Inasmuch as there is distinction between the various laser wavelengths used in dentistry and oral surgery, there is also a demarcation between the broad levels of interaction of lasers and target tissue. The adjectives “hard” and “soft” relate, not to the type of tissue exposed, but to the type of interaction. Laser-tissue interaction is dependent upon wavelength, tissue type, power (incident energy), and time. Where the effect is ablative (essentially photothermic), direct and primary, such lasers are termed “hard.” Alternatively, where tissue effects are non-direct and through secondary (essentially biostimulatory), intermediate action, such lasers are termed “soft.” This group also can be termed Low-Level Lasers.

Dental clinicians, in their role as providers of primary oral care, have generally enjoyed the position of delivering treatment to their patients in a positive, interactive, and often immediate form. This is unlike their medical practitioner counterparts, who often employ indirect treatment, e.g., drug therapy and referral. Laser development in dentistry, in common with other treatment modalities, has had to contend with the expectations of the Profession and so it is understandable that the uptake of soft lasers has been so poor.

The use of low-intensity laser radiation for therapy was pioneered by Endre Mester in Hungary in the late 1960s and independently by Friedrich Plog in Canada. In many parts of the world, but certainly outside the United States, LLLT has been applied in physiotherapy, in the treatment of wound healing, soft and hard tissue inflammation, and pain relief. It has also been employed in the field of veterinary surgery in similar clinical circumstances.

The two major areas of action of LLLT are in biostimulation and photodynamic therapy.

**Biostimulation**

Living tissue subjected to an ascending thermal gradient will undergo a succession of warming, coagulation (protein base), vaporisation (water base) and finally, carbonisation (all tissue). This thermal gradient effect is seen when cutting (hard) lasers are used, the effect being essentially dependent upon power and time of exposure. With LLLT, the energies used being smaller and over greater tissue areas, the tissue effects are essentially photochemical and photobiological, and are seen through selected increased cellular activity (see below).

Studies carried out on tissue response to LLLT cite responses as follows:

- proliferation of macrophages (1)
- proliferation of lymphocytes (2)
- proliferation of fibroblasts (3)
- proliferation of endothelial cells (4)
- proliferation of keratinocytes (5)
- increased cell respiration and adenosine triphosphate (ATP) synthesis (6, 7)
- release of growth factors and other cytokines (1, 5, 8)
- transformation of fibroblasts into myofibroblasts (9)
- collagen synthesis (10).

It can be appreciated that the above represents local tissue activity consequent upon physical injury and the acceleration of these actions through LLLT could justify their claimed therapeutic use.

Historically, the major wavelength used in LLLT has been Helium-Neon (633 nm), although the major wavelength used nowadays is GaAlAs (880 nm). Other wavelengths have been used, either commercially or experimentally, such as GaAs, argon, car...
bon dioxide. It is essential that the power density of the incident beam is controlled, in order that maximum therapeutic benefit can be gained. In a recent study (11), hamster ovarian cells were subjected to various incident energy levels with the following results:

-  < 60 mJ/cm² — zero bioactivation
-  120 - 240 mJ/cm² — biostimulation
-  240 - 300 mJ/cm² — zero bioactivation
-  300 - 600 mJ/cm² — bioinhibition

(release of cellular singlet oxygen).

The biostimulatory range has been found to compare favourably with other studies carried out on human fibroblasts (11).

Consequently, the use of LLLT in a biostimulatory role in dentistry may prove beneficial in the treatment of the following:

- temporomandibular joint (TMJ) disorders
- trigeminal neuralgia
- atypical facial pain syndromes
- major/minor aphthous ulceration
- herpetic infections
- lichen planus
- glossitis
- dentine hypersensitivity
- post-surgical and post-injury wound healing management
- nonobstructive sialadenitis
- mucositis.

**Photodynamic Therapy (PDT)**

PDT is used as a treatment form in the management of certain malignant tumours. Originally intended as a palliative end-stage modality, the scope and development of PDT has led to its definitive use in the treatment of certain cancers. It is based on a cytotoxic photochemical reaction. This reaction requires molecular oxygen, dihematoporphyrin ether (DHE), which is administered intravenously, and laser light. Malignant tissue selectively absorbs and concentrates the DHE and, following exposure of the tissue to laser light, typically 630 - 80 nm, the drug reacts with molecular oxygen to produce singlet oxygen, a highly reactive free radical, which ultimately leads to tissue necrosis.

Patients given PDT will also exhibit severe reaction to sunlight. Such skin sensitivity has, however, proved useful in the treatment of conditions such as eczema.

