ACTA SCIENTIFIC DENTAL SCIENCES (ISSN: 2581-4893)

Volume 3 Issue 2 February 2019

Review Article

When Less is More - An Update on Low Level Laser Therapy Applications in Endodontics for Predictable Outcomes - A Review Article

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Received: October 17, 2018; **Published:** January 21, 2019

Abstract

The introduction of lasers and more specifically soft lasers has been historic in almost every field of dentistry. The benefits of this specific laser has been multidirectional and hence the benefits are multifold. Better understanding and constant research in this direction has led to a higher appreciation of the stimulatory, anti-inflammatory and biogenerative effects of LLLT, not only on soft tissue but also on hard tissue.

The purpose of this article is to bring perspective to the application of Low Level Laser Therapy in the field of endodontics, be it irrigation, disinfection, surgical procedure, pain management or just an uneventful and quicker wound healing following endodontic surgery. This in turn reduces the dependence on medications and with it reduces the occurrences of drug interactions or complications.

Keywords: Low Level Laser; Cold Laser; Soft Laser; Endodontics; Root Canal Therapy; Irrigation

Abbreviations

LLLT: Low Level Laser Therapy; PDT: Photodynamic Therapy; PACT: Photoactivated Antimicrobial Chemo-Therapy; LED: Light Emitting Diode.

Introduction

The first laser specifically designed for dentistry was marketed in 1989. In medicine, the technology was first used in 1963, and carbon dioxide (CO2) lasers were being employed during the 1980s for general and oral surgery [1]. A very low percentage of dentist's own lasers, and even a fewer number use it regularly. Despite new research studies which continue to increase the indications for use in oral procedures, the rate of incorporation and utilization of lasers in our day to day clinical work remains low. The basic hindrance is the lack of proper means of dissemination of updated research and procedural expertise to practising dentists, and a general hesitance to move towards such a technology.

The purpose of this article is to discuss the basics of lasers, in brief, and give basic understanding of the advantages of LLLT procedure in the utilization in the field of endodontics, while discussing the most effective power setting and techniques.

Basic LASER Science [2]

The acronym LASER stands for Light Amplification by Stimulated Emissions of Radiation. Elaboration of each of these words will give an idea of the basic laser production.

- **Light:** It is a form of electromagnetic energy that behaves both as a wave and a particle. This basic unit of energy is called photon. There are a few very basic differences which exists between ordinary light and laser. Light normally is perceived as white in color by the human eyes and when made to pass through a special prism, is seen to be a sum of many colors which is in the form of a spectrum, Violet, Blue, Green, Yellow, Orange and Red (VIBGYOR). Lasers on the other hand are of only one specific color which is related to a very specific wavelength, hence Monochromatic. Lasers are also Coherent (phased emission) and Collimated (parallel emission) and hence behave very differently from ordinary light and hence tend to possess more energy density. The two inherent properties of EM radiation in Amplitude (total height of wave oscillation) and Wavelength (distance between two corresponding peaks or troughs) this information is important for laser radiation as well to understand the how a laser will interact with a particular type of tissue and to what end.

- **Stimulated Emission:** It was Albert Einstein who laid down the foundation of the understanding of stimulated emissions, when in 1916, he theorized that if additional energy in the form of photon was incident on an already excited atom, would result in the release of the incident energy in the form of two quanta, or coherent wave of two photons having identical physical properties and energies, which he termed as stimulated emissions. This forms the basis of laser production of the same wavelength, amplitude and energies.
- **Amplification:** Inside a laser unit, the above process of stimulated emissions if continued would lead to an increase in the number of subsequent excited atoms and the release of identical photons and lead to a phenomenon called as population inversion where the number of photons are high, and the majority of atoms in the enclosed area are in an excited mode, leading to constant production of identical photons. These photons are made to reflect back and forth between two mirrors until they are ultimately collimated. This phenomenon is known as amplification.
- **Radiation:** Depending on the active medium and the type of energy source, the amplified, collimated beam of radiation will have a very specific wavelength, amplitude and energy level which are denoted by specific readings. Diode lasers which are the most commonly available and used lasers in dentistry and also in endodontics have a range between 300nm to 1064nm. They are normally invisible to the human eye as they are Near the Infra-red radiation zone of the wavelength. Since they are towards the IR side of the wavelength they do not have ionizing properties and are thus safe to be used on human tissues.

