**LOW LEVEL LASER THERAPY IN THE TREATMENT OF PERIODONTAL DISEASE**

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The general objective of this study was to demonstrate that the application of low level laser therapy (LLLT), in addition to standard procedures employed to treat periodontal disease, improves the outcome of the treatment. Periodontal disease is an infectious process that is the leading cause of tooth loss and attacks the structures of the periodontium (the ligaments around the teeth), the gingivae, epithelial attachment, cementum that cover the root of the tooth, and the alveolar bone that supports the tooth. Diabetes mellitus is a strong risk factor for periodontal disease. Diabetic individuals are three times more likely to have attachment and bone loss than non-diabetic patients. Furthermore, osteoporosis is always associated with alveolar bone loss. Women with osteoporosis have increased alveolar bone retraction, attachment loss, and tooth loss compared with women without osteoporosis. Estrogen deficiency has been linked to decreases in alveolar bone. There is evidence that LLLT has an anti-bacterial effect, acts as an anti-inflammatory agent, and stimulates collagen and bone growth. Over the last decade, much progress has been made in elucidating the underlying principles. Approximately half of the diabetic patients and half of the patients with osteoporosis received LLLT in addition to the classical treatment. In this study we searched for the effects of LLLT on advance chronic periodontal diseases that had caused severe destruction of the periodontal structures, i.e., clinical attachment loss over 5 mm, increased bone loss, increased pocket depth (usually 5 mm or greater) and increased tooth mobility. For all four groups (1) diabetic patients treated with LLLT; (2) diabetic patients without LLLT; (3) osteoporotic patients treated with LLLT; and (4) osteoporotic patients without LLLT) we determined the mean and standard deviations of the following parameters: gingival bleeding time, pain relief time, bone recovery time, inflammation, complete healing. The LLLT-treated groups were superior to the non-treated control groups in both the diabetic and osteoporotic patients General social benefits are the development of a novel LLLT modality for treatment of periodontal disease, which allows for early non-invasive treatment of periodontal infection. LLLT technology promises to become even more cost effective and may reduce the cost of patient care.

**Key Words:** Periodontitis, diabetes mellitus, osteoporosis, laser therapy, bone growth

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**Introduction**

Periodontal disease is an infectious process that is the leading cause of tooth loss in adults. (1) It attacks the structures of the periodontium (the ligaments around the teeth), the gingivae, epithelial attachment, cementum that cover the root of the tooth, and the alveolar bone that supports the tooth. Periodontal disease causes a breakdown of the periodontium, resulting in loss of tissue attachment and destruction of the alveolar bone.

Almost 75% of all adults have some form of periodontal disease, and most are unaware of the condition. Certain systemic conditions increase the patient’s susceptibility to periodontal disease, and periodontal disease, in turn, may increase a patient’s susceptibility...."
to certain other systemic conditions. Disease-causing bacteria are necessary for the periodontal disease to begin, but they are not solely responsible for the destruction of the periodontium. Other risk factors can also alter the body’s response to the bacteria present in the mouth. These factors include traumatic occlusion, overhanging restorations, sub-gingival placement of crown, orthodontic appliances or partial dentures may also contribute to the progression of the periodontal disease as well as smoking. Furthermore, the course of the disease is often influenced by other general medical factors, such as genetic preposition, specific medication, hormonal deregulation, and systemic disease, some renal or hepatic conditions, diabetes, osteoporosis, metabolic calcium dysfunction, immune system deficiency and stress.

Diabetes mellitus is a strong risk factor for periodontal disease. Diabetic individuals are three times more likely to have attachment and bone loss than non-diabetic patients. Furthermore, osteoporosis is always associated with alveolar bone loss. Women with osteoporosis have increased alveolar bone retraction, attachment loss, and tooth loss compared with women without osteoporosis. Estrogen deficiency has been linked to decreases in alveolar bone.

Tetracycline and non-steroidal anti-inflammatory drugs (NSAIDs), have a beneficial effect on the periodontium. At the same time they have a very toxic effect on the liver, which toxicity has a boomerang effect on the periodontium. Decreased salivary fluid (xerostomia) can be caused by more than 400 medications, including diuretics, antihistamines, anti-psychotics, anti-hypertension agents, and analgesics. Anti-seizure drugs and hormones such as estrogen and progesterone can cause gingival enlargement. Any of the above medications can accumulate to levels of hepatic and renal toxicity that will adversely affect periodontal tissue.

