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Laser phototherapy (LPT) in dentistry

Author: Jan Tunér, DDS

Although laser phototherapy has been practiced for more than 40 years, there is still some remaining controversy regarding its scientific standard. During recent years, about 250 scientific papers are published annually on PubMed, and the knowledge about the basic mechanisms and the optimal clinical parameters are gradually better known.

The effects exerted on cells and tissue are well-documented and, to a certain degree, also in animal models. Large clinical studies are still scarce. The safety of the treatment is well-documented. Some controversy remains for several indications in spite of enthusiastic clinical observations for a great variety of conditions.

The problem of finding consensus in this area of dental laser applications is greater than for “hard laser” applications due to the fact that so many parameters are involved. Different wavelengths, power densities, energy densities and application modes have been used and there is no current consensus about optimal standards. The reporting of actual laser parameters and dosimetry in studies is too often substandard\(^1\) and control studies are then difficult to perform. Consequently, the evaluation of the various applications becomes problematic. The optical properties and performance of commercially available lasers vary a lot, adding problems in the evaluation process.\(^2\)

Surgical lasers are rather precise in their indications and the results are easier to verify by the naked eye. Therapeutic lasers work on the cellular level, enhancing the fundamental functions of the cells. This means that any pathological condition can theoretically be improved if the suitable wavelength and energy of light is applied. This is the beauty of laser phototherapy, but also the problem: how can one single therapy be used in so many situations? There is supposedly no “take-it-all” method in the history of medicine and a skeptical attitude from dentists is basically a sound reaction.

Two sides of the same coin

For decades, efforts have been made to separate “soft” and “hard” lasers and the plethora of suggested names partly stems out of these efforts. “Low-power laser,” “low-level laser” and “low-energy laser” are examples of this confusing nomenclature. The modern name of the tool is therapeutic laser and the therapy itself is more frequently called laser phototherapy (LPT).

It is becoming increasingly clear that the strict division between the two types of lasers cannot be...
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maintained. Soft lasers are now being used in the Watt range (although defocused), and the stimulatory effects of surgical lasers are being taken into consideration. The stimulatory effect of surgical lasers is not new. Already in 1980 Goldman published a report about the use of Nd:YAG laser for arthritis. The Er:YAG laser is a more recent laser and, up until now, only a few studies have been published using this laser for a priori laser phototherapy.

**Contraindications**

There are no known absolute contraindications for LPT, but there are several relative contraindications and caveats. At the present time, areas of malignancies or suspected malignancies must be avoided due to insufficient knowledge. The wavelengths used in LPT are much longer than the ionizing wavelengths known to cause cell damage, so LPT in itself cannot cause cancer.

Further, due to insufficient knowledge, irradiation of patients with coagulation disorders should be avoided. Irradiation over the thyroid has been reported as a contraindication, but present knowledge does not substantiate such risk when irradiation is performed in or close to this area. However, care is recommended in cases of hyperthyroidism.

Pregnancy is reported as a caveat, but this would only be applicable to large doses over the abdomen. As for epilepsy, there are anecdotal reports about seizure attacks triggered by pulsed light, but it would probably have to be in the visible range and observed by the patient. Irradiation over testicles and diabetic wounds has been reported as contraindications, but are rather confirmed as good indications for LPT. Older literature mentions patients wearing pacemakers as a contraindication, but this is clearly a misunderstanding.

**Safety**

The U.S. Food and Drug Administration considers therapeutic lasers safe. The only known hazard is the risk of eye injuries, so it is recommended patients wear protective goggles that are adapted for the wavelength used. The real risk for eye injuries is minimal even without goggles, but still recommended for legal reasons. Protective instructions for therapeutic lasers were initially mimicking the safety regulations for surgical lasers, but the levels of risk are certainly very different. Indeed, the use of therapeutic lasers for treatment of macular degeneration has been reported.

**The mechanisms**

To the skeptical reader, it may seem improbable that one therapy can affect so many conditions. However, the effects of LPT take place in the cells, and all cells in the body have a common architecture. Irradiation causes fundamental changes such as enhancement of ATP and cell membrane permeability.

The main, but not the only, photoreceptor is located in the mitochondria and is the cytochrome-c oxidase, a subunit in the mitochondrial electron-transport chain. It has been demonstrated that laser illumination increases both intracellular reactive-oxygen species (ROS) and adenosine triphosphate (ATP) synthesis and nitric oxide (NO) release after exposure to low levels of red and near-infrared light. This suggests that ROS might play an important role in the LPT signaling pathway. It can induce expression of several redox-sensitive transcription factors, such as nuclear-factor kappa B (NF-kB) that can then increase transcription of many gene products.

The basic irradiation changes generate a cascade of secondary and tertiary events, which are complicated and difficult to study, especially because they are more or less related to the wavelength and intensity of the light. Cells in a normal redox balance do not react much, whereas cells in a reduced redox situation react by increasing the pH situation toward normalization. Karu describes this in the book, "Ten Lectures on Basic
Science of Laser Phototherapy.\textsuperscript{10} The biologic effects of LPT are not based upon heat\textsuperscript{71} but high-output lasers can produce unwanted heating effects. However, the amount of pigmentation in the tissue will create different heat sensations and dark colored individuals may feel a temperature increase in the skin when lasers of rather high output are used.\textsuperscript{72} Intraorally this is not a great concern, though even a 400 mW laser in contact with an incisor can increase pulp chamber temperature by 5.5 degrees centigrade.\textsuperscript{78} Thus, although the biologic effect of the laser is not based upon heat, unwanted heating of the tissues can be achieved.

**The wavelengths**

Therapeutic lasers generally operate in the wavelength range of 630–980 nm. Output powers can be from 10 mW to 500 mW (Class 3B). They are often named after the contents of the substances of the lasering medium. Thus, red-light lasers are often called InGaAlP lasers, or Indium lasers, infrared lasers GaAlAs (aluminium lasers) or GaAs (gallium lasers). However, the best way is to just indicate the wavelength because these different materials are found in a wide wavelength range.

**The tools**

There is a great variety in design of the therapeutic lasers. For dentistry, it is obvious that a battery-based design similar to that of many curing lights is favorable. The probe can be sterilized, the unit is easy to move from one operatory to the other and there are no cables. However, the problems with battery-operated gadgets remain, although batteries have been greatly improved in recent years. A separate or built-in power meter is required to keep control of the actual output.

**Dosage**

Practitioners often find the issue of dosage complicated because it has to be adapted to the condition of the tissue, depth of location, chronic or acute, etc. To get to the dosage, the energy has to be calculated first, and that is quite uncomplicated. The energy is the power of the laser in milliwatts times the number of seconds.

For instance, a laser of 50 mW used during 20 seconds produces an energy of 50 x 20 = 1,000 millijoules = 1 joule (J). Clinicians often use “energy per point” in this fashion. This is acceptable, but not the whole truth. The energy is not the “dose,” although from a semantic point of view we tend to look at it that way.

The dose is a function of the size of the irradiated area, so in order to calculate the dose, the area also has to be taken into consideration. If the size of the probe, kept in contact with tissue, is 0.25 cm\(^2\), then the 1 J in the example above becomes 1 divided by 0.25 = 4 J/ cm\(^2\). If the probe is held at a short distance and the divergence of the beam makes the light cover an area of 1 cm\(^2\), then the dose becomes 1 divided by 1, equals 1 J/cm\(^2\).

These examples simply show that when the energy
The depth of penetration varies with the wavelength. Red laser light has a limited penetration depth while there is an “optical window” around 800 nm in the infrared. The penetration increases with higher power, but only marginally. Oral tissues such as mucosa and teeth are quite transparent, whereas bone is less transparent and muscles even less.

Therefore, each wavelength has its limitations. Red is best for superficial structures, such as wound healing, while TMD (except for the superficial joint) is best treated with infrared. Blood is the main absorber of laser light. Therefore, the penetration into muscles can be increased by using slight pressure, creating an ischemic area.

It is obvious that a lot of factors influence the numbers of photons reaching the desired target area and the clinician needs to understand these factors in order to obtain good results. Rather than considering the dose applied at the contact between the laser tip and the tissue, the clinician should think “dose at target.” This means considering the depth of the target and the kind of tissue between the laser eye and the target. 

**Pulsing**

Therapeutic lasers are generally continuous but can have an option for “chopping.” This means that the light can be shut off and on at given intervals. The GaAs (904 nm) laser is always pulsed though. In vitro studies confirm the importance of the pulsing, but the relevance in the clinical setting is quite obscure. Heat dissipation when using very powerful lasers is so far the only obvious advantage of pulsing.

**Some indications for dental LPT**

**Laser acupuncture**

Few dentists are trained in acupuncture, but there are some safe points that could be used to advantage, e.g., the P6 on the wrist is useful for reducing gagging. fMRI studies have confirmed that laser and needles actually have similar, although not identical, effects.

**Bone regeneration**

Several in vitro and animal studies indicate that LPT has a positive effect on bone regeneration. This has consequences for both periodontology and implantology. Repeated irradiation can activate osteoblasts and also stimulate the integration of implants. Optimal irradiation should start during the surgery and continue during the first two weeks.
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Caries

A cavity or crown preparation is a burden for the pulp. LPT applied after preparation and before cementation can save a lot of postoperative problems and potential endodontic work.\textsuperscript{16,19}

Dental hypersensitivity

Several studies\textsuperscript{20–25} have been published regarding the effect of laser phototherapy for dental hypersensitivity. While stronger lasers have the ability to seal dentinal tubuli, therapeutic lasers do not have any such effect but will influence the odontoblasts and the pulp. The therapeutic effect of surgical lasers has not generally been realized.