Diode Lasers

These are basically composed of solid-state semiconductors wafers made with mutli-layered arrangement of metals containing gallium, aluminium, indium or arsenide. The active medium is placed sandwiched between silicon wafers, where one side is positively charged and the opposite side is negatively charged. The source of energy may either be an electrical current which leads to a continuous wave emission type (common in diode lasers) or maybe a flash lamp strobe device which leads to free-running pulse type of emissions (seen with solid state yttrium lasers). The laser unit will have a few other components like cooling system, focusing lenses and other controls.

To best describe a laser assisted procedure, a few basic readings maybe necessary for a clinician to understand and recognise a particular procedure conditions which may help them to create the same settings to achieve similar results. These can be clustered as: Laser Manufacturer, Model no., Type of laser, wavelength, delivery system, emission mode, energy density, pulse width. We shall not go deep into these parameters as we intend to discuss the clinical aspect of lasers in endodontics rather than the physics.

LASER-Tissue interactions

The goal of dental laser surgery is to optimize various photobiologic effects. The photothermal conversion of energy permits soft tissue and excisions to be accomplished with accompanying precision and haemostasis, some of the many advantages of laser devices over conventional modalities.(2) Photo-activated disinfection is an example of a photo-chemical effect, known in medicine as photodynamic therapy. PAD utilizes a solution of tolonium-chloride that, when activated with visible red laser energy, releases a singlet oxygen radical that ruptures cell membranes. Studies show this therapy is effective in helping to disinfect root canals during endodontic therapy. Certain biologic pigments, when absorbing laser light, can fluoresce, a property which can be used for caries detection. A laser can be used with powers well below the surgical threshold for biostimulation, producing more rapid wound healing, pain relief, increased collagen growth, and a general anti-inflammatory effect.

Photothermal events

The principle effect of laser energy is photothermal. This thermal effect of laser energy on tissue depends on the degree of temperature rise and corresponding reaction of the interstitial and intercellular water. The rate of temperature rise plays an important role in this effect and is dependent on several factors such as the coolant used, ability of tissue to dissipate the incident heat energy. If absorption of the laser occurs it leads to immediate heating. If the laser is used in gated mode or pulsed mode, a thermal relaxation time is available which helps the target tissue to cool and the surrounding tissue to lose heat before the next pulse is incident. Dental structures have a complex composition and the four basic modes of interactions that laser have with tissue, occur in different proportions which will ultimate determine the type of effect they will produce at the target point.

These 4 modes are: transmission, reflection, absorption and scattering. As laser is focused on a target tissue several immediate as well as few delayed changes can be observed.

- The immediate effect is that of hyperthermia, as energy is absorbed leading to increased localized temperature without any damage or changes occurring. The temperatures may increase to about 55-60 degrees Celsius. It has been observed that at this temperature non-sporulating bacteria may be inactivated.

- At temperature above 60 degrees, denaturation of proteins is observed along with coagulation. These temperatures can be used to removed diseased granulomatous tissue, destroying cells without vaporization.
- Higher temperatures of about 70-80 degrees Celsius, cause the unfolding and intertwining of the helical structure of collagen and increasing their stickiness which can be used to produce adherence which can be used to close incisions or cause tissue welding or anastomosis. This also leads to the formation of a eschar formation which is highly protective and immediately reduces pain and sensitivity which can be used to reduce patient discomfort and pain.
- At temperatures of 100 degrees Celsius, vaporization occurs which leads to ablation of the tissues containing water. This temperature is when the excision of soft tissue can begin. However for the ablation of hard tissue the mechanism is different where the water molecules when vaporized, lead to an explosive ejection of hard tissue along with the steam jet, leading to removal of hard structure, this leads to a safe and predictive type of hard tissue ablation, as very less transfer of heat energy occurs between target tissue and adjacent tissue, leading to a very narrow zone of collateral damage which is mainly in the form of cracks due to the explosive expulsion.
- When more energy is incident, the tissue temperature may increase to as high as 200 degrees Celsius, at this temperature the desiccation process is complete, and tissue carbonizes, leading to a phenomenon known as charring. This causes a layer of carbon to build up on the target tissue. And carbon having the capacity to absorb all wavelengths, acts as a heat sink, leading to more collateral damage to the adjacent tissues and ultimately, tissue necrosis, delayed healing and possible scar formation.

