersensitivity.[14]

Carbon Dioxide Laser

The CO_2 laser has the longest wavelength of all dental lasers (10.6 µm). Compared with other lasers, such as the Er:YAG, its absorption coefficient in hydroxyapatite is very high (10^4), but the absorption coefficient in water is low (10^3) (**Fig. 1**),[15] accounting for the powerful ablative properties of this laser.

Almost all studies of CO_2 lasers for periodontal debridement are in vitro; information from clinical settings is limited. All in vitro

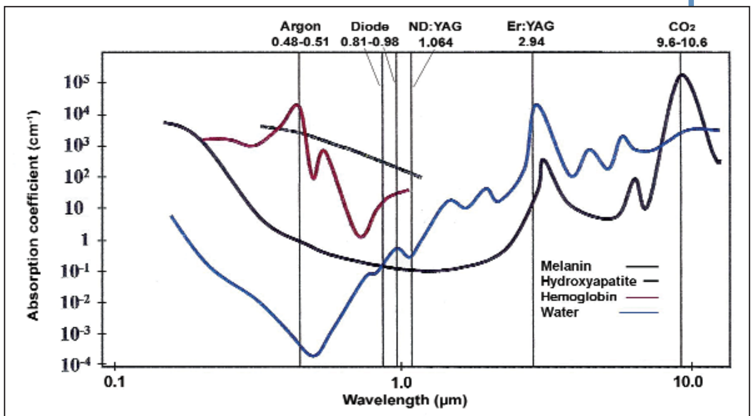

Figure 1: Absorption coefficients and wavelengths of various lasers. Note the significant differences between short and long wavelength lasers. Reprinted with permission from the Institute of Laser Dentistry.

studies noted similar effects on the root surfaces of extracted teeth, i.e., charring, cratering, carbonization, surface cracking, meltdown and resolidification of minerals like calculus.[16] The use of a coolant had no effect.[15,17,18] Less aggressive results have been reported when a pulsed defocused beam was used, but this resulted in non-favourable morphologic changes in the tooth surface.[19]

One of the problems associated with the use of a CO_2 laser is the estimated depth of laser energy penetration into the calculus masses. In vivo, microbial plaque thickens to 100 µm within hours of colonization. Complete eradication of such a thick layer would require a penetrating wavelength with higher energy density or longer and more repeated exposures, which would lead to increased risk of damage to the adjacent tissues.[16]

There is also evidence that CO_2 lasers may produce toxic substances by photothermal vaporization. The high absorption of CO_2 laser energy by hydroxyapatite results in transformation of some of the radiant energy into heat, increasing the local temperature to over 700°C, which is sufficient to melt hydroxyapatite, and resulting in the emission of cyanate and cyanamide — both toxic substances.[15]

In vivo, CO_2 laser treatment had no significant long-term effect on levels of *Porphyromonas gingivalis*, interleukin-1 beta (IL-1β) or gingival crevicular fluid (GCF) and actually led to an increase in IL-1β.[20] In this study, probing depths at 12 weeks had decreased after CO_2 laser treatment although less than that observed after Nd:YAG laser treatment and ultrasonic scaling. Improvements in clinical attachment levels were only significant in the latter 2 groups.

Diode Laser

Surgical diode lasers emit coherent, monochromatic light of short wavelength. The shorter wavelength results in a small absorption coefficient in water and hydroxyapatite; therefore, diode lasers do not ablate hard tissues very well due to their weak interaction with mineralized structures. However, this wavelength results in a high absorption coefficient in dark media such as hemoglobin, making diode lasers excellent for surgical cutting in well-vascularized soft tissues.[21] The procedure results in coagulation and minimal bleeding when used on gingiva.

