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 annually published 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 the 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 theoretically can 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 sceptical 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 ef-

Fig. 1_A theoretical description of the effects of a strong laser beam. Courtesy: Edson Nagib.
Fig. 2_Red laser light penetration through dry bone.
Figs. 3a & b_HSV-1 blister on day 1 and 2.

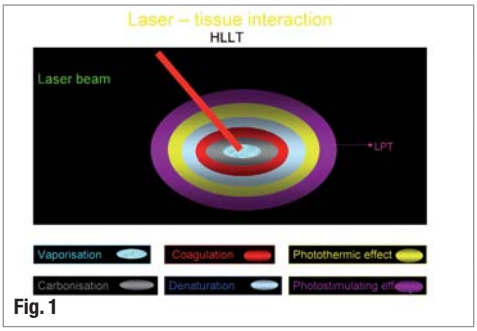


Fig. 1


Fig. 2


Fig. 3a


Fig. 3b


Fig. 4a


Fig. 4b

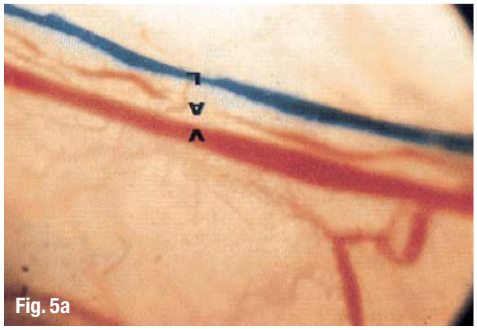
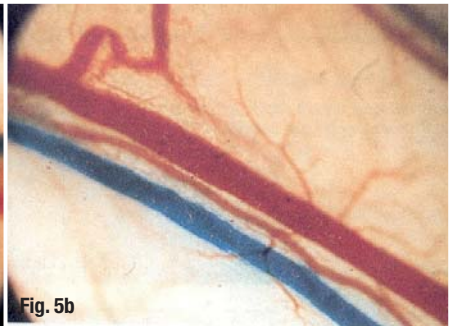


Fig. 5a


Fig. 5b

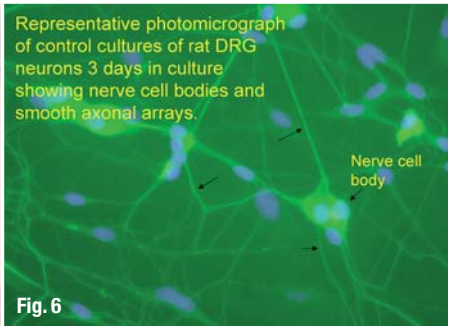


Fig. 6

forts. "Low power laser", "Low level laser, 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 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. This stimulatory effect of "surgical" laser is not new. Already in 1980 Goldman[3] published a report about the use of Nd:YAG laser for arthritis. The Er:YAG laser is a more recent laser and up till now only a few studies have been published using this laser for a priori laser phototherapy

_Contra indications

There are no known absolute contraindications for LPT but several relative contraindications and caveats. Areas of malignancies or suspected malignancies must be avoided due to insufficient knowledge at the present time. For the same reason 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 on 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] Old literature mentions patients wearing pacemakers as a contraindication, but this is clearly a misunderstanding.

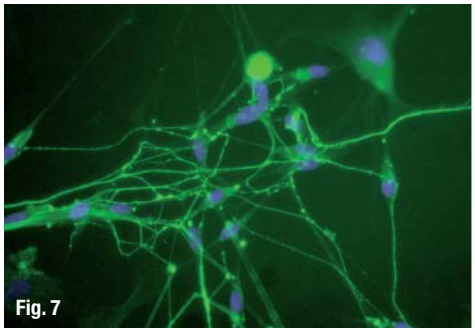
_Safety

Therapeutic lasers are considered as safe by the US Federal Drug Administration. The only known hazard is the risk of eye injuries and it is recommended that patients wear protective goggles, 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 laser were initially mimicking the safety regulations for surgical lasers but the levels of risk are certainly very different. Indeed, the use of therapeutic laser 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, the termi-

Figs. 4a & b_Mucositis after 6 days of radiation started, result after 6 days. Courtesy: Alyne Simoes.
Figs. 5a & b_Effects on artery, vein and lymph vessels of 904 nm laser. Courtesy: Pierre Lievens.
Figs. 6 & 7_Axons in vitro before and after 830 nm laser irradiation. Courtesy: Roberta Chow. Full stop in analogy with the above.