The results from studies vary and so do the dosages, wavelengths and application techniques. All used wavelengths apparently have an effect given the proper dosage. Irradiation has been directed toward the exposed dental necks and sometimes also over the projection of the apices. For this latter approach, infrared is needed, except for the upper incisives.

Extractions

LTP is reported as useful to promote pain relief and wound healing after tooth extractions.\textsuperscript{87,88}

Herpes Simplex Virus (HSV1)

LPT has been reported to be a fast and very effective treatment for this indication. If treated in the prodromal stage, a great likelihood for the attack to subside until the following day is reported. Pain relief is immediate and the intermediate period between the attacks is prolonged. The effect is supposed to be similar to that of Acyclovir, but without any side effects. Interestingly enough, it has been shown that patients with recurrent herpes attacks can be treated even in the silent periods. In spite of few available studies, this therapy appears to be safe and effective.\textsuperscript{26–28}

Lichen and leukoplakia

LPT is reported to have an effect similar to topical corticosteroids in the treatment of erosive-atrophic oral lichen planus.\textsuperscript{85} The pain after cryosurgery of leukoplakias is reported to be reduced by the subsequent application of LPT.\textsuperscript{86}

Mucositis

Mucositis is an inevitable follower of radiation therapy and sometimes also of chemotherapy. LPT has been documented as an effective method to reduce pain and incidence of mucositis.\textsuperscript{29–34,74} The HeNe laser was first documented, but the red and infrared laser diodes appear to be useful as well. Best results are obtained when LPT is initiated before the radiation/chemotherapy because LPT has a radio protective effect.\textsuperscript{25}

Intraoral irradiation is rather time consuming and extraoral application via red LED arrays\textsuperscript{36} has been proven effective, and future research may look into the same concept for less staff-intensive laser applications.

Nerve recovery

There are many papers about the effect of LPT on the function and recovery of peripheral nerves. This therapeutic modality seems very attractive in oral surgery where injuries of nerves such as the IAN and the facial nerve are likely to occur in some types of surgery. LPT can be used as an immediate protective treatment\textsuperscript{37}, but it is reported that even long-standing aberrations can be influenced.\textsuperscript{36–42}

Oedema

Oedema is a daily guest in dental operatories, either
caused by pathologies or by dental interventions. LPT decreases the permeability of the lymph vessels, increases the vessel lumen and can stimulate lymph vessel collaterals, thus reducing the oedema.\textsuperscript{43–46} Irradiation of the involved lymph nodes is recommended for all oral pathologic conditions as an adjunctive therapy to local irradiation.

\textbf{Orofacial pain}

Reduction of pain is one of the most desired effects of LPT. This is obvious in dentistry where pain is one of the most feared situations. Pain reduction requires higher doses than general stimulation and, therefore, pain reduction and tissue stimulation cannot be achieved at the same time.

Pain can be gradually reduced by the ability of LPT to shorten the period of inflammation, but the dose window for this is lower than that of immediate pain reduction. LPT stimulates opioid precursors and causes transient axonal vesicles that reduce neural transmission.\textsuperscript{47–50} Trigeminal neuralgia\textsuperscript{51} and post herpetic neuralgia\textsuperscript{52,53} are two indications suitable for LPT. The laser therapy is not likely to cure trigeminal neuralgia, but will facilitate a reduction of Carbamazepine intake.

\textbf{Orthodontics}

There is some documentation for the use of LPT to reduce the pain experienced during tooth movements and also to increase the velocity of tooth movement.\textsuperscript{55–58} Low dosage seems to accelerate the speed of movement whereas higher dose appear to slow down movement. In the latter case, this could possibly be used for stabilization of completed orthodontic therapy.

This phenomenon is in accordance to the Arndt-Schultz law, which stipulates that for every substance, small doses stimulate, moderate doses inhibit, large doses kill. Here, the killers are the surgical lasers. LPT has also been proposed as a viable option for luxated teeth before applying orthodontic stabilization.\textsuperscript{76}

\textbf{Periodontics}

While high-power lasers have received much attention for their ability to reduce pocket microbes and to remove the pocket epithelial lining, therapeutic lasers have received less attention. However, a number of studies suggest that LPT can reduce pocket inflammation and be useful in combination with SRP.\textsuperscript{59–62} Similar results have been seen for smokers and non-smokers.\textsuperscript{77}

Irradiation in connection with SRP reduces postoperative pain and discomfort, but several irradiations are needed to produce significant clinical results. LPT in itself has no germicidal effect, but if used in combination with a suitable dye, a PDT-like effect can be achieved where singlet oxygen is produced. Typically, the dye toluidine blue O (TBO) is used in combination with a 635 nm laser of about 100 mW.

\textbf{Sinusitis}

Sinusitis may or may not have a dental background, but dentists still meet many patients with this condition. The patient is uncomfortable in the dental chair due to tenderness in the local area and has difficulties breathing through his or her nose. Infrared LPT over the projection of the sinuses will lower the sensation of pressure and tenderness. Irradiation into the nostrils will reduce the mucosal swelling and open the nasal obstruction.\textsuperscript{89, 90} Thus, dental treatment can become more comfortable. To actually cure sinusitis, repeated irradiations are needed. In this author’s experience, LPT is also an excellent help in the dental situation for patients with pollinosis.

\textbf{Temporomandibular joint disorders (TMD)}

TMD can be either arthrogenic, myogenic or both in combination. The effect of LPT on arthritic conditions is well investigated and there is some evidence of an
effect on myogenic pain and trismus. For arthrogenic conditions, low doses are required whereas myogenic conditions require an infrared laser and high dosage. The pain- and spasm-relieving effects are fast and the condition of trismus can be resolved or improved within minutes. Because the occipital and neck muscles are frequently involved in TMD, the laser will add benefits for the dentist and patient. Patients with stiff necks are difficult to treat and a session of LPT can soften the neck. In addition, irradiation over the joint and masseter after surgery will decrease the postoperative consequences of a long period of overstretched muscles.

**Wound healing**

The literature contains a multitude of studies on the wound-healing aspect of LPT. Some of the underlying mechanisms have been documented, but still there is no certain knowledge about the optimal laser parameters and dosimetry. The early studies were performed on healthy test animals and showed moderate results. Modern studies using a diabetic-rat model have proven more successful. This has a general bearing on periodontics and oral surgery because the healing process in diabetic patients is impaired. The best clinical effects are also seen in long-standing wounds where traditional therapies have failed.

**Xerostomia**

LPT can be used to stimulate the salivary flow in patients with mouth dryness. Recent studies suggest that the effect is not only transient. It is also suggested to stimulate the impaired salivary flow in patients subjected to radiotherapy.

**Other indications**

The indications mentioned above are some of the major ones, but since LPT has an effect on almost any pathological condition, the list could be much longer. These would not only be purely dental indications either. The limit of TMD problems does not end with the masticatory muscles; the neck and upper trapezius are frequently involved and easily reached by the laser. The “laser dentist” has many opportunities to help patients and staff with problems that may not be dental related.

**Abstract**

Therapeutic lasers (low-level lasers) are defined as: “Treatment using irradiation with light at low power intensities and with wavelengths in the range 540–830 nm. The effects are thought to be mediated by a photochemical reaction that alters cell membrane permeability, leading to increased mRNA synthesis and cell proliferation. The effects are not due to heat, as in laser surgery. Low-level laser therapy has been used in general medicine, veterinary medicine, and dentistry for a wide variety of conditions, but most frequently for wound healing and pain control.” (MeSH—Medical Subject Headings, 2009).
It is apparent that these lasers are different from the Nd:YAG and Er:YAG lasers now gaining popularity in dentistry. However, the two types are actually only two sides of the same coin because thermal lasers also have biostimulative qualities.

This article presents a general overview of therapeutic lasers and presents some of the mechanisms and examples of clinical indications in dentistry.

A complete list of references is available from the publisher.
Lasers in dental traumatology

Author_Claudia Caprioglio, DDS

Introduction

Dental traumas occur frequently in children. They can be complex events and sometimes real emergencies. Traumatic injuries involve all the branches of dentistry (endodontics, restorative, periodontics, oral surgery, orthodontics) such that traumatology can be considered a multidisciplinary discipline.

Laser technology lends itself well to the problems encountered in dental traumatology (from simple crown fractures to replantation, root fractures and different types of luxation injury) because it is able to replace or complete, and also to simplify, traditional dental procedures. It contributes to the reduction of postoperative sensitivity through a minimally invasive and highly selective technique that has a positive psychological impact for the patients. In addition, it is an alternative technique for non-vital bleaching procedure to solve post-traumatic esthetic problems.

Working without anaesthesia through laser-induced analgesia is another challenge. Laser-assisted therapies drastically reduce the need for postoperative medications compared to conventional procedures. The international literature doesn’t report extensive references on laser-assisted dental trauma therapy, and there are no well-coded guidelines for specific laser application in this clinical field. Even though this challenging technology is ideal for trauma-related problems, the existing dental trauma guidelines and protocols should nevertheless be widely consulted (Andreasen et al. 2007).