In vitro studies testing the efficiency of the diode laser in periodontal debridement have been carried out using several models: the 665-nm AlGeAs (aluminium–germanium–arsenide) laser,[22] the 810-nm GaAlAs (gallium–aluminium–arsenide) laser,[22,23] the 655-nm GaAlAs laser[12] and a 980-nm diode laser.[24] In all of these studies, there were minimal thermal increases over the 5°C accepted limit. The bactericidal effect of these lasers depended on species of bacterium, wavelength and dose.[12] The in vitro removal of calculus using a diode laser seemed to be consistent and comparable with manual scaling and root planing (SRP).[12,22–24]

In in vivo studies with diode lasers, large amounts of calculus remained after treatment and there was significant structural damage to root surfaces.[12] Yilmaz and others[25] used a GaAlAs laser in a randomized controlled trial and found no beneficial effect over SRP alone. The differences between in vitro and in vivo studies may be attributed to the presence of blood in vivo, which may influence the amount of fluorescence radiation reaching the calculus.

Although diode lasers are currently being investigated in other aspects of dentistry, including treatment of peri-implantitis, they do not seem to provide any advantages over SRP in periodontal debridement. However, as this is a soft tissue laser, it may have potential as an adjunct to classical periodontal debridement rather than as monotherapy. Romanos and others[24] found the 980-nm laser to be superior to SRP in removing thin pocket epithelium. More research is needed in this area.

Neodymium:Yttrium–Aluminium–Garnet Laser

Nd:YAG lasers have a slightly longer wavelength (1,064 nm) than diode lasers. Although their absorption by healthy human enamel is very low, their much greater absorption by carious enamel makes them worthy of investigation.[26] The Nd:YAG laser has been tested in periodontal therapy since the early 1990s.[27–29]

Table 1 Summary of in vitro studies of the erbium:yttrium-aluminium-garnet laser

Authors	Outcome measures	Sample size	Water coolant	Controls	Random	Pulses/s	Tip size	Energy output; mJ/pulse	Results
Aoki and others[42]	SEM observation of effect of laser in calculus removal SEM observation of root and thermal effects of laser with and without water coolant	53	Yes Yes	No	Yes	10 (200 µs)	600-µm diameter	10, 20, 30, 50, 80, 120	Ablated calculus and underlying cementum and dentin Maximum calculus selectivity at 30 mJ/pulse Fewer thermal effects with water irrigation Minimal rises in pulpal temperature
Gašpirc and others[32]	Morphology, chemical structure and diffusion processes of root surface	60	No	Yes	Yes	10 (250 µs)	—	60, 80, 100	Cementum and dentin removed without thermal side effects Chemical structure of root surface maintained Diffusion process increased more than with Nd:YAG laser
Frentzen and others[41]	SEM and light microscopic examination of root surface characteristics and calculus removal	40	Yes	Yes	Yes	—	1.10 × 5, 1.65 × 5 mm	160	Adequate calculus removal, roughened surfaces and increased cementum removal compared with SRP Crater depths within range of those with SRP and ultrasonics
Aoki and others[47]	Histologic/SEM observation of root surface and efficiency of scaling Thermal changes	53	Yes	Yes	Yes	10 (200 µs)	600-µm diameter	40	Lower level of vibration than with ultrasonic debridement No major thermal damage Rougher root appearance than with ultrasonic debridement Settings not selective enough for calculus removal without root damage
Folwaczny and others[43]	SEM examination of root surface Evaluation of substance removal (calculus and root surface)	50	No	Yes	Yes	15 (250 ns)	1.65 × 0.5 mm	60, 80, 100, 150	Significantly more substance removal than controls at all energy levels No residual deposits or smear layer formation and no thermal side-effects

Nd:YAG = neodymium:yttrium–aluminium–garnet; SEM = scanning electron microscopy; SRP = scaling and root planing.

Several in vitro studies have used scanning electron microscopy to investigate the effects of Nd:YAG lasers on root surfaces.[17,30–32] Most of these studies used a pulsed laser beam with a contact optical fibre, except for that of Wilder-Smith and colleagues,[31] who positioned the tip of the laser 5 mm from the root surface. All 4 studies found that the Nd:YAG laser had a detrimental effect on the root surface; damage ranged from heat cracking to charring, cementum meltdown and crater formation. Although surface cooling with water, air or both decreased the damage, a 25% to 40% increase in laser energy density was needed to produce equivalent ablation effects.[17]