Fig. 7

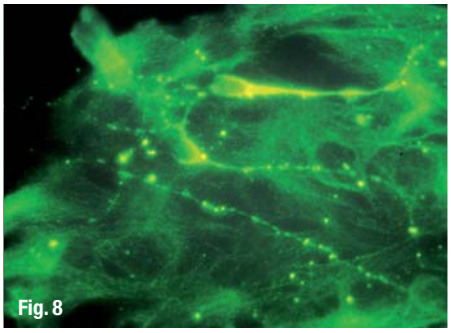

Fig. 8


Fig. 9

Fig. 8_The same effect from Nd:YAG irradiation. Courtesy: Ambrose Chan.
Figs. 9 & 10_Extraction wound healing in 24 hrs after 660 nm irradiation. Courtesy: Talat Qadri.

nal enzyme of the Kreb's cycle. The basic irradiation changes generate a cascade of secondary and tertiary events, which are complicated and difficult to study, especially since 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. The basics of LPT are extensively described by Karu in the book "Ten Lectures on Basic Science of Laser Phototherapy".[10]

_The wavelengths

Therapeutic lasers generally operate in the wavelength range of 630–980 nanometers (nm). Output powers can be anything from 10 to 500 mW. 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 just to indicate the wavelength, since 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.

_Dosage

Practitioners often find the issue of dosage complicated, since 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 x 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 we from a semantic point of view 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 preferrably with superscript 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. The above examples simply show that when the energy (J) is concentrated to 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 fibre of 0.5 cm^2 and 0.1 cm^2 are quite different.

_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 de-


Fig. 10


Fig. 11a


Fig. 11b

Figs. 11 & 12_Necrotic frozen fingers tips treated with red laser for five sessions.

sired target area and the clinician needs to understand these to obtain good results.

_Some indications for dental LPT

Laser acupuncture

Few dentists are trained in acupuncture but there are some safe points which could be used at advantage, e.g. the P6 on the wrist, useful to reducing gagging. fMRI studies have confirmed that laser and needles actually have similar, although not identical effects.[11, 12]

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.[13–17]

Caries

A cavity or crown preparation is a burden for the pulp. LPT applied after preparation and before cementation can save a lot of postop problems and potential endodontic work.[18, 19]

Dentinal hypersensitivity

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

Herpes Simplex (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 till 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 to advantage can be treated even in the silent periods. In spite of few available clinical studies this therapy appears to be safe and effective.[26–28]

Mucositis

Mucositis is an inevitable follower of radiation and chemotherapy. LPT has been documented as an effective method to reduce pain and incidence of mucositis[29–34], not full stops. 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/chemo therapy, since LPT has a radio protective effect.[35] Intra oral irradiation is rather time consuming and extra oral application via red LED arrays[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[37] 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 and can also stimulate lymph ves-


Fig. 12


Fig. 13


Fig. 14


Fig. 15

Figs. 12 & 13_ Non-healing angular cheilitis treated daily for one week.
Figs. 14 & 15_The same patient had a non healing ear wound. Also treated for one week.

sel 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 reduce the period of inflammation, but the dose window for this is lower than that of immediate pain reduction. LPT stimulates opoid precursors and causes transient axonal vesicles which reduce neural transmission.[47–51]Trigeminal neuralgia[52] and post herpetic neuralgia[53, 54] are two indications suitable for LPT. The neuralgia therapy is not likely to cure a 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 a finished orthodontic therapy. This phenomenon is in acc. 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.

_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] Irradiation in connection with SRP reduces postoperative pain and discomfort but several irradiations are needed to produce good 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.

_Temporomandibular joint disorders (TMD)

TMD can be either arthrogenic, myogenic or both in combinations. The effect of LPT on arthritic conditions is well investigated and there is some evidence of an effect of myogenic pain and trismus. For arthrogenic conditions low doses are required whereas myogenic conditions require infrared laser and high dosage. The pain and spasm relieving effects are fast and a condition of trismus[63] can be resolved or improved within minutes. Since the occipital and neck muscles are frequently involved in TMD, the laser will add benefits for the dentist and patient. Patients having 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.[64–66]

_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. The best clinical effects are also seen in long-standing wounds where traditional therapies have failed.[67, 68]

_Other indications

The above mentioned indications are some of the major ones but since LPT has an effect on hardly any pathological condition, the list could be much longer. These would not only be purely "dental". 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 less dental-related problems, as shown by the cases below.

_The therapeutic window

From the 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 above mentioned 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.

_The documentation

There is an extensive literature on the biological effects of laser light. About 4,000 studies have been published since the mid 60ies; about 10 % 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, since the thermal lasers also have biostimulative qualities. This article presents a general overview of the therapeutic lasers and presents some of the mechanisms and examples of clinical indications useful in dentistry.

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Editorial note: The whole literature list can be requested from the editorial office.

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