Epidemiology and prevention

Dental traumas are sustained mainly during play (56 percent), sports activities (21 percent), road accidents (11 percent) or as a result of acts of violence (12 percent), which continue to be underestimated. In the literature, the high incidence of dental trauma is demonstrated by large-scale American studies that show that one in six adolescent boys is twice as likely as a girl to suffer a dental trauma, and the type of lesion varies depending on the age of the subject; in young age groups the incidence is usually equally high in both sexes (Glendor 2008).

Around 20 percent of children suffer a traumatic injury to their primary teeth and more than 15 percent to their permanent teeth (Andreasen et al. 2007). The teeth most frequently affected, both in primary and in permanent dentition, are the upper central incisors (50 percent) and the upper lateral incisors (30 percent). Pediatricians and dentists need to draw attention to the importance of prevention in this field.

These injuries, together with tooth decay, are the...
most frequent pathologies encountered in pediatric dentistry. Thus, specific training, adequate continuing education conventions, a high level of knowledge and updated guidelines for the management of traumatic dental injuries are needed.

**Classification**

In 1978, the World Health Organization created a classification of traumatic dental injuries. In 1992, this classification, revised and extended, was published. The following classification includes injuries to the teeth, supporting structures, gingival and oral mucosa. It is applicable both to primary and permanent dentition (Table I) (Andreasen et al. 2007).

**Lasers application in dental traumatology**

Taking a careful dental history report and doing a clinical examination are the basis of an accurate diagnosis. In order to save time and to be exhaustive, specific standardized charts are recommended. Every phase, both pre- and post-treatment, must be fully documented through radiographic and photographic examinations and pulp vitality tests, making it easier and quicker to monitor the evolution of the clinical case at subsequent visits and to compile a full medico-legal report, which is often required during and at the end of dental trauma treatment.

In dental trauma, pulp testing is a controversial issue; different tests have been proposed: the laser doppler flowmetry (LDF) is an experimental value method to diagnose the state of pulp revascularization; however, at this time this method cannot be of general use, but it looks promising.

Laser technology is an advancement that fits into the concepts of tooth preservation (microdentistry) and prevention. The use of lasers in many medical fields has become the standard treatment; this is not the case of dental traumatic injuries but this author is confident that these technologies will offer better quality treatments and will make our profession more enjoyable.

There are different types of lasers available to treat dental injuries. The properties of each type make them suitable for different tissues and procedures; each wavelength has a particular use determined by its specific tissue-interaction and affinities.

Due to their versatility, two types of lasers are more frequently used by pediatric dentists in dental traumatic injuries: Er:YAG and Er,Cr:YSGG because they can be used on hard and soft tissues (Gutknecht et al. 2005). In addition, other technologies are indicated: the KTP, the Nd:YAG laser, the Diode laser and the CO₂ (Table II).

No randomized clinical studies exist concerning traumatic dental injuries and laser-assisted therapy, so in this article the author describes his own clinical experience and aims to stimulate more extensive scientific research.

**Traumatic injuries to hard dental tissue and the pulp**

*Uncomplicated and complicated crown fracture*

This type of fracture involves the enamel and dentin and exposes the pulp (if complicated).

The examination should be preceded by cleaning the injured area and doing a careful search for pulp exposure.

Take an X-ray, perform vitality tests because sometimes there is accompanying damage to the soft tissue (tongue and lips: look for tooth fragments).

The use of modern bonding agents and laser technology has considerably changed our clinical practice. Erbium lasers can guarantee good results in reducing postoperative discomfort and sensitivity as well as providing minimally invasive dentistry (Genovese et al. 2008).

Erbium lasers are indicated for the treatment of crown fractures, both complicated and uncomplicated, and whether or not the tooth fragment is available. In the first decade of research, various...
Authors studied the parameters and variables for using the Erbium laser, evaluating the morphological effects on hard and pulp tissues: the effects of energy density, pulse repetition rate and air-water jet were reported: the results obtained with the laser were the same as those achieved with orthophosphoric acid (Moritz et al. 2006).

Various studies and clinical reports show how the laser, used by numerous operators as an alternative to rotary instruments in pediatric restorative dentistry, brings an added measure of safety even when used in the treatment of very young children, is a new possibility for minimal interventions (Kornblit et al. 2008) and overall has better acceptance compared to traditional techniques (Keller et al. 1998).

Laser cavity preparation is closely related to different variables. Fluence, power density and pulse length, but also laser angulation, focus mode and the amount of air-water jet are all factors that can cause substructural damage to the dentin. A final conditioning at low wattage both on dentin and enamel is advisable.

Acid etching on lased dentin and enamel produces uniform results, eliminating the thin layer of substructural damage, exposing the collagen fibers and creating a substrate for the formation of the hybrid layer; acid etching modifies the Silverstone enamel Class 2 and 3 into Class 1, allowing better composite adaptation.

The action of Erbium lasers on hard tissues and pulp is extremely precise: the surfaces treated are cleansed and sterilized.

Temperature increase during treatment is minimal and may decrease while working with water-spray cooling.

Due to bactericidal capacities, there is no production of smear layer nor opening of dentinal tubules or allowing hybrid layer formation, these lasers can be used to perform the entire procedure: excavation, coagulation of the exposed pulps (if needed), pulpotomy or pulpectomy (Figs. 1–4).

Another feature is the very superficial thermal effect, therefore, the necrotic zone is likely to be very small. This kind of injury exposes a large number of dentinal tubules: 1 mm² of dentin exposes 20,000 to 45,000 dentinal tubules. They constitute a pathway for bacteria, thermal and chemical irritants that can determine pulpal inflammation. Erbium lasers are effective at removing organic material and the smear layer, and can achieve a bactericidal effect, but the Nd:YAG laser and the diode laser can provide an effective decontamination action as well.

The Erbium laser’s fusion and sealing capacity of the dentinal tubules (depth of up to 4 µm) can result in a reduction of the tissues’ permeability to fluids, thus reducing dentinal hypersensitivity.

Another structural change induced by these lasers is the phenomenon of vitrification, which can be very useful because it increases hard-tissue resistance to acid remineralization, dental hardness and dental abrasion.

The Nd:YAG and the diode laser have a beneficial therapeutic action in direct traumas. By exploiting their phototermic effect, these lasers can be used to treat both pulp and dentin. They can be applied:

- to treat dentinal hypersensitivity,
- to perform indirect or direct pulp capping,
- to remove endodontic material and
- to treat infected root canals.

The CO₂ laser has a purely thermal effect on the tissue, 90–95 percent of the energy it delivers to tissue is absorbed by a fine tissue layer and transformed into heat. It’s indicated for:

- pulp capping (following dentin fracture),
- pulpotomy (following crown or root-crown fractures) and
- surgical cutting (e.g., to remove a tooth fragment) (Figs. 3–5, 15).

Few studies that investigate laser performance in maintaining pulp tissue vitality are indexed in the PubMed library. Different laser wavelengths and parameters related to the different devices were used. The common delineator was the low-laser energy applied (from 0.5 to 1.0 W), delivered in defocused mode, preferably using low repetition rate or super-pulsed mode.

Pulpotomy is a very common technique in primary teeth: although pulpotomy with formocresol (1:5 dilution) is used with success, there is a tendency today to seek alternative techniques considering the carcinogenic and mutagenic potential of this formaldehyde component. Lasers have been proposed...
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for pulpotomy, and one study compared favorably CO2 laser treatment to formocresol for pulpotomy in primary teeth, with a survival rate from 91 to 98 percent (Pescheck et al. 2002). Other studies reported that the superpulsed mode produced a markedly higher success rate than the continuous wave mode.

During this procedure, attention must be given to the energy applied. Low energy delivered in defocused mode and pulse or superpulsed mode guarantees good superficial coagulation and good decontamination to maintain the vitality of the residual pulp in pulp capping application (Olivi et al. 2007). Particular care must be taken with the application of laser energy into primary root canals for root canal cleaning and disinfecting due to the characteristic anatomy of the apex and to the penetration depth of near infrared lasers (Soares et al. 2008).

Crown-fracture and root fracture
In contrast to root fractures where the fracture is located entirely within the alveolous, fracture healing cannot be expected in crown-fractures. The coronal fragment is usually removed and the treatment should be focused on the possibility of using the remaining fragment.

On a superficial fracture without pulp exposure, it’s suggested to remove loose fragments, smoothing the rough subgingival fracture surface, and covering the exposed dentin. When the coronal fragment comprises one-third or less of the clinical root after the removal of loose fragments, a pulpectomy and root canal filling is recommended.

The fracture surface has to be exposed with a gingivectomy or osteotomy and subsequently a prosthetic restoration (Figs. 5–8).

Laser-assisted therapy can be useful not only for the coronal fragment restoration but also for supporting tissue surgery and endodontic therapy (gingivoplastics, gingivectomy, crown lengthening) (Sarver and Yanosky, 2005).

Lasers are effectively used in these soft-tissue procedures because they can easily incise, cut, ablate and reshape the soft tissue with no or minimal bleeding, less pain and have a bactericidal effect.

In these clinical events, deeply penetrating lasers, such as Nd:YAG and diode-lasers, show a thicker coagulation layer than superficially-absorbed ones, such as CO2-Erbium lasers. The technique used with the first pair is similar to removing the tissue with electrosurgery.

Treatment factors such as optimal repositioning and flexible splinting have a positive influence upon healing, such as immature root formation, lower age and less displacement of the coronal fragment.

Because a splint has to be kept in situ for at least several weeks, an esthetic orthodontic splint can also be used (ceramic brackets).