The Gaussian Beam [3]

Optical engineers and researchers working on optics deal with laser beams and optical systems as usual tools in their specific areas. For dentists too, the knowledge of the special characteristics of the propagation of laser beams through optical systems has to be one of the keystones of our actual work, and the clear definition of their characteristic parameters has an important impact in the success of the applications of laser sources. Gaussian beams are the simplest and often the most desirable type of beam provided by a laser source. They are well characterized, and the evolution is smooth and easily predicted. The amplitude function representing a Gaussian beam can be deduced from the boundary conditions of the optical resonator where the laser radiation is produced. The geometrical characteristics of the resonator determine the type of laser emission obtained. For stable resonators neglecting a small loss of energy, the amplitude distribution is self-reproduced in every round trip of the laser through the resonator. Unstable resonators produce an amplitude distribution more complicated than in the stable case. Besides, the energy leaks in large proportion for every roundtrip. The curvature of the mirrors of the resonator and their axial distance determine the size and the location of the region showing the highest density of energy along the beam. The transversal characteristics of the resonator allow the existence of a set of amplitude distributions that are usually named as modes of the resonator. The Gaussian beam is the lowest-degree mode, and therefore it is the most commonly obtained from all stable optical resonators [3].

It is this Gaussian effect which lead to the low level laser therapy with almost every laser which is used in dentistry. This lead to a zone of unfocused low energy level irradiation around the concentrated beam, or the purposeful unfocussing of the beam on target tissue to obtain 'Cold laser effect' or 'LLLT'.

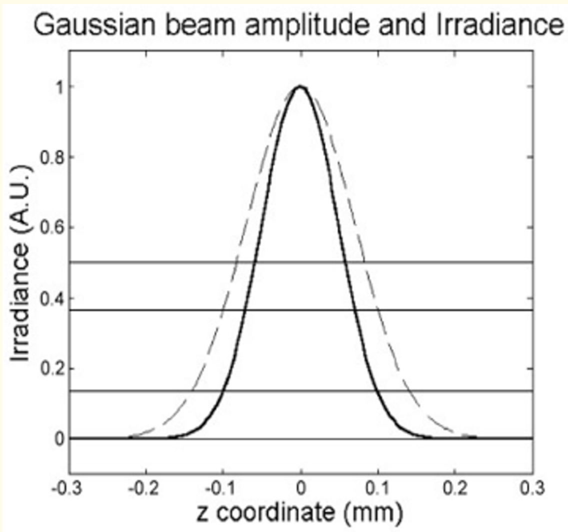

Figure 1: Transversal profile of the Gaussian beam amplitude at the beam waist (dashed line) and irradiance (solid line). Both of them have been normalized to the maximum value. The value of the width of the beam waist coo is 0.1 mm. The horizontal lines represent (in increasing value) the 1/e2 of the maximum irradiance, the lie of the maximum amplitude, and the 0.5 of the maximum irradiance and amplitude.

According to Posten., *et al*. properties of low level lasers are [4]:

- Power output of lasers being 0.001- 0.1 Watts.
- Wave length in the range of 300-10,600 nm.
- Pulse rate from 0, meaning continuous to 5000 Hertz (cycles per second).
- Intensity of 0.01-10 W/cm^2 and dose of 0.01 to 100 J/cm^2.2

Biomodulation at cellular level

It is now understood that all types of cells respond to irradiation with monochromatic radiation from laser and non-laser light sources (e.g. LEDs), with changes in their metabolism. This consistent character of cell response to irradiation is believed to be due to the universal presence of the photoacceptor, the terminal enzyme of the respiratory chain cytochrome c oxidase, in mitochondria. It is generally accepted that mitochondria are the initial site of light action in cells, and cytochrome c oxidase is the responsible molecule. This event is a starting point for changes in cell metabolism via mitochondrial retrograde signalling [5]. Photoexcitation of certain chromophores in the cytochrome c oxidase molecule influences the redox state of these centers and, consequently, the rate of electron flow in the molecule [6]. At least four types of primary reactions can occur with irradiation. One process possibly involves acceleration of electronic transfer in the respiratory chain due to a change in the redox properties of the carriers following photoexcitation of their electronic states. It is believed that CuA and CuB, as well as hemes a and a3, are involved.

Several theories exist to explain this occurrence:

- o NO Hypothesis;
- o Transient local heating hypothesis
- o Superoxide anion hypothesis
- o Role of mitochondria.

