An erbium:YAG laser can be used to achieve an effect termed “laser analgesia”. This is based on the concept that "simultaneous low level laser therapy" (LLLT) may occur along with high level laser treatment, as outlined by Ohshiro and Calderhead. Laser analgesia is a non-destructive, non-thermal bio-modulation of dental pulp responses. It is not profound anaesthesia (the lack of all sensation), as gained with an injection of local anaesthetic solution.

In vivo studies of the analgesic effect of LLLT on nerves supplying the oral cavity have demonstrated that LLLT with a near or middle infrared laser decreases the firing frequency of nociceptors (pain receptors). There is a threshold effect seen in terms of the irradiance required to exert maximal suppression. It appears that laser irradiation may selectively target fibers conducting at slow velocities, particularly the afferent axons from nociceptors. This explains why the LLLT effect of laser analgesia is not a complete anaesthesia of the lased tooth.

In vivo, LLLT has been shown to selectively inhibit a range of nociceptive signals arising from peripheral nerves, including neuronal discharges elicited by pinch, cold, heat stimulation, and chemical irritation. In contrast, neuronal discharges induced by brush stimulation (similar to gentle proprioceptive signals) are not affected by LLLT.

When operated at pulse energies below the ablation threshold of tooth structure, the laser energy penetrates into the tooth, and is directed along hydroxyapatite crystals (which function like waveguides) towards the dental pulp. Here, the frequency of the laser pulses (15 –20Hz) coincides with the natural “bio-resonance” frequency of the cell membranes of type C and other nerve fibers in the dental pulp. The laser pulses alter the behaviour of the nerve cell membrane, causing a temporary disruption in the action of the Na-K pump. This results in a loss of impulse conduction, and thus an analgesic effect. Clinical experience indicates that the duration of this effect is approximately 15 minutes. While there is some suggestion that part of the analgesic effect may be due to thermal changes, direct examination of lased teeth (with either the Er:YAG or Nd:YAG laser) have not shown any evidence of adverse pulpal change at the histological level over the short or long term.

The use of infrared laser energy to achieve an analgesic effect in the dental pulp for restorative procedures was first noted with the Nd:YAG in the early 1990’s. With the increasing clinical use of the Er:YAG laser for caries removal and cavity preparation, the clinical use of "pre-emptive laser analgesia" is becoming more widespread as a clinical technique for those few cases where patients experience unpleasant sensations during laser caries removal.

Laser analgesia develops routinely during cavity preparation with the Er:YAG laser. The intention of the technique of “pre-emptive laser analgesia” is to reduce sensation in that small percentage of patients who may experience unpleasant sensations during caries removal. The typical case where it would be used is extensive buccal caries in an otherwise unrestored premolar or canine tooth, in a younger patient with a high caries rate. Older patients and previously restored teeth often give little or no sensation during cavity preparation with the laser,
due to the attenuating effects of dentine sclerosis. In severe caries and younger patients, there may be little opportunity for a defensive pulpal reaction to lay down dentine in the tubules.

**Clinical technique:**

*Pulse frequency 15 - 20 Hz; Pulse energy 80 - 120 mJ; Water mist spray set to “on”; focussed or slightly defocused beam; contact or non-contact handpiece. For maximum effect, the energy should be delivered at the cemento-enamel junction (pointing directly towards the dental pulp) on each of the four line angles of the tooth, moving the laser handpiece in a sweeping action at approximately 2 mm per second during a 20-30 second period (at each line angle).*

*One series of exposures would normally give sufficient analgesic effect to allow for removal of an amalgam restoration using an air turbine (prior to then removing recurrent caries with the Er:YAG laser). Laser radiation will not pass through, but will absorb in dental amalgam, and this dental amalgam should not be lased. The same is true for composite resin restorations which may be present at the cemento-enamel junction of the tooth.*