Debonding procedures can be atraumatic when using a Nd:YAG laser. Intra-pulpal temperature rises less than using conventional high-low speed instruments for orthodontic brackets removal.

Therefore the laser-assisted procedure is safer, quicker and more comfortable (Figs. 3–5, 15).

Traumatic injuries to the periodontal tissues
Indirect traumas are lesions to the supporting structures, in particular the alveolar bone, the periodontum, the gingiva, the ligaments, the fraenum and the lips. The Nd:YAG laser and the diode laser have a beneficial therapeutic action in traumatic injuries to the periodontal tissues. These lasers have a decontaminating effect, as well as a biostimulating and reparative effect, with no suture, good and rapid healing by second intention and minor discomfort for the patient.

They are useful for:
- decontamination of the alveolous following a traumatic avulsion,
- treatment of a periodontal defect following a dental luxation or sub-luxation,
- microgingival surgery for the treatment of a traumatic dental injury,
Lasers are increasingly being used for gingival dental surgery and to replace the use of electrosurgery. A study to evaluate and compare the temperature rise in hard and soft tissue when using the CO\textsuperscript{2} and diode laser and electrosurgery units for soft-tissue dental surgery came to the conclusion that both procedures are considered soft to local tissue in terms of temperature rise if the provided guidelines are followed. The CO\textsuperscript{2} laser caused more heat in the gingival area.

The CO\textsuperscript{2} laser is specifically used for surgical cutting (e.g., to remove a tooth fragment from the lip or oral mucosa) (Figs. 3–5).

**Injuries to developing teeth**

Disorders of permanent teeth caused by traumatic injury to primary teeth can be divided into two groups according to the type of dental trauma: direct traumatic impact or indirect lesion. The prevalence of these disturbances ranges from 12 to 69 percent depending on the study. Avulsion and intrusive luxation are injuries associated with very high frequencies of developmental complications.

Laser-assisted therapy can be useful in:

- **enamel discoloration:** treatable with Erbium laser,
- **circular enamel hypoplasia:** treatable with Erbium laser and
- **ectopic eruption:** treatable with surgical exposure or soft-tissue laser surgeries (all the wavelengths of the near-medium and far infrared spectrum of light).

**Gingivectomy and gingivoplasty and surgical cutting** (e.g., to remove a tooth fragment) (Martens 2003).

Finally, they also exert an appreciable analgesic effect both on hard and soft tissues.

In oral surgery, both the diode laser and the Nd:YAG laser are used. The former is used in continuous or pulsed mode, the latter always in pulsed mode but with different pulse amplitudes.

The increase in temperature that these lasers produce has an excellent thermostatic effect. In all luxation injuries, the bactericidal effect and detoxification of lasers (Er:YAG, Nd:YAG, diode and argon lasers) provide favorable conditions for the attachment of periodontal tissue (Figs. 9–12).

Laser decontamination and/or laser photobiomodulation can be required for tissue repair (cutaneous and subcutaneous tissue irradiation) and for pain relief. It has been reported that photodynamic changes may occur in several physiologic processes, but additional clinical studies are necessary to establish suitable irradiation conditions. The Nd:YAG laser, diode laser and KTP can also be an alternative technique for a non-vital bleaching procedure.

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Low-level laser therapy (LLLT) or soft-laser therapy

A non-traumatic introduction to dentistry can be represented by low-level laser therapy or soft-laser therapy. There is a large body of literature on this particular topic even though methodologically and in terms of doses, there is still a considerable difference of opinions.

Even though helium-neon lasers were initially used (632.8 nm = l), the ones in use today are the semiconductor diode type (830 nm or 635 nm = l). The water absorption coefficient of the wavelengths used for this purpose is reduced and the beams are able to penetrate both soft and hard tissues from a distance of 3 to 15 mm.

LLLT has a number of applications in dentistry, both at the soft-tissue level (biostimulation of lesions, aphthous stomatitis, herpetic lesions, mucositis, pulpotomy) and neurally (analgesia, neural regeneration, temporo-mandibular pain, post-surgical pain, orthodontic pain).

Between one and three days after biostimulation it is already possible to observe a considerable reduction of swelling and an acceleration of the epithelization and collagen deposition phase.

The clinical importance of this acceleration of the reparative processes is considerable, especially when the general defense system of the patient is compromised (young patients but also older patients with insulin dependent diabetes, valvar dysfunction or malformations, history of endocarditis, patients with prosthetic cardiac valves and cardiac surgical reconstruction).

In short, LLLT stimulates tissue repair processes and, influencing a large number of cell systems, can have a series of benefits on inflammatory mechanism. (antalgic, biostimulating and anti-inflammatory effects) (Nascimento et al. 2004, Weber et al. 2006) (Figs. 13–15). These effects are specific to some wavelengths and they cannot be obtained with non-polarized and non-coherent light sources,
such as LEDs.

The author hopes that the pursuit of these new horizons might lead to the definition of protocols containing more specific indications in regards to times, doses and sites of application.

LLLT has the main indication in dental traumatology (Caprioglio C. and Caprioglio A. 2010, Turner and Hode 2004): Brief analgesic effect in the mucosa allowing painless injection with a needle or treatment without anesthesia.

Direct application into the exposed cavity of a deciduous tooth can be used for pain reduction. Also, the trans-mucosal irradiation in the apical portion and a reticular irradiation to the cervical area of the tooth has an analgesic effect in post-traumatic treatment after lip and front-tooth trauma to reduce swelling and pain, and for post-endodontic therapy, after pulp capping and after apexitogenesis or specification. There is also an analgesic effect for orthodontic movements, TMJ disorders and pain, traumatic mucosal lesions (ulcers) and aphthous or herpetic lesions.

Knowing that the analgesic effect of light at 800–900 nm is 30 joules x cm² and the biostimulating effect is 50 joules x cm², it becomes possible to develop operating protocols that can be compared, standardized and repeated (Benedicenti 2005).

**Conclusions**

Lasers are very effective not only in pediatric dentistry but also in traumatic dental injuries. They enable optimal preventive, interceptive and minimally invasive interventions for both hard- and soft-tissue procedures.

It is important for the professional to understand the physical characteristics of the different laser wavelengths and their interaction with the biological tissues to ensure that they are used in a safe way in order to provide the benefits of this technology. Therefore, a period of education and training is highly recommended before applying this technology, especially to pediatric patients.

A complete list of references is available from the publisher.

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The antibacterial effects of lasers in endodontics

Author_Selma Cristina Cury Camargo, PhD

_Endodontic infection_

The success of endodontic treatment reaches values between 85 to 97 percent. Adequate treatment protocols, knowledge and infection control are the basic components to achieve such values (Fig. 1). It is well known that apical periodontitis is caused by the communication of root-canal microorganisms and their byproducts with the surrounding periodontal structures. Exposure of dental pulp directly to the oral cavity, or via accessory canals, open dentinal tubules or periodontal pockets, are the most probable routes of the endodontic infection.

Clinically, apical periodontitis is not evident as long as the necrotic tissue is not infected with microorganisms. There are up to 40 isolated species of bacteria present in the root canal. Cocci, rods, filaments, spirochetes, anaerobic and facultative anaerobic are frequently identified in primary infection, fungus can also be isolated.

Endodontic microbiota can be found suspended in the main root canal, adhered to the canal walls and deep in the dentinal tubules at a depth of up to 300 µm (Fig. 2). The absence of cementum dramatically increases bacteria penetration into dentinal tubules.

It has been shown that bacteria can also be found outside the root-canal system, located at the apical cementum and as an external biofilm on the apex. Following conventional endodontic treatment, 15 to 20 percent of non-vital teeth with apical periodontitis fail.

The presence of bacteria after the decontamination phase or the inability to seal root canal after treatment are reasons for failure. The remaining contamination in endodontically treated teeth is able to maintain the infectious disease process in the periapical tissue.

Retreatments are the first choice in failed root canals. The microbiota found in persistent infections differs from that in primary infection. Facultative anaerobic gram positive (G+) and negative (G-) microorganisms and fungus are easily found. Special attention is given to Enterococcus faecalis, a resistant facultative anaerobic G+ cocci, identified in a much higher incidence in failed root canals.

The importance of bacterial control plays a significant role in endodontic success. Adequate and effective disinfection of the root-canal system is necessary. Based on that, all efforts must be done in order to achieve this result.
The bacterial flora of the root canal must be actively eliminated by a combination of debridement and antimicrobial chemical treatment. Mechanical instrumentation eliminates more than 90 percent of the microbial amount. An important point of note is the adequate shaping of the root canal. Evaluating the antibacterial efficacy of mechanical preparation itself, Dalton et al. concluded that instrumentation to an apical size of #25 resulted in 20 percent of canals free of cultivable bacteria, when a #35 size was made, 60 percent showed negative results.

Irrigant solution has been associated with mechanical instrumentation to facilitate an instrument’s cutting efficiency, remove debris and the smear layer, dissolve organic matter, clean inaccessible areas and act against microorganisms. Sodium hypochlorite is the most common irrigant used in endodontics. It has an excellent cleansing ability, dissolves necrotic tissue, has a potential antibacterial effect and, depending on the concentration, is well tolerated by biological tissues. When added to mechanical instrumentation, it reduces the number of infected canals by 40 to 50 percent.

Other irrigant solutions are also used during endodontic preparation. EDTA, a chelating agent used primarily to remove the smear layer and facilitate the removal of debris from the canal has no antibacterial effect. Chlorhexidine gluconate has a strong antibacterial activity to an extensive number of bacteria species, even the resistant Enterococcus faecalis, but it does not break down proteins and necrotic tissue as sodium hypochlorite does.