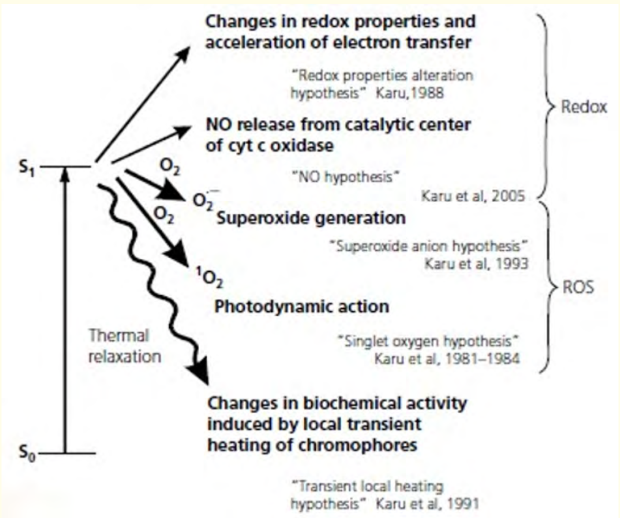

Figure 2: Possible primary reactions in the photoacceptor molecule (cytochrome c oxidase) after promotion of excited electronic states. ROS, reactive oxygen species (adapted from Karu 1999. With permission of Elsevier).

NO Hypothesis

The latest developments indicate that under physiological conditions the activity of cytochrome c oxidase is also regulated by nitric oxide (NO). This regulation occurs via reversible inhibition of mitochondrial respiration. It was hypothesized that laser irradiation and activation of electron flow in the cytochrome c oxidase molecule could reverse the partial inhibition of the catalytic centre by NO and in this way increase the O_2-binding and respiration rate under pathological conditions the concentration of NO is increased (mainly due to the activation of macrophages producing NO). This circumstance also increases the probability that the respiration activity of various cells will be inhibited by NO. Under these conditions, light activation of cell respiration may have a beneficial effect [7,8].

Transient Local heating hypothesis

Transient local heating hypothesis When the electronic states of the photoabsorbing molecule are excited with light, a notable fraction of the excitation energy is inevitably converted to heat, which causes a local transient increase in the temperature of the absorbing chromophores ("transient local heating hypothesis"). Any appreciable time- or space-averaged heating of the sample can be prevented by controlling the irradiation power and dose appropriately. The local transient rise in the temperature of the absorbing biomolecules may cause structural (e.g. conformational) changes and trigger biochemical activity (cellular signalling or secondary dark reactions [9].

Superoxide Anion Theory

It was suggested that activation of the respiratory chain by irradiation will also increase the production of superoxide anions ("superoxide anion hypothesis"). It has been shown that the production of O2 •– depends primarily on the metabolic state of the mitochondria. The belief that only one of the reactions discussed above occurs when a cell is irradiated, and excited electronic states are produced is groundless. The question is, which mechanism is decisive? It is entirely possible that all the mechanisms discussed above lead to a similar result - a modulation of the redox state of the mitochondria (a shift in the direction of greater oxidation [10].

Role of ATP

The excitation of the photoacceptor molecule by irradiation sets in motion cellular metabolism through cascades of reactions called cellular signalling or retrograde mitochondrial signalling, another signalling pathway starting in the mitochondria is connected with ATP. The increased synthesis of ATP in isolated mitochondria and intact cells of various types under irradiation with light of different wavelengths is well documented. ATP is a universal fuel in living cells that drives all biological reactions. It is known that even small changes in the ATP level can significantly alter cellular metabolism. Increasing the amount of ATP may improve the cellular metabolism, especially in suppressed or otherwise ailing cells. A long series of discoveries has demonstrated that ATP is not only an energy currency inside cells but is also a critical signalling molecule that allows cells and tissues throughout the body to communicate with one another. This new aspect of ATP as an intercellular signalling molecule allows a broader understanding of the universality phenomenon of LLLT. It is now known that neurons release ATP into muscle, gut, and bladder tissue as a messenger molecule. The specific receptors for ATP as a signalling molecule (P2 family) and for its final breakdown product, adenosine (P1 family), have been identified [11,12].

Primary responses, comprising

Vasodilation, blood circulation and lymphatic drainage enhancement, increased activity of neutrophil and fibroblast, improvement of cellular metabolism and increased stimulus threshold of pain receptors [13].

Secondary responses, comprising

- Increased concentration of certain prostaglandins such as PGL2 which has an anti-inflammatory effect.
- Increased immunoglobulins, lymphokins and their effect on the immune system.
- Increased beta endorphins and encephalins which are effective in analgesia [13].