The accessibility of tissue sites through PDT was originally limited to surface tumours, e.g., squamous cell carcinoma, but, with the advent of fibre delivery through endoscopy and vascular channels, the scope of treating deep or distant sites has increased. Through the use of PDT, many malignancies can be treated nonsurgically or, as a result of tumour shrinkage, allow surgical excision with greater success.

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**References**


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**So, Why the Controversy?**

The progressive use of LLLT during the past 30 years has spanned many countries and each National certification agency will have sanctioned (or not) the use of this therapy by Professionals within each National network. Consequently, a great deal of subjective criticism has arisen, mainly through the difficulty in representing clinical results, interpreting research and the validation of research. Within the hierarchy of research techniques, the use of double-blind random clinical trials remains a benchmark of excellence. Sadly, the universal uptake of LLLT has suffered through poor or biased investigative trials. Nonetheless, the profusion of anecdotal reports continues to prompt proper research by respected centres and this trend is encouraging. “Evidence-based” remains a key base of any clinical procedure, yet the assimilation of evidence need not lie solely within the laboratory, and laser dentistry is an area where the validation of clinical results has prompted research, much to the credit of the esteemed clinicians involved.

Low-Level Laser Instrumentation is currently unavailable for purchase in the United States. In spite of that, conventional dental lasers can be used to deliver small increments of laser energy, and are being used in that way by many American practitioners. Some of the surgical devices do have panel settings that allow very low energies per pulse. For example, the pulsed Nd:YAG laser at 20 mJ per pulse, and the Er:YAG laser at 30 mJ per pulse operating at 3-10 Hz, certainly match the power output of the low-level instruments. The continuous wave diode instruments have low power settings of about 0.4 W. Moreover, operating a few millimeters out of contact with the target tissue insures that the fluence and power density measurements are quite low, since the laser beam is consistently divergent after exiting the tip of the fiber. Of course, the operator must constantly observe the site to insure and minimize the photothermal temperature rise.

Basic physics dictates that each wavelength has both a preferred absorbency into different kinds of tissue and a specific depth of penetration into that tissue. Generally speaking, wavelengths approximately 1000 nm and below prefer both pigmented and highly vascularised tissue and can penetrate deeply. Longer wavelengths are usually absorbed by surface water. Laser light, no matter at what output power, behaves according to those principles. The issue is that it takes a certain number of photons to do the work of vaporisation. A lesser amount will not accomplish that task.

Many instruments have U.S. FDA marketing clearance for treatment of aphthous ulcers, and the treatment consists of low power output in a de-focused, non-contact manner. When used properly, there is usually very little or no surface change seen on the lesion, but the discomfort is almost always substantially reduced. This is not a surgical ablative procedure, although there is some thermal effect, most probably one of protein denaturation.

Likewise, there can be an analgesia-like effect on hypersensitive dentine when very low energies of Nd:YAG and/or Er:YAG are applied from a few millimeters distance, again not a photo-ablative procedure. This is currently an “off-label” use of those lasers in the United States, but the treatment does have clinical indications.

Perhaps further research and more clinical studies will both acknowledge and confirm the experiences that we clinicians have when we use our laser devices. Anecdotally, there seems to be better (not necessarily faster) wound healing, less post-operative discomfort, and healthier tissue tone when a laser is used surgically. It makes sense that these results can be in part due to the low-level laser effect of the wavelength utilized.
Low-Level Laser Therapy
Jan Tunér DDS
Gränjesberg, Sweden

Ever since the first reports of biological responses to low doses of laser irradiation were published in the late 60s, there has been a controversy regarding this therapy. The most dubious trait of the therapy was that it seemed to be some sort of panacea. In spite of hard criticism from the medical profession, there was a boom for low-level laser therapy (LLLT) in the late 80s. The skeptical attitude was justified in those days, but is it still? This article will briefly look at the historical background and the scientific base for LLLT today. A few indications for dental LLLT will also be discussed.

The History

Some of the earliest reports about “biosimulation” came from the laboratory of the Hungarian surgeon Endre Mester. Some of his first studies were published in Hungary in 1968 (1) and the first report in a western journal appeared in 1971 (2). Mester wanted to find out if there were any adverse cellular effects of the lasers recently introduced in medicine. He therefore shaved the left and right dorsal parts of rats, made standardized incisions and irradiated one side with low doses of ruby laser. He was surprised to see that the wound on the irradiated side healed better than on the non-irradiated side. But even further, the fur on the irradiated side grew more rapidly.