Because the association of mechanical instrumentation and irrigant solutions are not able to totally eliminate bacteria from the canal system — a status that is required for root-canal filling — additional substances and medicaments have been tested in order to suppress the gap that occurs in standard endodontic protocols.

The principal goal of dressing the root canal between appointments is to ensure safe antibacterial action with a long-lasting effect. A great number of medicaments have been used as dressing material, such as formocresol, camphorated parachlorophenol, eugenol, iodine-potassium iodide, antibiotics,
Calcium hydroxide and chlorhexidine.

Calcium hydroxide has been used in endodontic therapy since 1920. With a high pH at saturation over pH 11, it induces mineralization, reduces bacteria and dissolves tissue. For extended antibacterial effectiveness, the pH must be kept high in the canal and in the dentin as well. This ability depends on the diffusion through dentin tubules.

Although most microorganisms are destroyed at pH 9.5, a few can survive over pH 11 or higher, such as *E. faecalis* and candida. Because of the resistance of some microorganisms to conventional treatment protocols—and the direct relation between the presence of viable bacteria in the canal system and the reduced percentage of treatment success—additional effort has to be made to control canal system infection.

_Lasers in endodontics_

Lasers were introduced in endodontics as a complementary step to increase antibacterial efforts in conventional treatments. The antibacterial action of Nd:YAG, diodes, Er:YAG and photo activated disinfection (PAD) have been explored by a number of investigators. In the following section, each laser is evaluated with the aim of selecting an adequate protocol that will result in a high probability of success in teeth with apical periodontitis.

_Nd:YAG laser_

The Nd:YAG laser was one of the first lasers tested in endodontics. It is a solid-state laser. The active medium is usually YAG: yttrium aluminum garnet (Y2Al5O12) where some Y3+ are substituted for Nd3+. It is a four-level energy system operating in a continuous or pulsed mode. It emits a 1064 nm infrared wavelength. Thus, this laser needs a guide light for clinical application. Flexible fibers with a diameter between 200 mm and 400 µm are used as delivery systems. It can be used intra canal, in contact mode (Fig. 4).

The typical morphology of root-canal walls treated with the Nd:YAG laser show melted dentin with a globular and glassy appearance and few areas are covered by persistent infection.
a smear layer. Some areas show dentinal tubules sealed by fusion of the dentin and deposits of mineral components.33,34 This morphologic modification reduces dentin permeability significantly.35,36 However, because the emission of the laser beam from the optical fiber is directed along the root canal, not laterally, not all root canal walls are irradiated, which gives more effective action at the apical areas of the root.37 Undesirable morphologic changes such as carbonization and cracks are seen only if high parameters of energy are used.

One of the major problems for intra-canal laser irradiation is the increase of temperature at the external surface of the root. When laser light reaches a tissue, a thermal effect occurs. The heat is directly associated to energy used, time and irradiation mode. An increase in temperature levels more than 10 degrees Celsius per one minute can cause damage to periodontal tissues, such as necrosis and anquilose. Lan (1999)38 evaluated in vitro, the temperature increase on the external surface of the root after irradiation with a Nd:YAG laser under the following parameters of energy: 50 mJ, 80 mJ and 100 mJ at 10, 20 and 30 pulses per second. The increase of temperature was less than 10 degrees. The same results were obtained from Bachman et al. (2000)39, Kimura et al. (1999)40, Gutknecht et al. (2008).41

In contrast to the external surface, intra-canal temperature rises dramatically at the apical area, promoting an effective action against bacteria contamination. For the Nd:YAG laser, 1.5 watts and 15 Hz are safe parameters of energy for temperature and morphological changes.33,41

The primary use of the Nd:YAG laser in endodontics is focused on elimination of microorganisms in the root canal system. Rooney et al. (1994)42 evaluated the antibacterial effect of Nd:YAG lasers in vitro. Bacterial reduction was obtained considering energy parameters.

Researchers developed different in vitro models simulating the organisms expected in non-vital, contaminated teeth. Nd:YAG irradiation was effective for Baccillus stearothermophilus43,44, Streptococcus faecalis, Escherichia colii45, Streptococcus mutans46, Streptococcus sanguis, Prevotella intermedia47 and a specific microorganism resistant to conventional endodontic treatment, Enterococcus faecalis.48–50 Nd:YAG has an antibacterial effect in dentin at a depth of 1000 µm50 (Fig. 5).

Histological models were also developed in order to evaluate periapical tissue response after intra-canal Nd:YAG laser irradiation. Suda et al. (1996)51 proved in dog models that Nd:YAG irradiation that 100 mJ/30 pps (pulses per second) during 30 seconds was safe to surrounding root tissues. Maresca et al. (1996)52, using human teeth indicated for apical surgery, confirmed Suda et al.51 and Ianamoto et al. (1998)53 results. Koba et al. (1999)54 analyzed histopathological inflammatory response after Nd:YAG irradiation in dogs using 1 watt and 2 watts. Results showed significant inflammatory reduction in four and eight weeks compared to the non-irradiated group.

Clinical reports published in the literature con-
firm the benefits of intra-canal Nd:YAG irradiation. In 1993, Eduardo et al.\(^5\) published a successfully clinical case that associated conventional endodontic treatment with Nd:YAG irradiation for retreatment, apical periodontitis, acute abscess and perforation. Clinical and radiographic follow up showed complete healing after six months.

Similar results were shown by Camargo et al. (1998).\(^5\) Gutknecht et al. (1996)\(^5\) reported a significant improvement in healing of laser-treated infected canals, when compared to non-irradiated cases.

Camargo et al. (2002)\(^5\) compared the antibacterial effects of conventional endodontic treatment and conventional protocol associated to the Nd:YAG laser. Teeth with apical radiolucency, no symptoms and necrotic pulps were selected and divided into two groups: conventional treatment and laser irradiated.

Microbiological samples were taken before canal instrumentation, after canal preparation and/or laser irradiation and one week after treatment. Results showed a significant antibacterial effect in the laser group compared to the standard protocol. When no other bactericidal agent was used, it is assumed that the Nd:YAG laser played a specific role in bacterial reduction for endodontic treatment in patients.

_Diodes_

The diode laser is a solid-state semiconductor laser that uses a combination of gallium, arsenide, aluminium and/or indium as the active medium. The available wavelength for dental use ranges between 800 and 1064 nm that emits in continuous and gated pulsed mode using an optical fiber as the delivery system (Fig. 6).

Diode lasers have gained increasing importance in dentistry due to their compactness and affordable cost. A combination of smear layer removal, bacterial reduction and less apical leakage brings importance to this system and makes it viable for endodontic treatment. The principal laser action is photothermal.

The thermal effect on tissue depends on the irradiation mode and settings. Wang et al. (2005)\(^5\) irradiated root canals in vitro and demonstrated a maximum temperature increase of 8.1 degrees Celsius using 5 watt for seven seconds. Similar results were obtained by da Costa Ribeiro.\(^6\)

Gutknecht et al. (2005)\(^6\) evaluated intra-canal diode irradiation with an output set of 1.5 watts observed a temperature increase in the external surface of the root of 7 degrees Celsius with 980 nm of diode irradiation at a power setting of 2.5 watts at a continuous and chopped mode and demonstrated that the temperature increase never exceeded 47 degrees Celsius, which is considered safe for periodontal structures.\(^4\)

Clean intra-canal dentin surfaces with closed dentinal tubules, indicating melting and recrystallization, were morphological changes observed at the apical portion of the root after intra-canal diode irradiation.\(^6\) In general, near infrared wavelengths, such as 1064 nm and 980 nm, promote fusion and recrystallization on the dentin surface, closing dentinal tubules.

The apparent consensus is that diode laser irra-
A 980 nm diode laser has an efficient antibacterial effect in root canals contaminated with *Enterococcus faecalis* at an average between 77 to 97 percent. Energy outputs of 1.7 watts, 2.3 watts and 2.8 watts were tested. Efficiency was directly related to the amount of energy and dentin thickness.

**Er:YAG laser**

Er:YAG lasers are solid-state lasers whose lasing medium is erbium-doped yttrium aluminium garnet (Er:YAG). Er:YAG lasers typically emit light with a wavelength of 2940 nm, which is infrared light. Unlike Nd:YAG lasers, the output of an Er:YAG laser is strongly absorbed by water because of atomic resonances. The Er:YAG wavelength is well absorbed by hard dental tissue. This laser was approved for dental procedures in 1997. Smear layer removal, canal preparation and apicoectomy are the indications for endodontics (Fig. 7).

The morphology of dentinal surface irradiated with an Er:YAG laser is characterized by clean areas showing opened dentinal tubules free of smear layer in a globular surface. The effects on bacterial reduction by Er:YAG was observed by Moritz et al. (1999). Stabholz et al. (2003) described a new endodontic tip that can be used with an Er:YAG laser system. The tip allows lateral emission of the radiation rather than direct emission through a single opening at the far end. It emits through a spiral tip located along the length of the tip. In order to examine the efficacy of the spiral tip in removing smear layer, Stabholz et al. (2003) showed cleaned intra-canal dentin walls free of smear layer and debris under SEM evaluation.