Responses mentioned above result in physiologic responses which includes [14]:

- Stimulation of biologic system
- Effect on immune system
- Anti-inflammatory and anti-edema effect
- Effect on vessels and circulation
- Effect on wound healing
- Effect on nerves
- Analgesic effect

Application of LLLT in dentistry

Before we discuss the various uses of LLLT in endodontics, lets enumerate the general uses in the overall field of dentistry. There is now encouraging data for LLLT application in a wide range of oral hard and soft tissues and covering a number of key dental specialties including endodontics, periodontics, orthodontics and maxillofacial surgery as described below. LLLT has also been shown to have efficacy in managing chronic pain and non-healing bone and soft tissue lesions in the maxillofacial region.

The laser or LED devices applied in LLLT typically emit in the 600-1000 nm spectrum range (red to near infrared), with typical irradiance of 5 mW/cm^2 to 5 W/cm^2 and generated by devices with as little power as 1 mW, and up to 10 W. Pulsed or sometimes continuous beams are delivered. Treatment time is typically for 30-60 s per treatment point and as little as one treatment point or a dozen or more may be treated at a given time. For acute and post-operative therapy one treatment is all that is usually required however for chronic pain and degenerative conditions as many as ten sessions may be necessary. Whilst other wavelengths outside the 650-850 nm spectrum can have similar effects they do not penetrate the tissues as well as those in the red and near-infrared range [15].

To-date more than 300 randomized double blind placebo controlled clinical trials have been reported. This has resulted in publication of a number of expert consensus reports for utilizing LLLT as part of standard clinical management, including [16]:

- The Lancet - systematic review of LLLT for neck pain.
- British Medical Journal (BMJ) - systematic review and guidelines for treating tennis elbow.
- International Association for the Study of Pain (IASP) - fact sheets for myofascial pain syndrome, osteoarthritis and neck pain.
- The World Health Organization (WHO) - task force on neck pain systematic review.
- British Journal of Sports Medicine (BJSM) - systematic review for frozen shoulder.
- American Physical Therapy Association (APTA) - systematic review and clinical practice guidelines for Achilles tendinopathy.
- European Society for Medical Oncology (ESMO) - clinical practice guidelines for oral mucositis.
- Multinational Association for Supportive Cancer Care (MASCC) - clinical practice guidelines for oral mucositis.

Other uses include

- Dentinal hypersensitivity
- Bisphosphonate related osteonecrosis
- Mandibular distraction

- Mandibular advancement
- Temporomandibular joint pain
- Trauma to mandible
- Burning mouth syndrome
- Herpes Simplex Lesions
- Lichen Planus
- Oral mucositis
- Xerostomia
- Extraction Socket healing
- Paraesthesia/Alveolar nerve damage
- Orthodontic Pain
- Titanium implants osseointegration
- Accelerated orthodontic tooth movement
- Gingivitis
- Denture Stomatitis
- Canal Disinfection
- Periapical lesion healing
- Pulp vitality testing

Application of LLLT in Endodontics

There are four common clinical targets for LLLT and this include [16]:

1. The site of injury, disease or dysfunction to promote healing, remodeling and reduce inflammation
2. Lymph nodes to help reduce edema and inflammation
3. Nerves to induce analgesia
4. Trigger points to reduce tenderness and relax contracted muscle fibres.

Dentinal Hypersensitivity

Dentin hypersensitivity happens as a short and sharp pain from naked dentin in response to various stimuli. To treat dentin hypersensitivity, different anti sensitivity substances are used. In more complicated cases like reversible pulpitis, it is possible to use laser energy to help. Low level laser irradiation of cervix and apex region of sensitive teeth can be an appropriate treatment to eliminate sensitivity. Effect of this laser is more based on changes created on pulp nerve transmission [17]. It is possible to relate laser effect at the cell level to the prevention of the signal transmission of pain from peripheral to central parts as well as blocking of the depolarization of sensory C fibres. In a study Gerschman., *et al.* used low level laser with 830nm to decrease sensitivity in the dentinal region of teeth and repeated treatment in three time intervals [18]. The most reduction of sensitivity was observed after the first treatment session. Also evidence has been presented on decrease of dental hypersensitivity immediately after beginning of treatment with He-Ne laser and lasted till 3 months after treatment and all teeth remained vital as well. GaAs and GaAlAs have more penetration. Irradiation is done in the apex region but by the use of Ne-He laser, irradiation would be only possible on the teeth in relation with the anterior cervical region. Sometimes irradiation on cervix, pulp and apex is recommended. A tooth that would not respond to 4 to 6 joules of irradiation on its root for 2 to 3 sessions probably needs root canal therapy [19].