Mester was using a ruby laser (694 nm, red) of 25 mW, and the suggested dosage was 1-2 Joules/cm². Later he used a Helium-Neon (HeNe) laser of 25 mW as well. It is therefore rather surprising to see that the boom in the 80s was based on HeNe lasers of 1 mW. Mester irradiated directly from the tube without energy loss. The 1 mW HeNe lasers had optical fibers with loss of 50-90%! Still, a number of studies (3, 4) reported positive results on indications such as pain and peripheral sensory nerve latency, using these lasers. Doses were in the range 0.001-0.01 J, even for conditions deeper in tissue than open wounds, thus actually requiring higher doses to compensate for absorption. Much of the following research seems to have been centered upon controlling these very low-dose studies rather than paying attention to the original dosages suggested by Mester and others.

The Literature

There are more than 2500 published studies in the field of LLLT. That sounds like a lot, but a problem is that more than 50 different applications are described, leaving many indications with but a few studies. However, recent U.S. meta-analyses (5, 6) on pain, wound healing, and tissue regeneration found a highly significant level of support in the literature. Evaluation of the literature is difficult because there are many possible pitfalls in such studies, not least in the laser parameters. An analysis of some of the most frequently quoted negative references (7) identified a lot of flaws, such as extremely low doses, miscalculation of dosage, unsuitable treatment technique, treatment of psychogenic pain.

A combined knowledge of laser technology, physics, medicine and laser therapy theory seems to be necessary to complete an impeccable study. Among the LLLT investigations there are more than 100 positive, double-blind studies and some 40 negative double-blind studies (8). While some of these negative studies are well-performed and should be taken seriously, too many of them have similar flaws as mentioned above. The positive double-blind studies differ a lot when it comes to quality. Only 27 of these were found in a Medline search, which is a marker of quality. Many have been published in national or regional journals, not indexed in Medline. The dental LLLT literature is not very extensive, but the 275 studies indexed by the author are from 84 dental institutions in 37 countries, and the percentage of studies with positive outcome is 94. All in all, the existing literature gives good support for efficacy of LLLT as such, but much remains before there is a solid knowledge about optimal parameters. So far we are active within a “therapeutic window” without optimising the parameters.

Mechanisms

Photobiology is an extremely complex science and certainly a lot remains to be learned about the effects of LLLT. Some of the effects observed in the literature are increased production of adenosine triphosphate (ATP) and deoxyribonucleic acid (DNA), influence on singlet oxygen, Ca²⁺ and NO, prostaglandins and opioids. Some of the photoreceptors are suggested to be endogenic porphyrins and cytochrome c oxidase. Suggested reading is the book by Karu (9).

Generally, there are two kinds of mechanisms: primary effects where the irradiation reaches tissue, and secondary effects through released metabolites. The carbon dioxide laser is a good example of the latter. Since this wavelength does not penetrate skin but a fraction of a millimeter at biosimulative energies, the described effects on pain and tendinitis cannot be primary.

High- and Low-Level Lasers

Is there a sharp border between high- and low-level lasers? Today the latter can have output of 1000 mW and are then class 4 lasers, although they are used as low-level lasers.

Dosage Calculation

The most important parameter is the dose which is the same as the energy density. Low-level laser doses are indicated in joules (J) per cm² or sometimes, for small areas, joules per “point.” Mathematically this is calculated as laser output in milliwatts multiplied by the number of seconds of irradiation per square centimeter. For example, 100 mW x 10 seconds produces a dose of 1000 millijoules, or 1 J, and, if this energy is distributed equally over 1 cm², we have given the dose 1 J/cm². Suitable therapeutic doses range from 1 to 10 J/cm² for superficial conditions. If we are treating a small area, this can be regarded as a “point” even though this is not correct mathematically. A “point” is usually an area with a diameter of 5 mm or less. A suitable dose for a “point” is 0.2 to 2 joules for superficial conditions. At this level, there generally is no heat sensation involved with the therapy.

Another important parameter is the power density (the light intensity in the treated area), which is measured in watts per cm².

If treatment is performed in contact mode and the probe is not moved, the area being treated is the area of the laser probe opening. If this area is 2 mm² (equal to 0.02 cm²), the dose (energy density) created by a 100 mW laser during 10 seconds is 100 mW x 10 sec/0.02 cm² = 50000 mJ/cm² = 50 J/cm². The power density in this little area is 100 mW/0.02 cm² = 5000 mW/cm² = 5 W/cm². These values are rather high, but they are only high in the directly illuminated surface of 2 mm²; a few mm away they are much lower. If the target area is an open wound, e.g., an aphtha, it may be too high for the cells in the surface, but if the problem is situated deeper (like an apex) and the tissue in between is healthy, the dose is correct. One always has to consider the location of the problem and the tissue condition in the surrounding area. Another way to avoid very high dose peaks is to move the probe during treatment, or — in some situations — to spread out the light.

