Lasers as an Adjunct to Scaling and Root Planing

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Summary: Since the development of lasers in 1960, the use of these instruments has become more popular in medicine and dentistry. All lasers consist of a laser medium, an optical cavity, and a source of energy to pump the laser medium. The laser medium can be in the form of: a gas, eg, carbon dioxide (CO\textsubscript{2}), argon, or helium-neon (He-Ne); a liquid (eg, a dye); a solid, eg, yttrium-aluminum-garnet bar doped with neodymium (Nd:YAG), holmium (Ho:YAG) or erbium (Er:YAG); or a semiconductor, eg, gallium-aluminum arsenide (Ga-Al-As). The laser beam can be transformed to radiant energy that can be focused to a very small spot size to yield the enormous power densities which are necessary for the cutting, vaporizing and coagulating effects of lasers. This paper presents a review of the literature for potential laser applications in periodontics.

Key words: soft laser, hard laser, scaling, root planing, root surface treatment.


The elimination of calcified deposits, microorganisms, and microbial products from the periodontally diseased root by scaling and root planing is considered necessary to produce a biologically acceptable root surface.\textsuperscript{1} Recent studies have suggested that lasers may function as an alternative or adjunct therapy in the control and treatment of periodontally diseased root surfaces.\textsuperscript{2,3}

There are two principal categories of lasers used in medicine and dentistry: soft and hard lasers. Soft laser irradiation takes place at thermal, low-energy settings at wavelengths believed to stimulate circulation and cellular activity. Hard lasers (through thermic or ablative effects) have been used extensively for surgical applications.\textsuperscript{4,5}

HARD LASERS

Nd:YAG Laser (Wavelength 1,064 nm)

The Nd:YAG laser, when operated at high energy densities, appears to achieve calculus removal comparable to conventional hand instrumentation.\textsuperscript{6} It is effective for removal of root surface smear layer remains after root planing in vitro.\textsuperscript{7} This can be achieved without inducing hard tissue damage at a total energy density of approximately 700 J/cm\textsuperscript{2}.\textsuperscript{14} However, at this setting, intrapulpal temperature increased from 9 to 22°C and root surface temperature from 18 to 36°C, both values being greater than clinically desirable. Thus, in spite of its effectiveness for smear layer removal, Nd:YAG lasers may not be appropriate for clinical use as an adjunct to conventional periodontal therapy.\textsuperscript{8}

In vivo studies on microbiological samples from pockets of periodontally affected teeth showed a reduction of the microbiological pathogens after Nd:YAG laser application when compared to the conventional technique of scaling and root planing alone.\textsuperscript{9,10}

The effects of Nd:YAG laser treatment vs scaling and root planing (SRP) on crevicular IL-1 beta levels was evaluated in 52 sampled sites obtained from 8 periodontitis patients. For a duration of 12 weeks, the level of IL-1 beta was significantly lower when scaling
and root planing were performed alone than after laser therapy. The laser combined SRP therapy showed a further reduction of IL-1 beta, 6 to 12 months after treatment. Side effects of Nd:YAG laser-treated root surfaces feature cementum melting and cracking, and charring and carbonization of the cementum with pit and crater formation. Nd:YAG laser irradiation also alters the chemical composition of root surfaces, decreasing the protein to mineral ratio.

CO₂ Laser (Wavelength 10,600 nm)

Morphological and chemical characterizations of root surfaces treated with CO₂ laser, Nd:YAG and Nd:YAG with water/air surface cooling (Nd:YAG-C) showed a direct correlation between increasing energy densities and depth of tissue ablation and width of damage. Infrared spectrometric investigation by Spencer et al suggest that similar to the Nd:YAG laser, a decrease of the organic matrix in relation to the mineral compounds of teeth can be found after CO₂ laser irradiation of root surfaces. This effect is extensive in areas where char layer formation has taken place.

Morphological changes following CO₂ laser treatment of calculus-afflicted root surfaces were evaluated by SEM. Laser-induced changes included charring, meltdown and recrystallization of calculus minerals. Residual debris and microbial plaque deposits in areas bordering the lased zones were observed. These changes indicate that CO₂ laser treatment of root surfaces is, at best, an adjunct to traditional methods of therapy.