Laser therapy in treatment of wounds and periapical lesions

In a study, low level laser was used in wound healing and the result showed that: Less inflammation was observed on days 3 and 7 in the treatment group ($p < 0.01$). The inflammation rate on both sides was the same on day 14 ($p > 0.05$). LLLT using optimal parameters can accelerate full thickness wound healing. Laser therapy result in better wound healing by the following mechanisms on the 3 phases of primary inflammation, proliferative and remodeling phases [13].

- Increased synthesis of RNA, DNA and proteins
- Angiogenesis and neovascularization
- Accelerated epithelialization

Anti-inflammatory effect by affecting leukocytes and macrophages, moving metabolism toward aerobic, reduction of pain and decreased secretion of pain mediators, activation of the immune system via effect on immunoglobulins IgM-IgG and complements. Also, daily use of low level laser in a treatment course resulted in stimulation of synthesis of type I collagen fibres and strengthens the scar tissue. The anti-oedematous effect of laser energy is based on a dilation of lymphatic vessels and a reduction in the permeability of blood vessels. Laser energy has a regenerative effect on lymphatic vessels, as it has on veins [20].

Laser therapy in repairing damaged nerves

Generally, damages on nerve repair slowly. Surgeries in dentistry and endodontics can result in nerve damages. Also, Extrusion of sealers containing formaldehyde from the end of the canals can affect the adjacent nerve tissue. Use of low level laser can be a good idea for the regeneration of damaged nerve tissue in animal models use of low level laser resulted in stimulation of damaged fibers' axon growth. Protocol of laser therapy includes the use of 4-5 J irradiation for 10 days. In a double blind clinical study by Khullar., *et al.* effects of LLLT on 13 patients with antecedent of injury of inferior alveolar nerves were evaluated. In the experimental group, after treatment with low level laser, significant improvement in touch sense was observed compared to control group. For sense of heat there was no difference between the two groups [21].

Laser therapy in accelerated anesthesia

In patients experiencing problems during anesthesia, with irradiation of 2 to 3 J of laser on apex of teeth, blood circulation of the area improves and anesthesia with lidocaine is obtained sooner. In addition, the start time of anesthesia is reduced because of improvement of local blood circulation. Irradiation of 2J of laser on injection area is effective in reducing patient's pain and increasing stimulation threshold. Injection in periodontal ligament is very painful, and irradiation of 3 to 4J under papilla, well decreases pain during injection [20].

Laser therapy to reduce nausea during stages of root canal therapy and radiography

Nausea is one of the most common problems during dental treatments. Many patients have a sensitive gag reflex making dental work very stressful for both the patient and dentist. Some clinicians use acupuncture to reduce nausea. It is possible to use laser instead of special needles. For this purpose, at least 2J of energy is used in the hand wrist area and P6 Meridian point. Application of the laser to the P6 acupuncture point of the wrist will decrease the gagging and nausea sensations many patients feel during dental treatments, impressions and x-rays. The P6 acupuncture point is one of a triad of points that calms your parasympathetic nervous system. Application of these points is also effective for patients who are anxious and nervous. Application of this method was accompanied with success in more patients [20-22].

Reducing Post-Endodontic pain

Several similar studies have been conducted and have unanimously reached a conclusion that LLLT post-endodontically seem to reduce the occurrence of flare-ups or discomfort and can be an effective alternative to the conventional use of NSAIDs for controlling pain and thus reducing side-effects associated with medication. 0.5 W irradiated for 30 secs, using a bleaching tip at the level of root apices shows good pain reduction [23-26].

Kreisler., *et al*. concluded in his study that postoperative pain relief after apicectomies can be achieved irradiating the operation site subsequent to suturing. The irradiation parameters in this study were chosen deliberately and laser treatment was per-

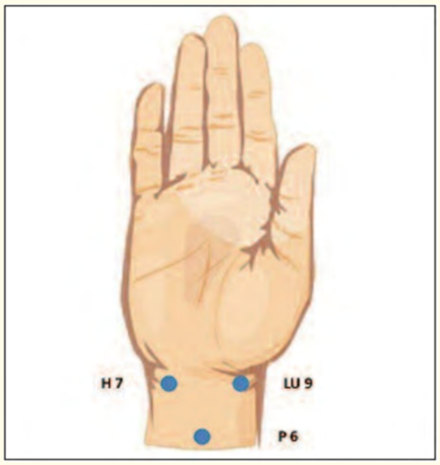

Figure 3: A graphic diagram of three parasympathetic calming acupuncture points for reduction of nausea and gagging. Courtesy of Donald j. Coluzzi, DDS. Adapted from Atlas of acupuncture points. Point locations [Internet]. Published by www.acupuncturePeoducts.com, 2007. [Cited 2009 Dec 28.] 39 p. Available from: http://chiro.org/acupuncture/ABSTRACTS/Acupuncture_Points.pdf.