If irradiation instead is performed from a distance with a divergent beam, and the laser beam is spread out over an area of 1 cm², then the calculation becomes (for the same laser power): 100 mW x 10 sec/1 cm² =1000 mJ/cm² = 1 J/cm².

This may seem very complicated at first glance, but in the clinical setting the “J per point” method is often best used and very easy. Dosage must be within the rather broad “therapeutic window” to achieve an acceptable effect.
lasers through “photo dilution.” Surgical lasers such as the carbon dioxide laser, with output around 5-15 W, are used successfully as biostimulators. So in order to change one and the same laser from surgery to biostimulation, it is only a matter of adapting the energy density. Indeed, the excellent healing seen with laser surgery is partly due to biostimulation. Adjusting the energy density of a surgical laser, we obtain carbonisation and burn-off at high energies, then vapourisation, coagulation, protein denaturation and, at the periphery, thermal photoactivation, and finally nonthermal photoactivation (or LLLT). So, in short, low-level lasers cannot be used as surgical lasers, but surgical lasers are secondary biostimulators, if defocused.

**Adverse Effects**

After 30 years of extensive clinical use there are still no reports of serious adverse effects. The fear of eye injuries has been vastly exaggerated in the past but with invisible lasers in the region of +100 mW in the facial area, this risk must now be reevaluated. The only absolute contraindication is suspected malignancies. Lack of medical training is an important but relative contraindication for LLLT. During my 14 years of practically daily dental laser therapy, no single adverse effect has been observed.

**Dental Indications**

Dentistry, unfortunately, is a lot about pain, inflammation and edema. At least that is the perception of most patients. LLLT is an excellent method for reducing these fears. In the following, a few dental indications will be described, with a selected reference for each.

- **Herpes simplex.** This is normally a reason for cancellation of a dental appointment. For my patients it is the other way around. Treated by 4-6 J per blister in the prodromal stage or slightly later, the pain will subside quickly and healing will take but a couple of days. Treating the herpes attack in the early form each time it appears will not only cause healing, it will also reduce the number of relapses. Schindl (10) has even showed that patients with recurrent Herpes Simplex Virus I (HSV1) attacks can be treated in the silent periods.

- **Mucositis.** Patients receiving radiation therapy for cancer in the head-neck region commonly develop mucositis. Red laser at 1-2 J/cm² has been shown to be effective as a therapeutic as well as a prophylactic measure in radiation and chemotherapy cancer patients (11).

- **Temporomandibular Disorder (TMD).** Infrared laser is excellent for trismus, arthrosis and for painful trigger points (12). High doses and energy densities are essential for muscular treatment. Red laser at lower doses can be used to advantage for arthritis since the joint is rather superficial. Starting the TMD therapy with LLLT will reduce pain and increase range of movement. This in turn will enable the dentist to make occlusal analysis and take impression for splints.

- **Paresthesia.** A common complication in maxillofacial surgery is the subsequent paresthesia. In most cases it will be transient but too many become permanent. Infrared laser has been able to promote elimination, partially or completely, of long-standing paresthesias (13). It is recommended to use LLLT as a prophylactic measure after maxillofacial surgery or immediately at signs of aberrations. For superficial nerves 1-2 J per cm² are applied along the nerve, for intraosseous nerves 6-8 J per cm along the nerve in the same manner. Indications of particular interest, but so far with an insufficient research base, are bone regeneration, osseointegration, orthodontic movement, and periodontal regeneration.

The indications described in the smorgasbord above will certainly not work with any wavelength and any dosage. Mucosal wounds, for instance, are optimally treated with red laser, 1-2 J per cm², whereas muscular pain requires 10-20 J with infrared. As with any other therapy, it is essential to have control over the parameters.

The purpose of this article is to point to the fact that low-level lasers are now worth another look after the turbulence in the past. I foresee a not too distant future when the low-level laser is hanging side by side with the curing light and the ultrasonic scaler in many dental operatories.

For further information about LLLT, please refer to the web site of The Swedish Laser-Medical Society, www.laser.nu.