An approach for root instrumentation with the use of CO₂ laser was evaluated on dog root surfaces in vivo. After flap preparation and root scaling, the flaps were repositioned and allowed to heal for 28 days. Clinical attachment levels were determined before and 28 days after surgery, accompanied by a histological examination. Results indicated that teeth treated with laser alone lost attachment levels. Laser-induced root alterations included a char layer with microfracture of the root structure, which acts as a significant barrier to soft tissue attachment.

Excessive removal of cementum and dentin by root planing after CO₂ laser treatment has adverse clinical implications, eg, dentinal hypersensitivity and cervical demineralization. An explanation for this phenomenon includes the wave guide theory, which was proposed by Attschuller and Grisimov. The theory suggests that laser energy is redistributed along the interface of two dissimilar tissues, thereby weakening their bond. This may occur at the cemento-dentinal junction, resulting in excess removal of the cementum layer during laser scaling.

When lasers are used in continuous wave mode, the ablation process in dental hard tissues is mainly determined by the mean power and the interaction time chosen. Pulsed CO₂ lasers are more effective than continuous wave CO₂ lasers in ablating mineralized tissue. Because of a reduction of heat diffusion in dental tissues, the size of damage zones of pulsed lasers is smaller than the size of damage zones of continuous wave CO₂ lasers. The extent of collateral damage is highly influenced by the optical properties of the irradiated tissues.

An in vitro study by Coffelt et al indicated that the use of a CO₂ laser with energy densities between 11 and 41 J/cm² might destroy microbial colonies without inflicting undue damage to the root surface.

The use of CO₂ laser for smear layer removal after root planing was evaluated and compared to the application of citric acid, EDTA, and hydrogen peroxide for the same purpose. Surface smear layer was effectively removed by the CO₂ laser at 1 s and 3 W with minimal changes in the diameter of the dentinal tubules when compared with EDTA- and citric-acid-treated surfaces. They were also effective in removing smear layer, but the exposed dentinal tubules showed a funnel-shaped widening.

Er:YAG Laser (Wavelength 2,900 nm)

The Er:YAG laser, emitting at a wavelength of 2.94 µm, is also a valuable tool in dental applications because its wavelength is highly absorbed in water. The absorption of the Er:YAG laser in water is theoretically about 10 times greater than that of the CO₂ laser, and about 20,000 times greater than that of the Nd:YAG laser. Er:YAG is also well absorbed by hydroxyapatite. Therefore, the Er:YAG laser can ablate dental hard tissues containing some water more effectively, and it can be assumed that this wavelength would cause less thermal damage to adjacent tissues than the Nd:YAG and the CO₂ lasers. Recent technological developments have made possible the transmission of the Er:YAG laser through an optical fiber. Although less flexible than those waveguides encountered in Nd:YAG laser systems, the use of a fiber delivery system with a tip
Fig 1 Scanning electron photomicrograph (SEM) of calculus (L) partially removed by laser application with the adjacent cracked cementum surface (K) (X 200).

Fig 2 Partial ablation of calculus (L) after laser application on periodontally affected root. Note the adjacent layer of unaffected calculus with its honey comb appearance (H) (X 350).

Fig 3 SEM of calculus deposits subjected to laser. Note large depression area (D) denoting calculus ablation and the adjacent fragmented calculus deposits (C) (X 350).

Fig 4 Calculus layer after laser application showing melting (M), cracking (K) and holes (O) (X 200).

Fig 5 SEM of calculus deposits subjected to laser, showing fragmentation of calculus layer in the form of needle like structures (N) and depression areas (D) (X 750).

Fig 6 Crater-like shape (R) of calculus after laser application (X350).
for contact mode operation facilitates the energy transfer to the periodontal pocket. Therefore, it is now possible to use the Er:YAG laser to remove subgingival calculus in the depths of the periodontal pocket. The clinical use of an Er:YAG laser results in a smooth root surface morphology even at a higher energy setting, and calculus removal can be selectively achieved in vivo.