formed once since no generally acknowledged recommendations are available. Although a slight positive effect was evident until the end of the follow-up period, the differences were significant on the first postoperative day only. operation site treated with an 809 nm-GaAlAs-laser (oralaser voxx, Oralia GmbH, Konstanz, Germany). A 600 micron optical fibre and an application tip was used to ensure a constant distance of 10 mm from the end of the fibre to the tissue. Power output was determined by means of an energy meter was 50 mW (cw-mode). The operation site was irradiated for 150 s with overlapping movements over the operation wound. The total energy applied was 7.5 J [27].

Antimicrobial Photodynamic Therapy

Unlike high-power lasers, low-power lasers do not increase tissue temperature [28]. Thus, when used alone, the same antimicrobial effect as that of high-power lasers in periodontitis active sites cannot be expected [29]. The antimicrobial effect low-power lasers is achieved by association with extrinsic photosensitizers, which results in the release of highly reactive oxygen species [30] that cause damage to membranes, mitochondria and DNA, culminating in the death of the microorganisms. This is the process of a PDT, and its use is being increasingly studied with the aim of complementing the microbial reduction achieved by conventional mechanical periodontal therapy.

Prado., *et al.* conducted a study evaluating the effect of photodynamic therapy on the improvement of sealing penetration efficacy and adhesion of sealer to canal walls using MTA Fillapex and AH plus, however no immediate statistical improvements or benefits were observed [31]. More studies are needed with variable parameters to further evaluate this finding and come to a definite conclusion.

Souza., *et al*. in her study concluded that in conclusion, the present study confirmed that the instrumentation/irrigation procedures significantly reduced bacterial populations in the canal. Chemomechanical preparation (instruments plus NaOCl) was confirmed to be more effective than mechanical preparation (instruments plus NaCl). Although the additional use of PDT promoted some reduction in the intracanal populations of an endodontic strain of *E. faecalis* after instrumentation/irrigation, the effects did not reach statistical significance [32].

In another study, Fimple., *et al*. investigated the photodynamic effects of methylene blue on *Actinomyces israelii, F. nucleatum, P. gingivalis and P. intermedia* in experimentally infected root canals of extracted teeth and found up to 80% reduction of colony-forming unit counts when root canal systems were incubated with methylene blue (25 μg/mL) for 10 min followed by exposure to red light at 665 nm with an energy fluence of 30 J/cm [33].

Pulp Vitality diagnosis

The laser is applied to the apex of each tooth until the patient feels a pain response, indicating the affected tooth. The laser is then taken away for one minute to allow the inflammatory chemicals to drain and then reapplied to the affected tooth. Patient should feel immediate pain, indicating it is a case of irreversible pulpitis [22].

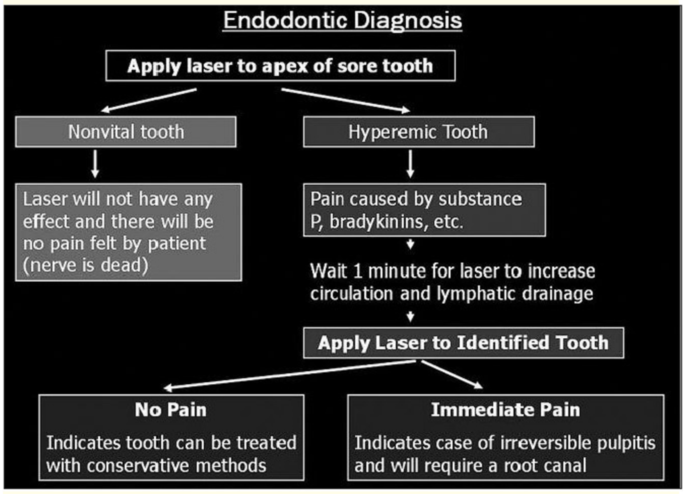

Figure 4: Flowchart for endodontic diagnosis.