Cytokines, such as IL-1β, have been implicated in the pathogenesis of various forms of periodontal disease. Endotoxin seems to be the most potent stimulator of IL-1β production. Therefore, it seems only natural to target the removal of cementum-bound endotoxin during root planing. Liu and others[33] examined the effect of Nd:YAG lasers on endotoxin in teeth extracted due to periodontal disease. They found that the laser alone could not produce a high enough temperature to destroy cementum-bound endotoxin and still remain within safe clinical limits. SRP alone or combined with laser treatment produced similar outcomes in terms of the reduction of IL-1β for up to 3 months.[34] In a comparison of Nd:YAG laser monotherapy in vivo versus ultrasonic scaling, probing depth reduction and attachment levels observed at 3 months were also similar.[20]

After observing positive results, investigators[8,35] suggested that perhaps the Nd:YAG laser should be used as an adjunct to SRP to perform sulcular debridement rather than to remove calculus. Its role would focus on the elimination of bacterially infested pocket epithelium rather than actual calculus ablation. As pocket epithelium in a diseased environment consists of significant granulation tissue (which is a dark colour due to dilated blood vessels), the laser could stimulate evaporation of the darker tissue thus reducing periodontal pathogens and prolonging their recolonization time. The tip of the optical fibre would be brushed over the treatment area allowing light contact with the pocket epithelium for the necessary amount of time. After treating and monitoring 744 periodontal pockets (pocket depth > 4 mm), Neill and Mellonig[36] found that SRP alone and SRP plus Nd:YAG laser treatment produced a pocket depth reduction of 1.6 mm and 1.7 mm, respectively, which was maintained at 3 months. Clinical attachment levels and microbial counts also showed similar improvement with

Table 2 Summary of in vivo studies of the erbium:yttrium-aluminium-garnet laser

Authors	Outcome measures	Sample size	Water coolant	Controls	Random	Tip size mm	Energy output; mJ/pulse	Time	Conclusions
Schwarz and others[14]	Clinical measurements Microbiological evaluation Follow-up at 6 months	20 patients 660 sites	Yes	Yes	Yes	1.65 × 0.5 1.10 × 0.5	160	Avg. 5 minutes/ single-rooted tooth; 10 minutes/ tooth	Significantly smaller increase in gingival recession and greater reduction in BOP and CAL gain over SRP Comparable reduction in motile rods and spirochetes to SRP
Schwarz and others[48]	Clinical measurements Microbiological evaluation Follow-up for 12 months	20 patients 600 sites	Yes	Yes	Yes	1.65 × 0.5	160	Avg. 10 minutes/ single-rooted tooth; 10 minutes/ tooth	Comparable improvements in clinical measurements and reduction in motile rods and spirochetes in both groups SRP combined with laser did not seem to improve clinical outcome over laser alone
Schwarz and others[49]	CAL gain Follow-up for 2 years	20 patients 660 sites	Yes	Yes	Yes	1.65 × 0.5 1.10 × 0.5	160	Avg. 5 minutes/ single-rooted tooth; 16 minutes/ tooth	At 1 and 2 years, laser had a significantly higher BOP reduction and CAL gain At 1 and 2 years, bacterial counts similar to baseline for both groups CAL gain in both groups maintained over 2 years

BOP = bleeding on probing; CAL = clinical attachment level; SRP = scaling and root planing.

the 2 methods; a tendency toward better results with the combined therapy was not statistically significant.

Because clinical results are not improved by adding laser treatment to the gold standard SRP, the use of lasers as an adjunct to debridement should be questioned. Their use potentially adds to treatment time and increases the cost significantly. In a split-mouth study, Sjostrom and Friskopp[8] investigated several parameters, including patient satisfaction and time added to treatment when an Nd:YAG laser was used as an adjunct to SRP. At 4 months, there tended to be greater improvement after laser-assisted periodontal debridement, although the difference between the groups was not significant. The authors made several important observations. They found that the use of the laser before debridement weakened the attachment of calculus to the root surface, thus facilitating its removal with hand instruments; however, the time needed for debridement increased by 15%. They also noted an analgesic effect of Nd:YAG leading to a significant decrease in requests for local anesthesia by the patients. The hemostasis effect may also prove important in patients who are on anticoagulants or have a bleeding disorder. Patients reported significantly less postoperative pain and swelling when laser treatment was used as an adjunct, although this could be due to the placebo effect that a "new" and "advanced" treatment may have on their perception.