**Selected references**


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Selected abstracts


A new subspecialty in the medical application of the laser has developed, especially over the last decade, depending on the therapeutic rather than the surgical applications of the laser. Laser therapy, or preferably, Low reactive-Level Laser Therapy (LLLT) is now being recognized as a valid medical tool. Two types of LLLT are presented, simultaneous and pure. In surgical laser applications, ranges of heat are generated in the target tissue, destroying or altering its architecture. This is referred to as high reactive-level laser treatment, or HLLT. In addition, nonphotothermally destructive reactions may also occur, such as photo-osmosis. These are also part of HLLT. Simultaneously, nondestructive thermal and nonthermal bioactivation occur at the periphery of the target tissue: this is "simultaneous LLLT" and occurs along with HLLT, explaining some of the advantages of laser surgery. Laser systems have been developed which deliver power and energy densities below the destructive level, only to activate the irradiated tissue. This is "pure LLLT." The history and background of LLLT are presented, the terminology discussed, and practical applications of LLLT are presented.


Low-power laser analgesic effect was generally accepted in clinical cases, whereas there was no direct evidence to indicate that low-power laser irradiation suppressed an impulse conduction within a peripheral nerve. The effect of low-power laser irradiation on electrically evoked responses within the sural nerve was electrophysiologically analyzed in anesthetized rabbits. High threshold evoked responses (conduction velocity was about 11 m/sec, unmyelinated A delta), which were induced by an electrical stimulation to the peripheral stump of the nerve, were significantly suppressed (9 to 19% inhibition) during low-power laser irradiation, which applied to the exposed sural nerve between the stimulus site and the recording site. The suppressive effect was reversible and recovered to the control level after the irradiation. Experimental evidence indicated that low-power laser irradiation suppressed the impulse conduction of unmyelinated A delta afferents in peripheral sensory nerve, which caused a pain sensation. Our data suggest that low-power laser acts as a reversible direct suppressor of neuronal activity.


The effects of low-power helium-neon laser irradiation on the cord dorsum potentials (CDP) evoked by electrical nerve stimulation of a distal portion of exposed sural nerve were observed in unanesthetized decerebrate cats. These evoked CDP were significantly suppressed (25.6 +/- 2.5%, p less than 0.01) during low-power laser irradiation. It is suggested that the analgesic effects of low power laser irradiation is based on the decrease of ascending signals from the spinal cord to the higher central nervous system. The suppressive effect of low power laser irradiation upon the impulse transmission of nerve fibers is discussed.

The effect of irradiation with a gallium-aluminum-arsenide semiconductor laser on responses evoked in trigeminal subnucleus caudal neurons by tooth pulp stimulation was investigated electrophysiologically in Wistar rats anesthetized with urethane plus alpha-chloralose. The pulp of lower incisor was electrically stimulated and the evoked action potentials were extracellularly recorded in the ipsilateral caudal neurons. The laser beam was applied on the cervical surface of the stimulated incisor. The rate of firing discharges and the numbers of spikes evoked in the caudal neurons were compared before and after laser irradiation. Laser irradiation suppressed the late discharges in the response of the caudal neurons which were evoked by excitatory inputs from C-fiber afferents, but did not suppress the early discharges evoked by inputs from A delta-fiber afferents. This indicates that low power laser irradiation (semiconductor laser: 830 nm, 350 mW, CW, through the tooth structures, for 120 s) inhibited the excitation of unmyelinated fibers of the pulp without affecting fine myelinated fibers. These results suggest that low power laser irradiation has a suppressive effect on injured tissue by blocking the depolarization of C-fiber afferents.


We have recently shown that Nd:YAG laser irradiation of rat peripheral nerve differentially impairs action potential transmission in small, slowly conducting sensory fibers compared to fast conducting afferents. In addition, the number of small sensory neurons of the A-delta- and C-fiber group labeled with HRP is significantly reduced after laser irradiation, while the number of labeled large sensory neurons and motoneurons was not affected. To further evaluate this laser-induced injury, we examined three distinct regions of the laser-irradiated rat peroneal nerve using ultrastructural morphometric methods. These regions were the site of laser irradiation and zones 10 mm proximal and 5 mm distal to the injury. The contralateral nerve was sham treated. Our results indicate that for the small nonmyelinated fibers, there was a significant increase in both mean fiber size and the number of microtubules per fiber, but a decrease in the number of neurofilaments. In contrast, the number of myelinated and nonmyelinated fibers is not significantly altered at 7 days following laser irradiation, and the mean diameter and frequency distribution of myelinated nerve fibers was unchanged. This study demonstrates that selective functional alterations in laser-irradiated nerves (nerve conduction velocity, HRP transport properties) are accompanied by ultrastructural changes of axonal organelles in nonmyelinated fibers. Nd:YAG laser light might ultimately prove to be a powerful tool to selectively alter functional properties in small, slowly conducting afferent fibers, without causing degeneration at the ultrastructural level at the site of irradiation. We hypothesize further that the laser-induced functional alterations might be related to differential thermally mediated changes.


