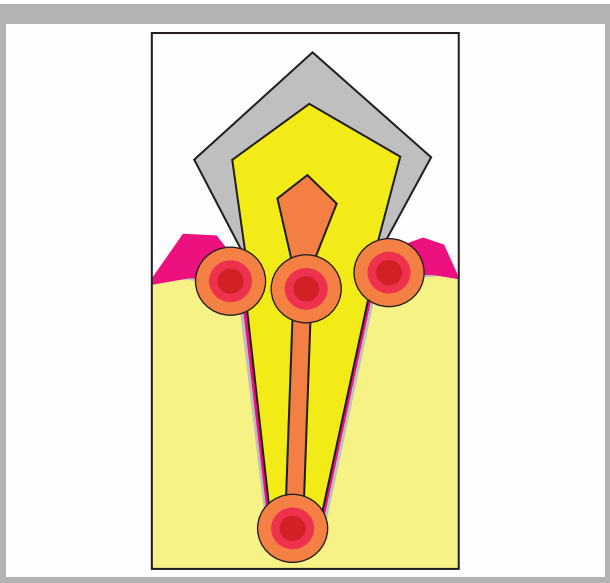
Abstract: Dentin hypersensitivity is a common condition associated with high dental pain. A new LED-based (light emitting diode) light source has been used as an experimental tool in some studies. Purpose: The main objective was to compare these two light sources emitting in the same spectral band (red – from 625 to 660 nm) to promote pain relief. Material and methods: A total of 6 sessions were accomplished, being three irradiation sessions and three follow-up sessions. This single-blind study compared a control group (Placebo) and two other groups with different equipments: low laser intensity treatment (LILT) and a light emitting diode system treatment (LEDT). Results: The results showed that there is no statistical difference between LILT and LEDT groups, however, both were better than control group ($p \leq 0.01$) in terms of treatment efficiency; there is no difference between the second and the third sessions for both treatment, it means that the third session was not necessary; finally, the improvement at the end of the entire research (follow up care of 30 days) was very expressive in comparison to pre-treatment situation for all teeth ($p \leq 0.01$). Conclusion: LILT and LEDT were equally effective to treat dentine hypersensitivity, a 3rd treatment session was not necessary/two sessions are enough.



Irradiation spots (3 at the cervical area and 1 at the apex)

Dentin hypersensitivity clinical study comparing LILT and LEDT keeping the same irradiation parameters

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Received: 7 June 2010, Revised: 15 June 2010, Accepted: 18 June 2010
Published online: 31 August 2010

Key words: laser; LED; LILT; LEDT; dentine hypersensitivity; pain relief

1. Introduction

Cervical dentin hypersensitivity can be caused by external stimuli as cold, heat, contact with solutions (sweet and sour) as well as pressure, it can happen whenever the exposed dentin surface is stimulated by any irritating agent. The more accepted theory regarding the dentin sensitivity is the "hydrodynamic theory of the pain", proposed by M. Brännström in 1982. According to this theory dentin hypersensitivity reduction can be achieved through the occlusion of the exposed dentinal tubules [1–3].

Laser is a phototherapy resource widely used for dentistry and medical proposes as tissue repair (bones, tendons, nerves, and muscles), destruction of malignant tissues as tumors (photodynamic therapy – PDT), inactivation of microorganisms (photodynamic antimicrobial

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chemotherapy – PACT), and survey of physical-chemical data from a sample (spectroscopy) [4–17].

The low intensity laser therapy has been widely applied in the cervical dentin hypersensitivity treatment minimizing the discomfort caused by this clinical problem. In long term, this acts at cellular level, increasing the cellular breathing with production of energy (ATP) and thus increasing the production of tertiary dentine which leads to the sealing of the dentinal tubules [18,19].

The pain relief or analgesic mechanism promoted by the infrared laser irradiation occurs when the light acts over cell membrane leading to a hyper polarization due to photo physical changes as a result of the biological light-cell interaction. The cytoplasmic membrane permeability increases to Ca^{2+}, Na^{2+} and K^{+} ions. As a consequence, the endorphin synthesis and the neural cells potential action are increased while there is a decrease on the bradykinin amount as well as on the activity of the pain stimuli conduction C fibers [20]. This sequence of events results in pain relief.