**Photo activated disinfection (PAD)**

Another method of disinfection in endodontics is also available. Photo activated disinfection (PAD) is based on the principle that photo-activatable substances that bind to the target cells and are activated by light of suitable wavelength. Free radicals are formed, producing a toxic effect to bacteria. Toluidine blue and methylene blue are examples of photo-activatable substances. Tolonium chloride is able to kill most of the existing bacteria. In vitro studies, PAD has an effective action against photosensitive bacteria such as *E. faecalis*, *Fusobacterium nucleatum*, *Prevotella intermedia*, *Peptostreptococcus micros* and *Actinomyces comitans*.
On the other hand, Souza et al. (2010) evaluating PAD antibacterial effects as a supplement to instrumentation / irrigation in infected canals with *E. faecalis*, did not prove significant effect regards to intra-canal disinfection. Further adjustments in the PAD protocols and comparative research models may be required to before clinical usage recommendations.

**Discussion and conclusion**

There are good reasons to focus the treatment of non-vital contaminated teeth upon the destruction of bacteria in the root canal. The chances for a favorable outcome of the treatment are significantly higher if the canal is free from bacteria when it is obturated.

If, on the other hand, bacteria persist at the time of root filling, there is a higher risk of failure treatment. Therefore, the prime objective of treatment is to achieve the complete elimination of all bacteria from the root canal system.

Today, the potential antibacterial effect of laser irradiation associated with the bio-stimulation action and accelerated healing process is well known. Research has supported the improvement of endodontic protocol.

An endodontic laser therapeutic plan brings benefits to conventional treatment, such as minimal apical leakage, effective action against resistant microorganisms and on external apical biofilm, and an increase in periapical tissue repair. Based on that, laser procedures have been incorporated into conventional therapeutic concepts to improve endodontic therapy (Fig. 8).

Clinical studies have shown the benefits of an endo-laser protocol in apical periodontitis treatment. For endodontic treatment, laser protocol is a combination of standard treatment strategies associating cleaning and shaping the root canal with a minimal adequate shape up to #35, irrigant solutions with antibacterial properties and intra-canal laser irradiation using controlled parameters of energy. Ideal sealing of the root canal and adequate coronal restoration are needed for an optimal result.

In practice, little additional time is required
for laser treatment. Irradiation technique is simple once flexible optical fibers of 200 µm in diameter are used. The fiber can easily reach the apical third of the root canal, even in curved molars (Fig. 9). The released laser energy has an effect in dentin layers and beyond the apex in the periapical region. The laser’s effect is applicable in inaccessible areas, such as external biofilm adhered at the root apex.

Irradiation technique must follow basic principles. A humid root canal is required and rotary movements from the coronal portion to the apex should be carried out, as well as scanning the root canal walls in contact mode (Fig. 10). The power settings and irradiation mode depend on one’s choice of a specific wavelength.

Nd:YAG, diodes in different wavelength emissions, Er:YAG, Er:Cr:YSGG and low-power lasers can be used for different procedures with acceptable results. Laser technology in dentistry is a reality. The development of specific delivery systems and the evolution of lasers combined with a better understanding of laser-tissue interaction increase the opportunities and indications in the endodontic field. _

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Technology-enhanced caries detection and treatment options

Abstract

Here we present a case report illustrating technology-enhanced caries detection and treatment systems on occlusal surfaces during a 26-month follow-up. The use of ozone therapy and a laser-induced fluorescence device on incipient occlusal caries lesions in a 25-year-old woman is described. The utilization of the ozone therapy monitored by the laser-induced fluorescence device enabled an alternative and comfortable treatment for incipient caries lesions on occlusal surfaces. Thus, technology-enhanced caries detection and treatment systems are helpful tools during clinical practice.

Introduction

Although the prevalence of dental caries in children has declined in the past several decades, there has been a continuing increase in occlusal caries. This fact may be explained by the changes in caries pattern and progression. Additionally, this may be due to the increased use of fluoride and its superficial remineralization, which seems to delay the cavitation (Strassler and Sensi 2008). In this way, incipient occlusal caries have become more difficult to detect.

The difficulty in diagnosing incipient caries has stimulated the development of new detection methods. Recently, new methods have become available as adjuncts to traditional methods, such as the fluorescence-based devices. These are based on the phenomenon that caries lesions fluoresce more strongly than sound tissues when stimulated by light at specific excitation wavelengths (Hibst et al. 2001, Bader and Sugars 2004). The most common laser-induced fluorescence device for caries detection used in dentistry is DIAGNOdent (laser-induced fluorescence [LF], DIAGNOdent 2095, KaVo, Biberach, Germany). This device emits a red light at 655 nm and quantifies the fluorescence from bacterial porphy-

Figs. 1a–c. Baseline clinical aspect of the incipient caries lesions on tooth #16 (Fig. 1a), tooth #26 (Fig. 1b) and tooth #46 (Fig. 1c). Note that all teeth presented brown and white opacities on the fissures.
The changes in the fluorescence intensity are numerically quantified and translated into values ranging from 0 to 99, according to the lesion’s depth. This can be used to help clinicians decide whether a tooth should be restored (Young 2002). The device has been used as an auxiliary to detect and quantify mineral loss in caries lesions on smooth and occlusal surfaces, presenting good reproducibility and accuracy (Lussi et al. 1999, Lussi et al. 2001, Mendes et al. 2006, Rodrigues et al. 2008, Diniz et al. 2009).

It is important to point out that the management of dental caries is based on appropriate detection of pathological changes and, consequently, on the correct diagnosis to provide the best treatment for each patient (Tranaeus et al. 2005).

Recently, a novel concept for the treatment of dental caries using ozone gas as a potent microbicide has been introduced (Baysan et al. 2000, Baysan and Lynch 2004, Dähnhardt et al. 2006, Baysan and Beighton 2007). Ozone is a gas that quickly kills microorganisms by oxidative degradation of the unsaturated fatty acids in the cell wall (Dähnhardt et al. 2006). The device delivers ozone, through a handpiece, directly to the carious lesion in a concentration of 2,100 ppm with a changeover of 300 times per second. A silicon cup is able to tightly seal the covered area (Baysan et al. 2000). Previous reports have assessed the effect of ozone gas on occlusal caries, non-cavitated occlusal caries and primary root caries, showing significant reductions in the number of microorganisms (Baysan et al. 2000, Brazzelli et al. 2006, Baysan and Beighton 2007). However, the inhibitory effect of ozone in the caries process is discussed and is controversial (Hauser-Gerspach et al., 2009; Kronenberg et al., 2009).

To date, there are some clinical studies evaluating improvements in the clinical status of non-cavitated occlusal caries and root caries after ozone therapy monitored by the laser-induced fluorescence device (Huth et al. 2005, Baysan and Lynch 2007). This clinical report illustrates the application of ozone therapy (and monitoring using the laser-induced fluorescence device) on incipient caries on occlusal surfaces in a young woman during a 26-month follow-up.

**Case report**

A 25-year-old Caucasian woman was referred to
the clinic of the preventive, restorative and pediatric dentistry department of the Dental School of Bern, Switzerland, presenting incipient caries lesions.

During the clinical interview, the patient reported that she presented a normal systemic status. The caries risk assessment indicated that she was at low risk.

Visual examination was performed by direct visualization of the teeth with the aid of a light reflector and a three-in-one air syringe. The patient presented incipient caries lesions on the distal fossae upper right first molar (16), on the distal fossae upper left first molar (26) and on the central fossae lower right first molar (46) (Fig. 1). The visual and tactile characteristics observed were the presence of brown and white opacities and roughness on the fissures, indicating caries activity.

Bitewing radiographs were taken and then analyzed using an X-ray viewer. No radiolucency was observed in the occlusal surfaces.

Based on clinical and radiographic observations, and considering anamnesis data, the treatment proposed was ozone therapy application (to reduce the microflora in the lesion) monitored by laser-induced fluorescence readings. The patient was instructed with respect to the maintenance of her oral hygiene. The patient signed an informed consent contract, agreeing to the treatment.

The laser-induce fluorescence device used was the DIAGNOdent 2095 (KaVo, Biberach, Germany). The occlusal surfaces were measured according to the manufacturer’s instructions (Fig. 2). The device was first calibrated using a ceramic standard and then calibrated on the buccal surface of the right permanent central incisor. For measurements, tip A for occlusal surfaces was used. The device was moved through the entire occlusal surface until the highest value was obtained (peak value).

The ozone device used was the HealOzone delivery system (Ozone therapy [Oz]; KaVo, Biberach, Germany). Ozone was applied on each tooth at room temperature according to the manufacturer’s instructions (Fig. 3).

In each session, the occlusal surface of each tooth was cleaned for 10 seconds with a water-powder jet cleaner (PROPHYflex II, KaVo, Biberach, Germany) and sodium hydrogen carbonate powder. Then the caries status was measured by the LF device, and ozone was used after carefully drying the occlusal surface. The visual characteristics of the lesions were evaluated and considered as gold standards during the monitoring.

The 26-month follow-up was performed according to Tab. 1. The LF device was checked and calibrated before each session. The ozone device was also checked on a regular basis. During the first recall visit, it was observed that the laser-induced fluorescence readings were lower than the baseline readings, indicating that 40 seconds of ozone therapy in each tooth was effective. However, after 10 months of follow up, the laser-fluorescence readings were higher than the baseline readings. In view of this fact, the time of the ozone therapy was increased to 80 seconds. After 26 months of follow up, a good response to the treatment was observed by the changes in clinical severity and in the LF readings (Figs. 4, 5).