These effects were studied by recording single-fibre discharges in the lingual nerve. A total of 11 heat nociceptors were tested and of these 60 per cent decreased their firing frequency following
soft-laser (GaAlAs semiconductor laser) irradiation for 1 min; firing frequency was decreased in all the nociceptors studied following irradiation for 3 to 10 min. The reduction in firing rate was similar between 5 and 10 min after irradiation suggesting the effect reached a plateau within this time. These findings suggest that soft-laser irradiation might have an analgesic effect on tongue pain.


A Ga-Al-As diode system that produces low-energy red light (830 nm, 40 mW) has been used for the treatment of many kinds of pain. The mechanism of action of this new laser irradiation for analgesia was studied in anesthetized rats. The effect of laser irradiation of the saphenous nerve was studied by recording neuronal activity at the L4 dorsal root filaments after the injection of a chemical irritant, turpentine. Laser irradiation inhibited both the asynchronous firing by that was induced by turpentine and increased part of the slow components of the action potentials. Thus, the laser irradiation selectively inhibited nociceptive signals at peripheral nerves.


The effects of diode laser irradiation on peripheral nerves was examined by monitoring neuronal discharges elicited by application of various stimuli to the hind-paw skin of rats. Neuronal discharges elicited by brush, pinch, cold, and/or heat stimulation, as well as chemical stimulation by injection of turpentine (0.1 ml, SC) were recorded from L5 dorsal roots in urethane-anesthetized rats. Diode laser irradiation (830 nm, 40 mW, 3 min, continuous wave) of the saphenous nerve exposed from the muscle of the lower leg significantly inhibited neuronal discharges elicited by pinch (68.4 +/- 6.5%), cold (45.4 +/- 9.2%), and heat stimulation (49.2 +/- 11.3%). Neuronal discharges induced by brush stimulation (104.3 +/- 4.7%) were not affected by laser irradiation. Injection of turpentine, a chemical irritant, into the hind-paw skin (0.1 ml, SC) elicited neuronal discharges in the ipsilateral dorsal root, and these discharges were significantly inhibited or abolished by laser irradiation. In 6- to 7-week-old rats treated neonatally with capsaicin (10 mg/kg, SC), injection of turpentine into the hind-paw skin did not elicit neuronal discharges and laser irradiation did not affect the background discharges. These data suggest that laser irradiation may selectively inhibit nociceptive neuronal activities.

Tsuchiya K, Kawatani M, Takeshige C, Sato T, Matsumoto I. Diode laser irradiation selectively diminishes slow component of axonal volleys to dorsal roots from the saphenous nerve in the rat. (Department of Physiology, School of Medicine, Showa University, Tokyo, Japan). Neurosci Lett. 1993 Oct 14;161(1):65-8.

Ga-Al-As laser irradiation (830 nm wavelength) inhibits the action potentials in the dorsal roots elicited from the saphenous nerve of the rat. Following laser irradiation to the saphenous nerve, the amplitude of slower conduction parts of action potentials (conduction velocity < 12 m/s) were suppressed. This suppression was irradiation time dependent. After 3 min irradiation, slowest conduction velocity group (< 1.3 m/s) were totally diminished and 1.3-12 m/s group were reduced to 12-67%. In contrast, faster component (> 12 m/s) was unaffected by laser irradiation. These findings suggest that laser irradiation may selectively target fibers conducting at slow velocities which include afferent axons from nociceptors.