By using the Er:YAG laser under water irrigation, the subgingival calculus can be effectively removed from the tooth root at low energy levels. In an in vitro study, the scaled root surface revealed some irregularity and chalkiness with very little or no charring. The water irrigation served as a coolant for both the root surface and the contact probe in order to avoid pulp damage. The ablation of the tooth substance was generally limited to the cementum at an energy setting of 30 mJ/pulse and less. However, sometimes it partly reached the dentin, which may be due to excessive irradiation or variability in cementum thickness. Distinct carbonization and clear cracks, which were common findings after the application of CO2 and Nd:YAG lasers, were not observed with an Er:YAG laser. Several investigators propose the use of water as a coolant during Er:YAG laser irradiation. Brukes et al reported that the ablation on a dry tooth was less efficient than on a moist tooth. Water irrigation may thus facilitate calculus ablation.

The wavelength energy of Er:YAG laser radiation is highly absorbed in water, which together with other hydrous organic contents can lead to instant vaporization. Thus, pressure within the irradiated dental hard tissue builds up until an explosive destruction of the inorganic substance occurs before the melting point is reached. Such "microexplosions" also seem to constitute the mode of action in Er:YAG laser-assisted calculus ablation, since calculus itself contains a significant amount of water in its structural framework and pores. However, if ablation also reaches the cementum, it may lead to tissue damage. It was also hypothesized that the by-products from protein breakdown may contaminate the root surface and alter the biocompatibility of cementum for fibroblast attachment. This hypothesis is supported by the fact that a decrease in fibroblast attachment following laser irradiation has been observed in vitro.

The use of specially designed delivery systems which guide the Er:YAG laser beam focused as a small line in an angulated and flatter mode to the root surface seem to account for the absence of a scaly surface texture. Another specially developed periodontal handpiece was used for calculus removal. The tip emitted a laser beam focused on the root surface, which corresponded to a light line and was similar in size to the gable end of the glass chisel. Depending on radiation energies, different amounts of root substance and/or calculus removal were seen.

Folwaczny et al evaluated the effect of different laser tip angulations at three energy settings (60 mJ, 100 mJ, and 180 mJ). Concrement removal was calcu-

* All photomicrographs were obtained by the use of the scanning electron microscope (JEOL, JSM-5300 Musashino 3 chome Akishima, Tokyo – Japan) after CO2 laser application.
lated by the use of a 3-dimensional scanning system and digital image analyzing software. Results provided clear evidence that besides the physical radiation parameters, the angulation of the application tip has a strong influence on the amount of root substance removal by the Er:YAG laser.

The Er:YAG laser provided subgingival calculus removal on a level equivalent to that provided by the ultrasonic scaler. However, on a microscopic level, the Er:YAG laser produced superficial, structural and thermal micro changes on the cementum in the form of microroughness and a discrete, deeply stained zone on the lased root surface.43

The effectiveness of periodontal treatment with Er:YAG lasers was compared to scaling and root planing in a clinical trial. Clinical parameters were determined prior to and at 3 and 6 months after treatment. A darkfield microscope was used to analyze subgingival plaque samples for the presence of cocci, non-motile rods, motile rods and spirochetes. Scores on the reduction of bleeding on probing and clinical attachment level improvement were significantly higher in the laser group than in the SRP group. Both groups showed a significant increase of cocci and non-motile rods and a decrease in the amount of motile rods and spirochetes. It was concluded that an Er:YAG laser may represent a suitable alternative for nonsurgical periodontal treatment.44 In another investigation, the Er:YAG laser exhibited a high bactericidal potential on Porphyromonas gingivalis and Actinobacillus actinomycetemcomitans at a low energy level.45

Er:YAG laser irradiation can effectively and rapidly remove 83.1% of lipopolysaccharides (LPS), supporting the theory that lasers might be able to remove LPS from the root surfaces in periodontal treatment. Removal of LPS might have been due to ablation on the root surfaces, mechanical elimination, and heat stress during irradiation. This also advances hopes that lasers will be capable of sterilizing the affected root surfaces and periodontal pocket microflora.46