**Discussion**

Ozone therapy was introduced as a conservative treatment for caries. The changes observed in the clinical aspect of the lesions over time (Figs. 4a, 4b, 4c) indicate the effectiveness of the treatment.
alternative in the treatment of primary caries, resulting in the in vivo reduction of the number of microorganisms present in lesions by 99 percent (Baysan and Lynch 2005, Baysan and Lynch 2006). The purpose of ozone therapy is to reduce the microflora in the lesion, to increase its pH and to oxidize pyruvic acid to acetate and CO₂, which opens up “channels” within the dentin to allow the penetration of calcium, phosphate and fluoride ions. This makes remineralization of the demineralized hard tissue possible (Dähnhardt et al. 2006, Hodson and Dunne 2007).

A significant reduction in the clinical status of small and non-cavitated occlusal caries lesions after ozone therapy has been reported (Huth et al. 2005). In the present case, we clinically observed that the incipient lesions arrested after 26 months of follow-up, indicating that ozone therapy remineralized lesions over time. However, the treatment adopted in this case was better achieved when the ozone therapy was applied for 80 seconds on each tooth compared to 40 seconds. Polydorou et al. (2006) evaluated the antibacterial activity of 40- and 80-second HealOzone application. The authors concluded that the 80 second ozone application is a very promising therapy for eliminating residual microorganisms in deep cavities.

This case report shows it is possible to treat incipient caries lesions using an ozone-delivering device monitored by laser-induced fluorescence. The treated caries showed lower readings compared to the baseline, indicating that the ozone therapy was successful. At the first recall visit, the LF readings were substantially reduced for teeth #26 and #46. This is in accordance with Dähnhardt et al. (2006), who observed that the use of ozone gas results in an average reduction of 13 percent of the laser fluorescence values immediately after ozone therapy.

In the present case, the clinical characteristics and severity of the carious lesions changed over time, indicating that the treatment was effective. Recently, an in vivo study compared the performance of the LF device to visual and radiographic examination (Diniz et al. 2009). The authors concluded that the LF device may be a useful complement to visual examination, and its diagnostic performance seems to be superior for dentin caries detection.

The same result was also observed by a systematic review (Bader and Shugars 2004) that showed laser-induced fluorescence tended to be more sensitive than the visual method in detecting occlusal caries in dentin and less sensitive in detecting enamel caries. The case presented in this paper was monitored by visual examination as an adjunct to visual examination because the LF device is supposed to be an auxiliary method for occlusal caries detection.

It is also important to consider that confounding factors might contribute to false-positive laser-induced fluorescence readings in clinical practice, such as the presence of stains, calculus, hypoplasia, polishing pastes and filling materials (Neuhaus et al. 2009). For this reason, a prophylaxis procedure was done on the occlusal surface of each tooth in each session to avoid possible false-positive readings.

While in this case report it was possible to monitor the caries status after ozone therapy by laser-induced fluorescence, there are some important aspects that clinicians should consider regarding this procedure.

For instance, ozone has not been proven superior to other clinical approaches in caries management, such as fluoride or chlorhexidine, sealants and stepwise excavation (Hodson and Dunne 2007). It may work better than these approaches, work well in
combination with these approaches or may prove to be entirely unnecessary (Hodson and Dunne 2007).

In a systematic review of the literature by Rickard et al. (2004), there was no reliable evidence that the application of ozone gas to the surface of decayed teeth stops or reverses the decay process.

The authors emphasized the need for more evidence of appropriate strictness and quality before the use of ozone can be accepted into primary dental care or can be considered a viable alternative to current methods for the management and treatment of dental caries. Additionally, the laser-induced fluorescence device should be considered as a second opinion because, to date, there is no method available that is completely reliable.

_**Conclusions**_

The utilization of ozone therapy monitored by laser-induced fluorescence enabled an alternative and comfortable treatment for incipient caries lesions on occlusal surfaces. However, the ozone therapy parameters and cost effectiveness is unknown. It should be recommended to increase the exposure time during the ozone therapy to achieve a better outcome.

In addition, the laser-induce fluorescence device cannot be considered a standard diagnostic tool by itself. It should be used as an adjunct to the traditional methods, especially considering important patient factors, such as caries risk, caries activity, oral hygiene, diet and fluoride supplements.

_**References**_


_A complete list of references is available from the publisher._
Surface analysis of Erbium:YAG laser etching vs. acid-etched surface

ESEM observations in vitro study

Authors: Roheet Khatavkar, BDS, and Dr. Vivek Hegde, MDS

Summary

The aim of this study was to compare the effect of conventional acid etching with 37 percent phosphoric acid and an Er:YAG laser (non-contact mode) on surface changes in enamel.

Materials and methods

A total of 50 non-carious extracted human teeth were collected for the study. The teeth were divided into five groups wherein one set of teeth was acid etched for 30 seconds with 37 percent phosphoric acid and four groups were laser-ablated with an energy output of 50, 75, 100, and 150 mJ using an Er:YAG (2,940 nm wavelength) laser in non-contact mode. Micro-morphological effects were evaluated using an environmental scanning electron microscope (ESEM) for change in the structure of enamel.

Fig. 1a. Low-power magnification (100x) image of enamel surface lased at 50 mJ and 15 Hz showing definite surface changes.

Fig. 1b. High-power magnification (2000x) image showing micro-roughened surface.
Results

The following observations were made: a comparison between acid-etching and laser treatment effects on tooth surface and smear layer for each group.

The ESEM evaluation showed that increasing the energy parameters showed a difference in the surface morphology of enamel from roughening to an etching-like micro-roughened pattern. Certain laser-treated teeth showed better micro-retentive features as compared to acid-etching.

Conclusion

Laser-treatment for providing a micro-retentive surface is a viable option that can be chosen. The Er:YAG laser energy levels that provide a comparable effect to acid-etching were also noted.

Introduction

Hard-tissue lasers were introduced in dentistry nearly 20 years ago and a number of wavelengths have been tried and experimented upon for ablation of hard tissue, including enamel, dentin, cementum and bone. Laser delivery devices today have a number of parameters that can be modified by the clinician to obtain the desired results.

These include minor variables such as water and air, and major variables such as pulse mode, frequency and energy output.

With respect to pulse duration (the duration of a pulse) there are five options available, namely, very long pulse (VLP = 1,000µs), long pulse (LP = 600µs), short pulse (SP = 300µs), very short pulse (VSP = 100 µs) and super short pulse (SSP = 50µs). Also, frequency (the number of pulses per second) can be modified.

Energy output can also be varied depending upon a requirement of high or low energy levels. And also the power, which is a product of the energy output and frequency changes. It has been shown through a number of studies that the Er:YAG laser is an effective tool in cavity preparation etching and removal of caries from enamel and dentin.

In the numerous hard-tissue applications that lasers have been used for, it has been suggested that lasers cause a surface etching effect that is comparable to conventional acid etching.

This study aimed to analyze the changes in the ultrastructure of human enamel resulting from simulated cavity preparation by an Er:YAG laser, and to investigate the optimal parameters of that laser for ablating enamel for etching with a VSP and variable energy outputs (EO), but repetition rates (RPR) were kept constant and compared with the surface characteristic of an acid-etched surface.

Materials and methods

Selection of samples

A total of 50 non-curious extracted maxillary human premolars were collected for the study. The teeth were washed in normal saline and gross calculus was removed using an ultrasonic scaler.
The teeth were stored in normal saline at room temperature until treated.

**Preparation of samples**

The cervical third of the buccal surface of each tooth was subjected to 15 seconds with an Er:YAG laser (Fotona Fidelis III Plus, Fotona d.d., Slovenia) at a 2,940 nm wavelength. A circular area of 2 mm in diameter (+ 0.25 mm) was prepared using the laser in non-contact mode at a distance of approximately 7 mm from the tooth surface, and set at different energy parameters.

Keeping the frequency constant at 15 Hz, the energy output was varied from 50 mJ, 75 mJ, 100 mJ and 150 mJ. The power reading on the laser device was also increased accordingly. The water and air were kept constant at a value of six each. Ten samples were also etched with the conventional method of 37 percent phosphoric acid (3M ESPE, USA) for a period of 15 seconds. Following preparation of the samples with the prescribed parameters (Table 1) the teeth were subjected to ESEM analysis.

**ESEM evaluation**

Micromorphological effects were evaluated on enamel using an ESEM at a magnification of 100x and 2,000x, wherein we noted the effects of the laser on the enamel surface and smear layer for each setting.

Comparison between the laser-etched and 37 percent phosphoric acid-etched samples, and the ideal parameters for laser etching compared to conventional acid etching.

The advantage of the ESEM over the scanning electron microscope (SEM) is that the sample does not have to go through any processing; it can directly be placed into the microscope, thereby avoiding drying of the specimens during processing.

**Results**

The effects of the laser application on the enamel as observed with the ESEM were as follows.

**50 mJ**

A definite change in the surface of the enamel was noted at low power magnification (100x) as compared to the adjacent sound enamel. However, at a higher power magnification, the circular laser-treated area showed only a superficial roughness without the presence of a micro-retentive surface. (Fig. 1)

**75 mJ**

The circular path followed by the laser beam was clearly visible on the 100x magnification. Slot-type pattern of enamel ablation is seen in the 2,000x magnification indicating selective ablation of the enamel prisms occurring over the lased surface. The lased surface showed a definite micro-retentive surface with presence of elevations and depressions (Fig. 2).

**100 mJ**

Lower magnification showed the superficial...
layer of enamel that melted and flowed in the direction of the laser beam. Higher magnification revealed the melting and partial recrystallization of the enamel prisms (Fig. 3).