Since the seventies, not long after the development of the first lasers in the early sixties, there was evidence that laser irradiation could result in modulation (stimulation or inhibition) of biological processes. At the beginning, what became known as Low Level Laser Therapy (LLLT) was empiric; it was not based on in vitro studies, so that the interaction mechanisms between the laser beam and the living matter were at first unknown. This empiric character of the clinical investigations lasted for quite some time, especially because the most medical laser users did not fully understood the principles of lasers, the characteristics of the laser beam, and the interaction mechanisms.

LLLT was originally defined as application of laser light with an intensity of less than 250 mW/cm² to treat various medical conditions. In fact, much stronger power densities, up to around 5 W/cm², have been proved to deliver athermal and atraumatic therapeutic effects. Over the last 30 years, laser therapy as distinct to laser surgery has been successfully applied to wound healing, pain management, for diabetes, in physiotherapy, dermatology, gynecology and dentistry. There is evidence that LLLT has an anti-bacterial effect, acts as an anti-inflammatory agent, and stimulates collagen and bone growth. Over the last two decades, much progress has been made in elucidating the underlying principles.

Light is scattered in the tissue in 3 possible manners: 1. Volumes of partially polarized light are formed, 2. Points of high light intensity appear, and 3. Areas of high difference in light intensity levels are formed. When volumes of partially polarized light are formed, light is absorbed in cytochrome molecules and stimulates the creation of oxygen that leads to the formation of ATP, and stimulates cAMP and enzymes. Triggered immunological chain reactions occur. Macrophages are activated. The number of mast cells is increased together with accelerated degranulation, namely processes that lead to anti-inflammatory actions, and procollagen synthesis in fibroblasts is enhanced, leading in tandem with some of the earlier reactions to regeneration of the tissue and healing.

When points of high light intensity appear and also areas of high difference in light intensity levels are present, the electrical field across the cell membrane creates a dipole moment on the bar shaped lipids that influence the permeability of cell membrane that effects transport channels for Ca, Na, and K, and the sodium-potassium, and sodium-calcium pumps are stimulated into action. The receptor activity on cell membranes increases as well as the serotonin level in blood. At the same time LLLT stimulates the synthesis of endorphins, decreases C-fiber activity and, in the areas of high intensity levels, increases, nerve cell action potentials. All these mechanisms influence the pain and anti-inflammatory processes.

The general objective of this study is to demonstrate that the application of low level laser therapy (LLLT), in addition to standard procedures employed to treat periodontal disease, improves the outcome of the treatment. The symptoms of periodontitis are a red, swollen, tender gingiva, bleeding while brushing, flossing or spontaneous, loose or separating teeth, pain or pressure when chewing, pus around the teeth or gingi-
val tissues. We sought to compare the effects of LLLT on examples of advanced chronic periodontitis that have caused severe destruction of the periodontal structures, i.e. clinical attachment loss over 5 mm, increased bone loss, increased pocket depth (usually 5 mm or greater) and increased tooth mobility with the same conditions untreated with LLLT in patients complicated with diabetes and osteoporosis.

**Subjects and Methods**

**Subjects**

To participate in this study, subjects had to have a confirmed diagnosis of advanced chronic periodontitis. Additionally, study subjects were screened to include patients with diabetes and with osteoporosis as well as subjects that had advance chronic periodontitis by local factors only. The subjects were diagnosed based on the status of the disease at the baseline. Furthermore, blood tests, bone density and local tests were performed on both the control group and experimental group. There was no restriction for enrollment based on gender, race or age, however only adult patients over the age of 18 were recruited. The addition of LLLT in the treatment group was offered to enhance standard clinical methods in the treatment of periodontal disease. The alternative to participating in this study was simply not to participate. All subjects, having had the purpose and methods of the trial explained to them, signed forms of informed consent before being recruited into the study. The study was conducted under the precepts of the Geneva Convention, and was approved by the relevant Ethics Committee.