The current investigation, for which ethical permission was obtained, was designed to assess the putative neurophysiological effects of low intensity (9.6 J/cm²) laser (830 nm) irradiation upon conduction latencies in the human median nerve in vivo. Antidromic nerve conduction studies were performed on the non-dominant arms of healthy human volunteers (n = 51), who were each assigned to one of a variety of laser, placebo or control groups under randomized, blinded conditions. Analysis of negative peak latency differences using analysis of variance showed small (approximately 0.4 ms) but significant increases in latencies as a result of direct laser irradiation, and, where two-site recording was used, distal to the site of irradiation. No such differences were seen in the other experimental groups. These results show that laser irradiation applied to intact skin at the parameters used here may produce a direct, localized effect upon conduction in underlying nerves.

Orchardson R, Whitters CJ. Effect of HeNe and pulsed Nd:YAG laser irradiation on intradental nerve responses to mechanical stimulation of dentine. (Division of Neuroscience, Institute of Biomedical and Life Sciences, University of Glasgow, Glasgow, Scotland, United Kingdom. orchardson@bio.gla.ac.uk) Lasers Surg Med. 2000;26(3):241-9.

BACKGROUND AND OBJECTIVE: Our study aimed to determine how lasing affected intradental nerve responses to dentine stimulation. Study Design/Materials and Methods: Intradental nerve activity was recorded from canine teeth of anaesthetised ferrets. Dentine exposed at the tip of the tooth was stimulated with a glass probe. After determining baseline responses to mechanical stimulation, dentine was lasered using a pulsed Nd:YAG laser at 60-150mJ/pulse and 10-30 pulses/sec (total power = 0.3-3.0 W). RESULTS: The HeNe aiming beam alone and Nd:YAG laser at 0.3 W (+ HeNe) had no effect on intradental nerve responses to dentine stimulation. Lasing at 0.6-1.5 W could either enhance or suppress intradental nerve responses. Lasing at more than or equal to 2.0 W or repeated lasing at lower intensities depressed intradental nerve responses. Lasing often induced intradental nerve firing. CONCLUSION: HeNe lasing had no effect on intradental nerve excitability. The Nd:YAG laser could depress intradental nerve responses to dentine stimulation.


OBJECTIVE: This study aimed to simulate the effects of lasing dentine on pulpal nerve function. METHODS: Rat spinal nerve roots were threaded through the prepared pulp canal of a 10 mm long tooth root segment which was mounted in a perspex bath. The protruding ends of the nerve were placed on platinum wire electrodes used to elicit and to record compound nerve action potentials (CAPs). Laser energy (average power = 0.3-3.0 W) was applied to the surface of the root segment using a pulsed Nd:YAG dental laser (dLase 300). RESULTS: With the laser probe tip placed in static contact with the tooth surface, the nerve CAP was irreversibly abolished within 60 s of lasing at 1.0-3.0 W power. When the laser tip was moved to and fro over the root surface in a scanning mode, similar levels of radiation produced less marked effects. In the latter
mode, CAP attenuation increased with increasing power and duration of lasing. After 60 s lasing at 0.3 W, the CAP size was 95% (+/- 5, S.D.) of the prelasing controls value; with 2.0 W the CAP was reduced to 54% (+/- 33). The CAP recovered to 90% of control levels after lasing at powers up to 1.5 W, but reached only 72% of control values after lasing at 2.0 W power.

CONCLUSIONS: Laser radiation applied to dentine caused a dose-dependent block of action potential conduction in nerve fibres in the underlying pulp chamber.


BACKGROUND AND OBJECTIVE: Dental lasers are claimed to produce analgesia, but the mechanisms and extent of any effects are uncertain. This study investigated the effects of lasing on nerve conduction in isolated nerves.

STUDY DESIGN/MATERIALS AND METHODS: Pulsed Nd:YAG laser energy was applied to spinal nerves in vitro and effects were measured as attenuation of the compound action potential (CAP) evoked by electrical stimulation. RESULTS: Lasing for 1 minute at 0.3-3.0 W caused a dose-dependent attenuation of all components of the CAP (P < 0.03). With 0.3-1.0 W power, the CAP recovered to > 95% of the control levels 7 minutes after lasing; recovery was incomplete after lasing at > 2.0 W. CONCLUSION: Isolated nerves were remarkably tolerant of lasing. The degree of nerve conduction block increased with laser power. The data indicate that lasing could diminish sensations, including pain, mediated by peripheral nerves in soft tissues.