The roughness of root surfaces treated with Er:YAG laser has been reported as 20 to 25 µm.45 According to Kathiblou and Ghodssi,47 a certain degree of roughness does not adversely affect the healing results. The micromorphology of Er:YAG laser-treated root surfaces was found to be comparable to surface structures achieved by conventional treatment and conditioning with citric acid or EDTA,48 for which some authors have reported improved attachment of fibroblasts.49,50 Low energy densities showed sufficient potential for root surface changes that promote the healing and regenerative processes.51

**XeCl Excimer Laser (Wavelength 200-358 nm)**

Excimer laser operating with xenon chloride as a laser medium can be transmitted through flexible quartz glass fibers. At a wavelength of 308 nm, it may only cause minor side-effects on irradiated dental hard tissue. In contrast to conventional scaling and root planing using curettes, no formation of smear layer was obtained on the root surface when irradiated with XeCl excimer laser.52

An extensive antimicrobial effect of XeCl excimer laser radiation was reported by Folwaczny et al.53 An improvement of periodontal health using this type of laser radiation may therefore be possible. The potential effect of this laser radiation on root surfaces when used for removal of calculus deposits was investigated in vitro. Results indicated that the XeCl excimer laser at low energy densities is capable of removing subgingival calcified deposits. The cementum removal at these energy densities is only moderate. Furthermore, the removal of calculus by laser radiation did not seem to occur by continuous ablation of calcified calculus, but rather by the cracking off of large pieces of the debris due to laser-induced mechanical stress.54

The absence of thermal side-effects on root surfaces irradiated with a 308-nm XeCl excimer laser are possible due to their special physical radiation properties. These types of laser radiation remove dental hard tissue by the process of photoablation, which was first described by Srinivasan.55 The exposure of tissue to an extremely short laser pulse transporting very high energy densities leads to deposition of high amounts of energy in a small volume of tissue. As a consequence, molecules are broken and a part of the irradiated substance becomes detached.56 Therefore, treatment of root surfaces with the nonthermal process of photoablation with excimer lasers may present alternatives to traditional treatment.56

**Argon Laser (Wavelength 484/515 nm)**

Argon lasers have wavelengths of 484 nm or 515 nm (blue-green, visible spectrum). Like the CO2 laser, argon lasers use gases as a laser medium, and are usually equipped with a fiber-optic system. It is not readily absorbed by water, but has an affinity for pigmented tissue and also a high affinity for hemoglobin. In oral tissues there is no reflection, some absorption, and some scattering and transmission. Argon lasers work both in contact and noncontact mode.57

The principle application of the argon laser is in
restorative and preventive dental procedures. The possibility of smear layer removal by argon lasers in endodontics was tested in vitro. The trial compared the effectiveness of argon laser with Nd:YAG laser and Er:YAG laser. Results showed that the argon laser and Nd:YAG lasers are useful in removing the smear layer, but that the Er:YAG laser is the most effective for removing the smear layer.

**Nd:YAP Laser (Wavelength 1430 nm)**

The beam of Nd:YAP is generated by a neodymium-doped, yttrium aluminum Perovskite crystal. Nd:YAP laser investigations have dealt with this laser’s application in endodontics, such as the effectiveness on canal cleanliness, which suggests that it has a potential in canal disinfection and preparation. An evaluation of the bactericidal effect showed that at a frequency of 30 Hz, the Nd:YAP laser effectively inhibited the growth of Streptococcus mitis in contaminated root canals. These results suggest the use of this type of laser for root surface debridement. The energy density levels between 509 and 637 J/cm² were considered less destructive to cementum, while higher energy density levels caused obvious cementum damage. It is recommended that future studies evaluate the effect of Nd:YAP laser on cementum as a trial for the application of this type of laser in root surface management.

**SOFT LASERS (ATHERMIC)**

**Helium-Neon (He-Ne) Laser (Wavelength 632 nm)**

The He-Ne laser emits at a wavelength of 632 nm, and since this wavelength falls within the visible part of the spectrum, it has the advantage of accurate placement. He-Ne lasers are currently widely used as a target beam for most dental hard lasers.