We recruited approximately 200 patients (diagnosed with either diabetes or osteoporosis) evidencing marginally advanced chronic periodontitis. A correct diagnosis was assessed based upon the medical and dental history. All of these patients received classic modern treatment. Approximately half of the diabetic patients and half of the patients with osteoporosis received LLLT in addition to the classical treatment. The number of patients enrolled was determined by statistical power calculations using the data obtained in our earlier pilot studies. Patients were randomly assigned to 4 groups: (1) diabetic patients treated with LLLT, (2) diabetic patients without LLLT, (3) osteoporotic patients treated with LLLT; and (4) osteoporotic patients without LLLT. For all four groups we determined the mean and standard deviations of the following six parameters: 1. gingival bleeding time; 2. pain relief time; 3. bone recovery time; 4. inflammation; 5. complete healing; and 6. Recurrence. These parameters are quantified as follows:

1. Bleeding time. We considered the gingival bleeding time as the time interval from the end of the curettage until the formation of the blood clot, established by the paper test. The time was measured with a chronometer. The measurement was performed in one location.
2. Pain relief time. Pain is a physiological consequence of the surgical trauma, accompanied by inflammation. We asked the patients to note the evolution of the pain intensity, and if they could use both jaws for normal mastication. The time interval described by the patient until the complete resolution of pain was measured.
3. Bone recovery time. We determined the bone regeneration by observing the plaque healing evolution (disappearance of dental mobility, improvement of the gingival color, recuperation of the masticator function and the comfortable state of the patient) and by evaluating X-ray images. When clinical parameters indicated bone recovery, we performed radiography. We considered bone regeneration time to be the interval between the onset of treatment and the radiographic confirmation of bone regeneration.
4. Inflammation and edema, produced by bacterial over-infection or caused by other agents, are considered as a post surgery complication. We measured the protein C reactivity with laboratory serum analysis.
5. Long term healing was quantified by:
   - rapidity of healing and the aesthetic aspect of the scar;
   - stability restored of the teeth determined by tooth mobility measurements;
   - documenting restored mastication and physiognomic functions.
6. The recurrence rate was monitored and statistically quantified.

For each subject participating in this study a complete detailed history and diagnostic evaluation was performed, based on the dental and medical history. The periodontal examination included the assessment of:

1. Plaque – the primary cause of the inflammation;
2. Calculus – hard, mineralized plaque adherent
on the surface of the teeth;
3. Gingival recession level - visualized on the chart by a dotted or colored line indicating the gingival margin;
4. Bleeding index- severity of the gingival inflammation, measured by the amount of bleeding observed during probing. There are several indices to measure bleeding. Each system is based on the principle that healthy gingival do not bleed;
5. The periodontal pocket which increases with the severity of the periodontal disease causing the normal gingival sulcus to become deeper than normal (a normal sulcus is 3 mm or less); and
6. Bone level - Bone density tests, radiographs and probing measurements were employed in assessing bone level and indicated on all patients’ charts. Radiographs could detect:
   a) Inter-proximal bone loss;
   b) Changes in the bone as treatment progresses;
   c) The crown to tooth ratio (the length of the clinical crown compared to the length of the root of the tooth); and
   d) Signs of traumatic occlusion.

Treatment protocols

The classic periodontal treatment as applied to all patients in both the LLLT and the unirradiated group consisted of the following steps: local and general anti-inflammatory prophylaxis; elimination of acute complaints e.g. pain, mastication problems and edema; rehabilitation and rebalancing of the occlusal plane; periodontium and bone nutrition; and amelioration of risk factors.

The surgical protocol consisted of sub-gingival curettage that involved scraping or cleaning the gingival lining of the pockets with a sharp curette to remove necrotic tissue from the pocket wall. Periodontal surgery provided access to the root surface, and allowed removal of the infected tissue as well as the addition of nutrition directly to the bone by applying local collagen, hydroxyapatite, bone grafts, enzymes or antibiotics. After the surgical intervention, anti-inflammatory treatment usually continued daily. Patients were monitored at regular intervals over the course of 2 years.