The purpose of this study was to investigate histopathological changes in the dental pulp after Er:YAG laser irradiation compared with those after high-speed drill preparation. For evaluation, repair of nerve fibers was observed using an immunohistochemical technique. There was no significant difference between the remaining dentin thickness in either cases. (Mann-Whitney U test). In the Er:YAG laser group a marked fibroblast proliferation and the formation of reparative dentin were observed relative to the high-speed drill group. The time course of the increase and decrease in calcitonin gene-related peptide-immunoreactive fibers in the high-speed drill group was similar to that of previous reports. In the Er:YAG laser group an increase in calcitonin gene-related peptide-immunoreactive fibers was seen earlier than in the high-speed drill group, and 7 days after operation these fibers decreased to control level. The results suggested that the Er:YAG laser leads to pulpal repair earlier than the high-speed drill.

Nair PN, Baltensperger MM, Luder HU, Eyrich GK. Pulpal response to Er:YAG laser drilling of dentine in healthy human third molars. (Department of Oral Structural Biology, Center of Dental and Oral Medicine, University of Zurich, Switzerland. nair@zzmk.unizh.ch) Lasers Surg Med. 2003;32(3):203-9.

BACKGROUND AND OBJECTIVES: Maintenance of pulpal health is a critical prerequisite for successful application of light amplification by stimulated emission of radiations (lasers) in the hard tissue management of vital teeth. The purpose of this study was to investigate the short- and long-term pulpal effects to cavity-preparations in healthy human teeth using erbium-
doped: yttrium, aluminum, and garnet (Er:YAG) laser. MATERIALS AND METHODS: A total of seven healthy third molars that were to be removed due to space-problem were used. Following the laser excavation, the cavities in dentine were closed temporarily and the teeth were extracted after 7 days (n = 5) and 3 months (n = 2) post-operation. The specimens were fixed, decalcified, subdivided, and processed for light and transmission electron microscopy.

RESULTS: In the short-term group, four of the five laser-drilled teeth did not reveal any pathological changes in the pulp-dentine complex. One tooth showed mild disruption of odontoblasts (OB) and vascular dilatation subjacent to the deepest point of the cavity-preparation with a remaining dentine thickness (RDT) of less than 80 microm. The two teeth under long-term observation revealed distinct apposition of tertiary dentine (TD), lined predominantly with cuboidal cells on its pulpal aspect.

CONCLUSIONS: These results would allow a conclusion to be drawn that the Er:YAG laser under investigation is a pulp preserving hard-tissue drilling tool when used with the specific energy settings and emitting radiation at a wavelength of 2.94 micron.


BACKGROUND AND OBJECTIVE: The aim of study this was to evaluate in vivo the pulpal blood flow rate, pulpal responsiveness, systemic blood pressure, and pulse rate during Nd:YAG laser irradiation of an isolated tooth. STUDY DESIGN/MATERIALS AND METHODS: Thirteen volunteers from the Tsurumi Dental University faculty participated in this study after giving their consent to the Nd:YAG laser irradiation test protocol. Gingivobuccal areas adjacent to mandibular canines were used for clinical evaluation. Each area was coated with India ink and treated with a Nd:YAG laser for 30 sec at 120-mJ pulses at 10 pulses/sec. Pulpal blood flow was measured by a laser Doppler flowmeter during Nd:YAG laser irradiation of the tooth. All pulp responses were measured by an electric pulp tester before and after Nd:YAG laser irradiation. In addition, the systemic blood pressure and pulse rate were monitored throughout the laser irradiation procedure. RESULTS: For all subjects involved in this study, the pulpal blood flow rate increased during laser irradiation. Threshold values of the electric pulp tests increased in six cases and decreased in six cases. One case showed no change. After 1 month, the threshold values for each subject had returned to previously recorded values. Neither systemic blood pressure nor pulse rate was affected during Nd:YAG laser irradiation. Pulpal blood flow was strongly influenced immediately after Nd:YAG laser irradiation, seen as an increase in the flow rate. CONCLUSION: The results of this study suggest that effects of the Nd:YAG laser irradiation are similar to those of low power laser for the improvement of local blood flow.