Faster wound healing post-operatively

Wound healing consists of several distinct phases, all of which can be affected at the cellular level by LLLT. The initial, pro-inflammatory and vaso-active phases of inflammation include clotting of any cut blood vessels and deposition of a platelet plug, after which the site is infiltrated by neutrophils and macrophages. The second phase of wound healing involves proliferation, with the formation of granulation tissue as a result of new blood vessel growth. Direct evidence for enhanced collagen gene expression both in skin fibroblast cultures *In vitro*, as well as in animal models of wound healing *In vivo,* has been presented [34]. A final aspect of the effect of LLLT on cells relates to the effects of laser light on the cytoskeleton. Several studies have suggested that LLLT can modulate cell behaviour by causing re-arrangements of the cytoskeleton [35,36]. Faster wound closure is of great importance in compromised patients, such as diabetics, and patients undergoing treatment for malignancies. Because LLLT can enhance the release of growth factors from fibroblasts, and can stimulate cell proliferation, it is able to improve wound healing in such compromised patients. Histological studies have demonstrated that laser irradiation improves wound epithelialization, cellular content, granulation tissue formation, and collagen deposition in laser-treated wounds, compared to untreated sites [37,38]. These findings have been confirmed in oral mucosal wound healing in clinical studies in humans.

LLLT in traumatized permanent dentition

Endodontic treatment is necessary after extrusive luxation of a tooth with completed root formation. Healing of the periodontal ligament will determine prognosis. When a normal ligament is obtained during healing, the tooth can be preserved for a long period. When progressive replacement resorption (ankylosis) develops, most teeth can remain in position for about 10 years. When inflammatory resorption develops, the tooth will be lost within a short time. The wound-healing mechanism for LLLT was reported previously. Studies on wound healing and pain relief are highlighted to show the clinical efficacy of laser therapy. In examining the effects of LLLT on cell cultures In vitro, some articles report an increase in cell proliferation and collagen production. Although there have been several studies that have addressed the action of LLLT on bone repair, osteogenesis, pulpal tissue, and the dentin repair process, there are no reports on its effects on teeth displaying periodontal tissue injury during orthodontic treatment.

In the present case study, the author decided that LLLT should be used in this case as a supplementary treatment originally, in view of these reported developments and effectiveness on wound healing, bone repair, and osteogenesis. However, the fast occurring healing observed in the patient caused a change of mind, and the authors decided not to perform endodontic treatment and to continue with only the LLLT treatment.

After the end of the LLLT, positive responses were obtained with the help of pulpal vitality tests for every incisor tooth in which negative responses were obtained just after the dental trauma. Furthermore, no color change in the crowns of the related teeth was observed. Symptoms such as sensitivity to percussion or spontaneous pain were not detected clinically, and no resorption was found either in the root or bone structure in radiographic examinations [39].

Safety regarding LLLT [40]

Since the radiation type that is used, is NIR (Near Infra-red radiation), they are basically nonionizing in nature and pose minimal risks at low levels as they do not increase the temperature of tissues. The principle risks with the use of lasers are associated with eye damage. Destruction of retinal photoreceptors may occur after a transient increase in 10C to the cells, due to the lens' focusing ability on the retina, even in low power settings. Once concentrated, they could rapidly produce damage. Low level lasers receive Class III hazard ratings because the use poses the potential for retinal damage and hence must never be operated without the appropriate wavelength eye safety glasses.

Conclusion

Based on results of reviewed articles, low intensity laser therapy can accelerate disinfection and healing in endodontics, with periapical bony lesions and post-surgical analgesia and healing associated with apicectomies. The mechanism of action might be through stimulation of cellular proliferation and differentiation and result in accelerated healing process.

Thus, it is necessary for any practitioner to recognise and advocate the use of lasers as an alternative and complimentary method of providing soft and hard tissue dental procedures for infants, children, adolescents, and persons with special health care needs, including geriatric patients. At the same time, it is necessary to stress on the fact that the dental professionals receive additional education and training to make the use of LASERS safe and predictable.

Even though the advantages and uses are numerous and with time the efficiency will undoubted increase and so will the applications, there are some disadvantages of laser use which can be enumerated as below:

- Different wavelengths are needed for various hard and soft tissue procedures; the dentists may need more than one type of laser.
- It requires specialized training and education for various clinical applications.
- High start-up costs are required to purchase the equipment, implement the technology and investment.
- Additional preparation with high speed dental handpieces maybe required to finish tooth preparations.

However, notwithstanding the above limitations, it has become a necessary investment in every dental clinic and with hope that with further research and development, the investment cost will come down.

Conflict of Interest

No conflicts of interest present between authors.

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