For the LLLT we conceived an irradiation protocol following the data in the literature, and our experience. In general we used an infrared diode laser type BF (EN 60 601-1), class 3B, safety class 1, with two laser beams, one infrared with a wavelength $\lambda = 810$ nm, and another visible red beam with a wavelength $\lambda = 660$ nm. Convergent beams with energy between 0.5 and 3 J/cm$^2$, were applied continuously or in pulsed mode. The parameters were adjusted depending upon the required penetration depth (2.5 – 12 mm).

LLLT begin immediately after surgical curettage, when we applied laser irradiation to the bone, through the inter-dental space, without contacting the surgical plaque at a dosage of 0.5 J/cm$^2$ per application, in the pulsed mode. Before the suture, we irradiated the external plane, scanning the maxillary area by treating the skin with a dosage of 2 J/cm$^2$. Thirty minutes after suturing, usually applied 1–4 J/cm2 to each hemi-arcade area, the total dose being 4–16 J/cm$^2$.

In the first three days after the surgery, we irradiated the external plane with the same dose daily. In acute forms, we usually applied a dose of 4J/cm$^2$ every two days for the first week, two sessions in the second week, and one session in the third week. In the following six months, we planned to apply one irradiation session monthly, at the same dose. In chronic cases, the treatment comprised additional irradiation sessions, at smaller doses, over a longer period of time.

LLLT was repeated every six months together with conventional periodontal disease prophylaxis and nutritional support of the immune system. We evaluated the results by x-ray after one month, three months, six months and every six months thereafter over the course of two years.

Results

The promising results of earlier pilot studies provided the impetus for the proposed work. These studies showed that subjects receiving LLLT in addition to traditional treatment enjoyed markedly better recovery and healing than subjects treated without LLLT. LLLT resulted in shorter pain recovery time, bleeding and reduced post surgery complications (edema, inflammation, infection,), faster formation and maintenance of the clot, and better maintenance of the masticatory functions.

These findings were corroborated in the present study. Looking first at postsurgical pain, Fig. 1 shows the time taken for complete pain relief (in hours) comparing the LLLT-treated and classic treatment only groups, broken down between the osteoporotic and diabetic patients. There was a significant difference in the pain relief time between the two treatment groups, but not between the two disease groups, with the average time taken to no pain post-surgery for the LLLT and
control groups of 3.75 hr and 11.9 hr, respectively. We also noted analgesic requirements of the two treatment groups, and the LLLT group required on average 65% less analgesics than the control group (data not shown).

Fig. 2 shows the time in months for bone recovery to occur, compared between treatment and disease groups. Full recovery was noted at an average of 31.75 months for the control and 16.45 months for the LLLT group, almost twice as quickly for the latter. There was a difference between disease groups, although not statistically significant, whereby recovery tended to be longer in the osteoporotic group for both treatment groups.

Bleeding stopped significantly faster postsurgery in the LLLT compared with the control groups (Fig. 3), 558.5 seconds on average for the latter compared with 117.8 sec for the former. A slightly longer time was required in the diabetic patients compared with the osteoporotic patients, but without statistical significance.

Figs. 4 to 7 show typical pre-intra- and immediately postoperative stages in a patient with periodontal disease from the LLLT-treated group. Immediately post-treatment, gingival hyperplasia has been removed, with a healthy-looking gingiva and teeth.

Radiographic findings showed better bone recov-
ery in the LLLT than in the control group, as seen in
Fig. 8a, b. These typical pretreatment findings showed
major resorption of the alveolar bone between the
roots of the teeth in the middle of the image, with
poor radio-opacity. One-and-a-half years after the treat-
ment, much healthier interdental bone was seen, with
an increase in the overall radio-opacity of the bone,
suggesting higher bone mineral density in this osteo-
porotic 48-year-old patient.

In short, in all LLLT-treated patients compared
with the classic-only treatment group we noted less
and faster-resolved postoperative pain, quicker bleed-
ing control, improved healing of the soft tissue, rapid
recovery of a more compact bone tissue restoring sta-
bility to the teeth, and good maintenance and improve-
ment of both the masticatory and esthetic functions,
with healthier gingival tissue. In particular, very good
results were obtained in diabetics for whom wound
healing is normally compromised. Otherwise there
were no statistically significant differences between the
disease-grouped patients. Recurrence was limited in
both groups, but was noticeably lower in the LLLT-
treated group.