Nerve excitability is principally determined by the state of membrane sodium channels, which can be influenced by factors such as drugs or the ionic composition of the extracellular fluids. The excitability of isolated nerves is increased by lowered extracellular calcium and hydrogen ion concentrations, and similar effects are seen on intradental nerve excitability. This is of interest as some agents used to desensitize hypersensitive dentine are believed to act by reducing intradental nerve excitability. A variety of ions, including potassium and divalent cations, have been shown to reduce intradental nerve excitability when applied in relatively high concentrations to dentine
close to the pulp. However, these conditions do not mimic the clinical situation, where agents are applied to outer dentine, up to 2 mm from the pulp. Also, when agents are applied to dentine it is difficult to quantify the precise changes in extracellular fluid composition, and there is the additional complication of possible interactions between the agents and dentine. These problems can be minimized by using isolated nerves, which allow better control over the conditions and ionic concentrations necessary to achieve nerve conduction block. Such methods can provide a convenient way to screen potential desensitizing agents before evaluation in vivo or in clinical trials.


OBJECTIVE: We determined that the Er:YAG pulsed 2.94 micron radiation was successful in the removal of caries, cavity preparation, and etching prior to acid etching. SUMMARY BACKGROUND DATA: The laser group was compared to a control group in which the high-speed drill was employed. Parameters measured included histological evaluation of the pulp, scanning electron microscopy of the surface morphology of the tooth, dye penetration studies, bond strength measurements, and rating of the laser's ability to remove caries and form the preparation. METHODS: We collectively evaluated 60 patients with 106 teeth in both the laser and control groups over a 1-year period. Teeth were treated in vivo and then extracted immediately, at 2 days, 1 month, and up to 1-year to assess pulpal healing, surface morphology, and the quality of the preparation, restoration, and pain. RESULTS: The dental laser was shown to be equal or better than the drill in the tested procedures of caries removal, cavity preparation, and etching prior to acid etching. The scanning electron microscopy revealed no microfracturing, open dentinal tubules, and effective etching with the laser having a mean of 2.7 with an optimum rating of 3. The histological testing confirmed that the pulp was not compromised using the laser with scores of theta for hemorrhage, 0.47 for hyperemia, and 0.12 for inflammation on a scale of 0 to 3 where 0 is no effect. CONCLUSIONS: The FDA has recently cleared the Er:YAG to remove all classes of caries, form the cavity preparation, and modify the enamel and dentin prior to acid etching. In this Phase I study conducted as part of the clinical trials, there were no complications and no tooth was compromised. Patients were consistently treated without anesthesia with the same or better results than the drill as confirmed by scanning electron microscopy and histological studies.


OBJECTIVE: We determined the real effect of Erbium:YAG laser ablation on human teeth in vivo. SUMMARY BACKGROUND DATA: We advocated the idea that overheating of teeth, specially pulp damage can be avoided if correct laser parameters are used. METHODS: We evaluated human premolars scheduled for extraction during orthodontic treatment. Before tooth extraction, an oval cavity preparation was made with a pulsed Er:YAG laser. After extraction, the teeth were decalcified for 6 weeks. Routine staining with haematoxylin and eosin was performed on longitudinal section. One hundred seventy-two sections were prepared and examined in a light microscope. RESULTS: Under Er:YAG laser application, reduction of the dentin layer was observed. Dentinal tubules had a radial course up to the surface. No cracks or structural injury were observed. Inflammatory reaction in the pulp was not found. The vascularity of the pulp was
normal. The odontoblasts were of the usual spindle-like or star-like cell shape. The cementum and epithelial attachment were healthy. No changes of structure or indications of inflammation were observed. CONCLUSIONS: The results of this in vivo experiment on human teeth confirm safety of Er:YAG laser ablation of enamel and dentin under the conditions described.