150 mJ

When lased at 150 mJ, there was a saucer-like cavitation seen on the surface. Higher magnification showed molten and partially coalesced structures instead of the prismatic pattern of enamel, and a number of microcracks were also noted on the laser treated surface (Fig. 4).

37 percent phosphoric acid-etched surface

The acid-etched surface seen at a high power magnification clearly showed the presence of the key-hole pattern of enamel with a type III etching pattern. This showed a uniform micro-retentive surface over the etched area (Fig. 5).

Discussion

An evaluation of all the laser-treated groups revealed that the lased surfaces were free of any smear layer, indicating a good surface for bonding. However, the morphology of the lased enamel showed a large variation as the energy output was increased.

Excessive energy parameters did not give the same results in all the samples because of the presence of induced alterations resulting from the thermal effect.

Higher energy values were shown to change the structure of the enamel prisms. The changes in the inherent structure of the enamel prism followed this order: microroughness, micro-retentive areas, reorganization and recrystallization of enamel prisms and microcracks.

A micro-roughened surface was observed at a low energy output level of 50 mJ, however, the depth of the roughened areas seemed lesser as compared to the higher energy output of 75 mJ.

The ultra-structural appearance of enamel lased at 75 mJ was similar to that of conventionally etched enamel with 37 percent phosphoric acid. However, the etched surface showed a non-specific, mixed-type pattern of the rods and prisms as opposed to a uniform type III pattern seen with an acid-etched surface. Clinically, the advantage of laser etching over a conventional bur is that a debris-free, smear-free and oil-free surface is obtained.

The Er:YAG laser has also been shown to have anti-bacterial properties. The taste of phosphoric acid may also not be well accepted by the patients, hence laser etching would be a better option.

Conclusion

Through this study we have concluded that lasers definitely can be used as an alternative to conventional procedures. We concluded that the correct parameter of energy level has to be chosen to get the desired result for bonding procedures. We also inferred that 75 mJ of energy output with 15 mJ frequency provided a micro-retentive surface that was comparable to a 37 percent phosphoric acid-etched surface.

These results are based on the surface changes that have been seen on the enamel only and may not be indicative of the bonding ability of the lased surface to composite resins. Hence, studies should be carried out to compare the bond strengths of the various surfaces.
lased and acid-etched surfaces to validate the etching effect of the Erbium:YAG laser.

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Dental lasers have been called many things — “game changer,” “the standard of care,” “a miracle product” — and they are the hottest products in dentistry. It seems you can’t open a magazine or listen to a lecture without hearing about lasers. The guy who is seems to be behind all the buzz is Alan Miller, president and CEO of AMD LASERS. I caught up with Miller for a rare inside look at his company’s success — and the future of laser technology.

“Mr. Miller, you came on the scene it seems like only two years ago. Nobody had ever heard of AMD LASERS, and now you have become a household name in the dental community. How did you accomplish this task?”

I guess you can say a lot of planning and a little luck. Launching a product in an economy that just had a meltdown can be a blessing or a curse. I have spent a decade in the promotion of laser technology and knew through the success of National Laser Technology, my aftermarket laser reselling and servicing company, that AMD LASERS would be an instant hit. There was a definite need in the market for affordable laser technology, and AMD LASERS filled that market gap by creating a high-quality dental laser at an affordable price point.

“At the time, most every other soft-tissue laser was selling between $12,000 and $20,000. How is possible for you to sell a quality product at $2,500?”

I applied several successful business practices into an innovative product design — Picasso. High quantity parts purchasing drives down pricing and unique internal designs reduced the labor load. Quite frankly, I priced the lasers to make a profit but not to gouge the dentists. Gouging is still the standard practice by most companies, and it really became apparent when they started reducing their prices by more than 50 percent.

“Two years have passed, and the Picasso line of dental lasers are No. 1 in the world. So where do you go from here? We have been busy working on the next generation
of soft tissue lasers, which are absolutely mind-boggling in their design. We have been focusing all of our efforts into “Experience AMD,” which simply means, the experience across every touch point that a potential or current client has with our brand. We strive to provide a memorable and engaging experience to anyone, whether it’s over the phone, at a tradeshow, or through our traditional and digital marketing efforts. It is our hope that these clinicians share their experiences with colleagues, family and friends. Our commitment to this level of service will play a huge role for us in the future.

Our iPad® laser app has been a huge success, and we have also started multi-city, hands-on laser educational workshops. We are also launching our new, all-tissue laser this year and have a number (no I am not going to tell you how many) of new hygiene, perio and surgical lasers with multiple wavelengths also launching this year.

Well there you have it everyone, some great exciting new products and services will be coming your way from AMD LASERS. Thank you, Mr. Miller, for your time.
Putting on my design engineer and marketing hat, I thought this was a good time to take a look at what's being offered with the new soft-tissue dentistry lasers and decided to be innovative and design something really low cost and cutting edge that addresses any outstanding issues (Fig. 1).

There are many choices right now, all pretty much the same, except for price, which as of late has become a deciding factor. Below the $2,500 price point, the door is open to purchase two or three lasers for the price of one, which is great news for dentists and hygienists.

Addressing the most important requirements in order, let's start with power. Due to the physical nature of diode degradation over time, and the need to have some overhead, I believe that anything below 3 watts will not give you enough margin in the long term. It's been easy so far to price 2 watt or even 2.5 watt lasers at lower price points.

If you do the math, you will see that from a power perspective, and considering the current pricing structure, for low-cost lasers with less than 3 watts, you should add at least $500 to the base price for every one half watt difference so it is equal to a 3-watt system.

In my opinion, having a 3-watt system is very important. This is where warranty really matters; anything less than three years is not adequate insurance. The diode array is the most expensive part of the laser and the component that will always fail first, especially when driven harder. An extended warranty option is best.

Another important question is what's most effective, 810 nm or 980 nm? Diode wavelength will be debated forever depending on whom you're talking to. What is not debatable is the cost road map for higher power. With 810 nm, the cost really goes up quickly, just compare the price of higher watt 810 nm lasers and you will easily see what I mean. This is not the case with 980 nm, which can be scaled up past 10 watts at a very reasonable cost ratio. Laser Dental, however, does offer its new laser in 810 nm or 980 nm.

One might ask, why not just buy a higher watt laser? This is a good question because that extra power costs a lot more. The risk of tissue damage from incorrect settings or thermal run always increase greatly, especially when metal cannulas or tips are used.

Engineered copolymer tips designed just for laser dentistry are the best choice. Laser Glow Tips bend your fibers 90 degrees and minimize tip failures (Fig. 2).

The other area I find of interest is what I call "bells and whistles." These are things such as wireless foot pedals, battery-powered lasers, touch screens and...
presets. In my opinion, these are nice to have but fall under the heading “more complexity translates into more to go wrong.”

Foot pedals could potentially fail to transmit, batteries are heavy and die at critical times, touch screens sometimes don’t respond to touch. A more cost-effective plan would be an extra hard-wired foot pedal and AC plugs in every treatment room.

Presets are nice, but most professionals have taken top-notch training and will have their own preference settings. After all, what happens with presets when you encounter something not cookbook? You adjust based on experience, so bottom line is, the less buttons to push the more reliable your system, which means more control.

The big move in the last three years has come in the form of pre-bent tips. These are plastic tips with a piece of fiber at a fixed length and angle that attach to a handpiece. These seem convenient but have some big drawbacks, including power loss, price and the number of tips required to do a procedure.

These single-use tips cost $5 to $10 each, and if you need to make a length or angle change during the procedure, another tip is required. Therefore, the potential exists that you need two or three tips per procedure or, in real dollar terms, up to $15 per procedure.

Consider this against the cost of the old style flexible fiber system. The costs are $1 per procedure, and you get length and angle adjustment on the fly using laser glow tips.

Another major drawback to these pre-bent tip systems is that most handpieces and connecting cables cannot be autoclaved, only wiped down. Herein exists a potential contamination problem.

I decided to innovate and designed Laser Dental’s newest handpiece cable assembly so that it attaches to most lasers, costs only $3.75 per procedure and can be autoclaved. It has the capability of length and angle adjustment on the fly in a very compact package. That’s right, $3.75 per procedure, not $5 to $15 like everyone else (Fig. 3).

Our laser also use standard fiber connectors, not special ones that are becoming obsolete. This translates into even more choices and does not lock your laser consumables into one manufacturer.

Last, but not least, is size. It does matter, but in this case smaller is better. Tiny footprints look better, weigh less and take up less space in each room.

Well, that’s my take on all of this, and in the end, I have always found simpler is better. Thus, we designed our new laser so that it is very low priced, with 3 full watts at either 810nm or 980 nm and has a minimum of bells and whistles plus lots of flexibility.

When you combine this laser with the new multi-use tip package now available, you really have chosen not to paint your practice into a corner. Now you have a real choice when purchasing a reliable, U.S.-manufactured, low-cost soft-tissue laser. In other words, take a long look at the Prometey™ Mini Laser and you will look no further (Fig. 1). _

Fig. 2. Laser flow tips.  
Fig. 3. Handpiece.

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Laser Dental Innovations specializes in the design of innovative and cost-effective products for laser dentistry since 1999. The company offers products directly to clinicians and partners with the best clinicians, trainers and laser dentistry leaders. The company’s corporate philosophy is simple: We design what you need, not what we think you want. Laser dentistry is what we do.
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