Overall we did note that the effectiveness of LLLT
varied somewhat as a function of the age, general
health and metabolic problems of the patient (specific
data not shown). This must be addressed in a future
study with better patient stratification according to
these aspects.

Discussion
In the entire experimental group subjects, laser therapy
associated with the classic therapy gave overall better
and longer-lasting results than in the control group
who received classic therapy alone. This is in agree-
ment with previous studies from ourselves and others
in the field of LLLT in orthodontics. (1,18,20) Immediate
and short-term effects were as follows: evolution of the
wound without bleeding; no post surgery complica-
tions such as oedema, inflammation, infection, and
pain, with quick formation of the clot in the wound, and good maintenance of it; good biological repair over a shorter period than without LLLT; maintenance and then improvement of the masticatory functions; and a good aesthetic appearance with no post surgery alterations, permitting the patient to continue their work and social lives without interruption.

Long term effects were: rapid healing with excellent cosmesis, healing of the soft tissue, fixation of the teeth and with the fixation of the teeth, recovery of more compact and radio-opaque alveolar bone tissue, thus restoring the masticator and esthetic functions, and maintaining them. Gingival tissue looked healthy with a firm aspect, and mobility of individual teeth in their sockets disappeared. We and others have previously reported on the regrowth of absorptive alveolar bone in this aspect, and at a molecular level, the photoactivative effect of near infrared laser energy on the upregulation of expression of the gene in oral osteoblasts responsible for 'switching on' bone production (F0F1-ATPase subunit-b) has also been shown.

For the diabetic patient group, we found that LLLT was efficient in its anti-inflammatory treatment so the healing was more secure and rapid than in the unirradiated, classic treatment only group: we must note here that this observation is connected only with the gingival and the periodontal disease, on which the present study was based and where we did our measurements, and showed a tendency rather than a statistically significant difference. From the important aspects of safety and efficacy, there was a lower percentage of recurrence in the LLLT-treated group, and we did not have a single patient in whom the laser therapy was seen to have any adverse effects.

From our data, LLLT performed in this study presented no known hazards. Unlike x-rays, the energy from light sources employed in this study was non-ionizing, non-accumulative and was incapable of damaging the target or adjacent tissue. The light intensities and exposure times were within limits set by the American National Standard Institute (ANSI) and recommended by the Occupational and Safety & Health Administration (OSHA) of the US Department of Labor. LLLT systems have been cleared for marketing by FDA through the Premarket Notification/510 (k) process as adjunctive devices for the temporary relief of pain, and are non-significant risk Class II medical devices which may be distributed in the U.S. to individual practitioners who have approval from an Institutional Review Board (IRB) for the investigational clinical use of the device.

According to these standards the maximum permissible exposure (MPE) before any tissue damage occurs is given by $MPE = 200 \times 10^3 \times \frac{0.002 (\lambda)}{\text{mW/cm}^2}$, where $\lambda$ is the wavelength of the light used in the study in nm (see ANSI Z136.1-2000, page 48, Table 7, entry for Visible and Near-Infrared light). For example at $\lambda = 810$ nm and 660 nm, the wavelengths used in the study, the incident intensities were at least 10 times less than the maximum permitted exposure. No adverse effects...
on the tissue exposed to light were thus expected. In addition, to avoid accidental optical hazards, all operator personnel and study subjects wore mandatory protective goggles of an appropriate wavelength-related optical density while exposed to the LLLT device.

Conclusions
All participating subjects benefited from the classic modern and complete dental treatment of their periodontal disease. Patients treated in addition with LLLT further benefited from improved healing times, less pain, less bleeding, less post surgery complications such as edema, inflammation, and infection compared with the classic treatment only group.

General social benefits are the development of a novel and inexpensive LLLT modality for treatment of periodontal disease, which allows for early noninvasive treatment of periodontal infection. LLLT technology promises to be more cost effective and may reduce the cost of patient care, while improving the good results already achieved by meticulous classic periodontal intervention.

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