Erbium:Yttrium–Aluminium–Garnet Laser

This is the type of laser most commonly studied for use in periodontal debridement. It has received an enormous amount of attention in dentistry since its first application in the late 1980s.[37,38] It has a wavelength of 2,940 nm (2.94 µm), and very high absorption coefficients in water and hydroxyapatite compared with the diode and Nd:YAG lasers. Because of its high rate of absorption in water, the Er:YAG laser ablates hard tissue through "microexplosions" rather than heating the tissue, resulting in minimal thermal side-effects.[32] This desirable property of the Er:YAG laser led to its approval in 1997 by the Food and Drug Administration in the United States for use on hard tissues; it was the first dental laser to receive approval for preparation of dental cavities.[39] Because calculus is also a hard mineralized substance, various studies have tested the Er:YAG laser for debridement of root surfaces.

Variation in experimental design and laser settings make studies difficult to compare. Most well-designed studies in the peer-reviewed literature are in vitro. Earlier studies[40] showed detrimental outcomes of Er:YAG laser treatment on cementum surfaces of extracted teeth, including cratering and heat cracking, regardless of the presence of water coolant. Others[41] noted a greater loss of cementum and residual root roughness when root planing with an Er:YAG laser compared with ultrasonics and hand instrumentation; under a scanning electron microscope, complete removal of cementum was apparent in 22.5% of laser-treated teeth compared with 12.5% of teeth treated by scaling alone. These negative outcomes were confirmed in vitro when energy outputs exceeded 50 mJ/pulse,[42] although undesirable thermal effects were decreased in vitro when water irrigation was used.[18] A water spray may decrease pulpal wall temperature by 2.2°C.[35] It seems that even at a relatively low radiation energy (e.g., 60 mJ), the Er:YAG laser removed considerable calculus, cementum or both, and penetration into the cementum increased significantly at 150 mJ.[43] Hand instrumentation may lead to removal of up to 264.4 µm of cementum[44] or even 343.3 µm.[45] Ultrasonic instrumentation may penetrate up to 83.3 µm of cementum depending on the roughness of the diamond coating and the application force used by the investigator.[46] Up to 386.12 µm of cementum was removed from teeth with a laser at 100 mJ.[43] However, Aoki and others[47] disagreed with these findings and reported the maximum removal of cementum by laser of 140 µm (**Table 1**).

In the few in vivo studies of the Er:YAG laser (**Table 2**), it was used alone or in conjunction with SRP. In a comparison of laser debridement as monotherapy (160 mJ) with laser debridement as an adjunct to SRP, most clinical parameters improved similarly and remained constant over one year.[48] However, the recession readings tended to favour the monotherapy laser group, although they were not statistically significant. The authors concluded that there was no clinical benefit derived from adding SRP to laser treatment alone. The same group of investigators[14] compared laser treatment with SRP as monotherapies and again obtained favourable results in the laser-treated teeth. In terms of probing depth and attachment level, both groups showed statistically significant improvement after treatment. For clinical attachment level, more improvement occurred in the laser-treated group than the SRP group, but the difference was not statistically significant. A 2-year prospective study[49] by the same investigator group confirmed the favourable results with lasers. Sculean and others[50] compared the use of a laser alone with ultrasonic debridement and found the 2 treatments comparable in effectiveness of calculus removal, although the laser was less efficient than ultrasonic debridement. No differences in clinical improvement were noted.

More prospective studies are necessary to confirm the optimistic results offered by these studies. The Er:YAG laser seems to have a place in periodontal debridement, but it remains to be seen whether predictably positive outcomes can be achieved using it as an adjunct or as a monotherapy.

Conclusions

Bacterial invasion cannot be eradicated by mechanical debridement alone. In some cases, combining mechanical therapy with laser treatment appears beneficial. Some recent controlled studies favour laser-assisted periodontal debridement with a soft-tissue laser or use of a hard-tissue laser as a monotherapy. More in vivo studies are needed to establish the safety and benefit of dental lasers, either as an adjunct or as an alternative to the traditional methods of scaling and root planing. ◆

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The authors have no declared financial interests in any company manufacturing the types of products mentioned in this article.

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