**Email:** Jan@tuner.nu

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**References**


**Dental Laser Training at Your Fingertips**

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**LLLTT Presentations and Posters During Previous Academy of Laser Dentistry Annual Conferences**

Good news! Readers who were unable to attend these past conferences and who would like more dedicated information about LLLTT can order a special videotape compilation of all 11 low-level laser topics presented during Academy of Laser Dentistry conferences from 1993 through 1999. Highlights range from Professor Paul Bradley’s 1999 overview to scientific and laboratory studies to clinical reports of specific treatments. For details about this three-videotape set of nearly five hours of LLLTT information, please contact Mr. Bob Coffin of JOYCO Productions (who videotapes all Academy conferences) at 303-421-0093 or fax 303-403-9112. Ask about the Low-Level Laser Therapy Compilation Videotape.

- Neckel CP. Biostimulation: A comparative study in the postoperative outcome of patients after third molar extraction. Academy of Laser Dentistry Sixth Annual Conference, Palm Springs, California, February 6, 1999.

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Use of Low-Level Lasers in a General Dental Practice
Gerald Ross, DDS • Tottenham, Ontario, Canada

Editor’s Note: For the convenience of our readers, Dr. Gerry Ross presents an overview of how he uses low-level laser therapy (LLLT) in his practice everyday. He offers a brief introduction, personal commentary, and summarizes the methodologies used for a variety of clinical applications. Practitioners accomplished in LLLT are encouraged to submit more detailed analyses of their own experiences following the Academy’s guidelines for clinical case presentations. All submissions will be considered for publication in future editions of Wavelengths.

I have been using a low-level laser in my general dental practice since 1992. I use it 8 to 12 times daily and it is now part of our office routine. In most cases, the application of the laser is done by one of my dental assistants. It has led to a 75% reduction in prescription pain medication.

Types of Low-Level Lasers Available
HeNe - 633 nm (visible red)
• very good for surface lesions
• little penetration, so poor for muscles, joints and teeth

GaAlAs - 820 - 830 nm (invisible infrared)
• good for surface lesions, muscles, joints and teeth
• moderate penetration

GaAs - 904 nm (invisible infrared), usually pulsed
• good for deep lesions but no effect on surface lesions
• deep penetration (3 - 5 cm)
• used mostly in physiotherapy and veterinary applications

I use a 830-nm GaAlAs low-level laser (P-Laser, Future Medical Technology, Inc., Scottsdale, Arizona) which provides four strengths: 50 mW, 100 mW, 200 mW (the one I prefer), and 400 mW. Four different tips are available: one intraoral and three intraoral sizes.

Mechanisms of Action
• Low-level lasers act on the cellular level to:
• Increase adenosine triphosphate (ATP) production
• Stimulate fibroblasts and odontoblasts
• Increase phagocytosis by leukocytes
• Decrease blood flow initially in extraction sites so that there is faster clotting in the first 30 minutes, followed by increased blood flow to allow healing

Dosage Spacing
• Acute Pain - Fewer treatments closer together for a short time. Acute lesions respond best.
• Chronic Pain - More widely spaced treatment is necessary; usually the interval is twice weekly for first two weeks and then weekly after that. With chronic pain the patient may rarely experience a treatment response. They may have a general malaise for 2 - 3 days. This is caused by the release of toxins built up in the chronic lesions into the bloodstream overloading the body's host response. I always warn the patient of this possibility when beginning treatment of a chronic problem.

Application Principles
• Teeth - Always use a water-based gel (either a gel used for Doppler or K-Y Jelly) when contacting the tooth surface with the laser. It has been my experience that the use of a gel on the tooth surface seems to increase the effectiveness of LLLT, perhaps by improving conductance of the laser radiation through hard tissues. After the tooth is irradiated, the laser should also be placed on the apex according to fig. 1.
• Soft Tissue - The laser should be in light contact with soft tissue except for aphthous or herpes lesions when the laser should be just out of contact.

Clinical Procedures
The table below indicates the exposure duration required to create the joules at different powers. The relationship is linear since the laser is nonpulsed.

<table>
<thead>
<tr>
<th>Laser Power</th>
<th>50 mW</th>
<th>100 mW</th>
<th>200 mW</th>
<th>400 mW</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 Joules</td>
<td>60 sec</td>
<td>30 sec</td>
<td>15 sec</td>
<td>7.5 sec</td>
</tr>
<tr>
<td>4 Joules</td>
<td>120 sec</td>
<td>60 sec</td>
<td>30 sec</td>
<td>15 sec</td>
</tr>
<tr>
<td>8 Joules</td>
<td>240 sec</td>
<td>120 sec</td>
<td>60 sec</td>
<td>30 sec</td>
</tr>
</tbody>
</table>

Continued on page 28

Wavelengths, Winter 2001 Volume 9 Issue 1