Laser phototherapy (LPT) in dentistry

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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 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.

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 Goldman3 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.4–8 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.9

**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 demonstrated9 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-κB) 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
The biologic effects of LPT are not based upon heat 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. 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. 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 $50 \times 20 = 1,000$ 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 cm², then the 1 J in the example above becomes 1 divided by 0.25 = 4 J/cm². If the probe is held at a short distance and the divergence of the beam makes the light cover an area of 1 cm², then the dose becomes 1 divided by 1, equals 1 J/cm².

These examples simply show that when the energy...
Fig. 8. The same effect from Nd:YAG irradiation. (Photo/Provided by Ambrose Chan)

(J) is concentrated onto a smaller area, the intensity increases. This is the same effect that we observe when we change our large curing light probe to a "turbo" tip with a smaller end tip.

The clinical importance of understanding the difference between energy and dose must be underlined. The biological effects between applying 1 J with a fiber of 0.5 cm² and 0.1 cm² are quite different. To obtain cell proliferation and reduction of the inflammatory process, low power and longer exposure time is more effective than high power and shorter exposure time, although the same energy is applied.

Acute pain, on the other hand, is a matter of inhibition and here stronger lasers can be used to advantage. It must also be kept in mind that the energy (J) as well as the dose (J/cm²) are independent parameters and both have to be within the therapeutic window.

Penetration

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. Optimally the irradiation should start during the surgery and continue during the first two weeks.
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Figs. 9, 10 Extraction wound healing at 24 hours after 660 nm irradiation. (Photo/Provided by Talat Qadri)

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.16, 19

_Dentinal hypersensitivity_

Several studies20–25 have been published regarding the effect of laser phototherapy for dentinal 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.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.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.85 The pain after cryosurgery of leukoplakias is reported to be reduced by the subsequent application of LPT.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.29–34 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.25

Intraoral irradiation is rather time consuming and extraoral application via red LED arrays36 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 treatment37, but it is reported that even long-standing aberrations can be influenced.38–42

_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.43–46 Irradiation of the involved lymph nodes is recommended for all oral pathologic conditions as an adjunctive therapy to local irradiation.

**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.47–51,55 Trigeminal neuralgia and post herpetic neuralgia are two indications suitable for LPT. The laser therapy is not likely to cure trigeminal neuralgia, but will facilitate a reduction of Carbamazepine intake.

**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.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.76

**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.59–62 Similar results have been seen for smokers and non-smokers.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.

**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.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.

**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
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.

The therapeutic window

Given the information above, it may appear to be very difficult to find the proper parameters to achieve a stimulative effect. However, like all modalities, LPT follows the Arndt-Schultz law. This means that too small a stimulation elicits no reaction and too high a stimulation elicits an inhibition. Fortunately, the "therapeutic window" between these extremes is fairly wide in LPT. Still, a reasonable knowledge about the various parameters involved in LPT is necessary to obtain consistent clinical results.

Documentation

There is extensive literature on the biological effects of laser light. About 4,000 studies have been published since the mid ’60s and about 10 percent of these are dental related. The quality varies a lot but has improved considerably during the last decade. The question these days is no longer whether LPT works or not, but rather how it works and which are the optimal parameters for the various conditions.

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.