The inhibitory effect of the He-Ne laser on the growth of dental plaque was examined, and the possibility of low-energy lasers for prevention of periodontal disease was considered in a study on golden hamsters. A He-Ne laser was used in a continuous mode at 6 mW. The hamsters were maintained on diet containing 56% sucrose to promote plaque accumulation. The laser was used to irradiate the periodontal tissue around the existing teeth for 2 min per day for 5 days per week and continued for 4 weeks. The state of dental plaque deposition was observed using a stereomicroscope and recorded on a periodontal chart. Results showed a significant difference in plaque scores between irradiated and unirradiated sites. It was suggested that the laser beam may directly affect the viability of bacterial cells.

He-Ne laser with a 6-mW output and a pulsed beam of coherent, bundled, monochromatic light was tested for the treatment of hypersensitive teeth. After initial soft laser treatment, patients described diminished sensitivity, and more improvement was noticed after repetition of the therapy.

Although the use of He-Ne laser is not useful for calculus removal and root planing, it could be efficient for periodontal maintenance therapy.

**Ga-Al-As Laser (Wavelength 830)**

Low-level laser therapy with a Gallium-Aluminum-Arsenide (Ga-Al-As) laser was tested for the management of dental cervical hypersensitivity. Results demonstrated that the Ga-Al-As laser is an effective method for the treatment of both thermal and tactile dentinal hypersensitivity. There were no reported adverse reactions or instances of oral irritation.

Microbiological and clinical parameters were evaluated after the use of a gallium arsenide diode laser in conjunction with methylene blue and/or mechanical subgingival debridement in human periodontal disease. Scaling and root planing (SRP), laser application (L), SRP combined with laser (SRP/L), and oral hygiene instructions (OHI) were given to ten patients in whom each dental quadrant was randomly designated to receive one of the four types of the treatment procedures. The selected teeth with pockets were first assessed for microbiological then for clinical variables. Within the limits of this study, methylene blue/soft laser therapy provided no additional microbiological or clinical benefits over conventional mechanical debridement.

Bacteria can be sensitized to killing by low-power lasers through prior treatment with a chemical photosensitizing agent. Lethal photosensitization of a wide range of cariogenic and periodontopathic bacteria has been demonstrated using light from He-Ne or Ga-Al-As laser in conjunction with a dye such as toulidine blue or aluminum disulphonated phthalocyanine as a photosensitizer. The advantages of the technique are that bacteria can be killed in very short periods of time, resistance development in the target bacteria would be unlikely, and damage to adjacent host tissues can be avoided.

It is conceivable that reduction of hypersensitivity...
and elimination of the periodontopathic bacteria by Ga-Al-As laser would be effective as an adjunct for root planing in supportive periodontal therapy, where minimal subgingival manipulation of root surfaces and sulcus areas may be necessary during recall maintenance visits.

Alexandrite Laser (Wavelength 377 nm)

The Q-switched frequency-doubled Alexandrite laser with a wavelength of 377 nm and pulse duration of 100 ns was examined for selective calculus removal. Investigations demonstrated that employing a frequency-doubled Alexandrite laser allows a fast and effective selective ablation of dental calculus. Moreover, ablation of microbial plaque is also possible.1

CONCLUDING REMARKS

- The use of lasers in treating periodontal disease has recently been advocated with hopes that it will be capable of sterilizing the diseased root surface and periodontal pocket microflora. Although it did not completely remove subgingival calculus, laser facilitated its removal by conventional periodontal instrumentation.

- Combination of air/water spray to control heat generation during laser irradiation of root surfaces may be an effective method for temperature control and reduction of heat transfer to pulp tissue and the vital structures surrounding teeth.

- Root surface conditions induced by Er:YAG laser radiation are promising due to lack of thermal damage that could interfere with re-attachment of fibroblasts to root surfaces.

- The use of excimer lasers on dental hard tissues seems to be encouraging, since it creates a root surface without a smear layer. Additionally, it can be transmitted through flexible glass fibers that can be inserted subgingivally.

- Low-power lasers (soft lasers) may be useful for hypersensitivity reduction and elimination of periodontopathic bacteria following root planing.

REFERENCES


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