On the other hand, the laser irradiation emitting on the red spectral band will induce photo excitation changes on the reduction potential of the oxidize C cytochrome and also on the flavin components leading to other reduction reaction (redox) and modulations in biochemical reactions through the cell membrane. To discuss this mechanism two pathways are suggested: reduction-oxidation regulation and ATP intracellular control. The diversity and versatility of the low intensity laser irradiation on the respiratory chain is due to the light interaction on the redox regulation mechanism, which may be fundamental for certain irradiation effects on for instance, in the chronic inflammation process, ischemia and chronic wounds healing, these clinical conditions are all characterized by acidosis and hypoxia.

With the advent of new light emitting diode (LED) based light sources, the need for further clinical experiments aiming to compare the effectiveness between them is paramount. The LED system therapeutic use can be denominated as light emitting diode therapy (LEDT).

According to A. Ostuni et al. [21], considering the phosphorylase oxidation process a LED-based system emitting at a wavelengths on the red band ($\lambda = 650 \pm 20$ nm) with an output power of 0.20 mW irradiating an enzymatic solution promote the decreased of the NADH and oxoglutarate concentration of about 25% when compared with the control and laser groups (HeNe laser, 632.8 nm, with power settings of 1.7 and 10 mW). This means that the LED system was more efficient to stimulate NADH oxidation process to NAD^{+} than laser systems. However, the free H^{+} ions excess inside the mitochondria changes its membrane electric potential unbalancing the proto motor force leading to edema and consequently unbalancing the cell metabolism.

Some studies have demonstrated satisfied clinical results using LED therapy to pain relief and tissue repair [22–26], as a similar light source than laser therapy is. Even in animal test [27], it is a fact.

Figure 1 (online color at www.lphys.org) LILT equipment (Twin Laser, MM Optics, São Carlos, Brazil)

It is expected that with the use of a LED system, the same or even better results than with the laser intensity treatment (LILT) system are obtained, once both present similar wavelengths. Considering that the LED system is as effective as the LILT system, the same treatment protocol can be possible, with the same effectiveness, however with cheaper equipment.

The objective of this clinical study was to compare the effectiveness of two devices emitting at red band to treat cervical dentin hypersensitivity using low intensity laser equipment emitting at wavelength of 660 nm and a LED-based (light emitting diode) system emitting at 630 ± 10 nm. Both light sources emit at the same spectral band (625 – 660 nm), being the difference only regarding the coherence characteristic.

2. Materials and methods

A total of 120 premolars teeth, from fifteen male and fifteen female patients, with at least one premolar in each quarter presenting cervical dentine hypersensitivity, with absence of endodontic treatment indications, restorative treatment, decay and severe periodontal disease were selected.

In this initial evaluation a fast air blast (3 seconds) was applied in the cervical region, being considered only the sensitive elements for the treatment.

Following the pain evaluation, the patients were randomly assigned in three groups: Group A (LILT irradiation), Group B (LEDT irradiation), and Group C (Sham illumination), forty premolars in each group. All the groups went through 2 irradiation procedures with 72 hours interval and 3 follow-up sessions with intervals of 72 hours (second session), 15 and 30 days after the last application.

Figure 2 (online color at www.lphys.org) LEDT equipment (a prototype – MMOptics, São Carlos, Brazil)

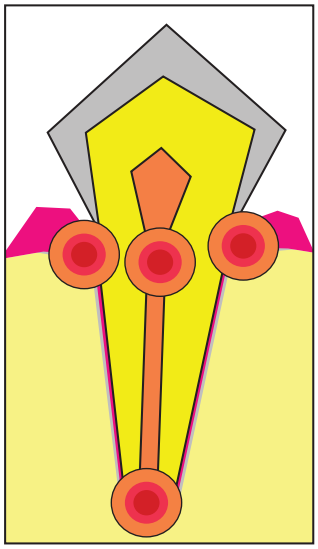

Figure 3 (online color at www.lphys.org) Irradiation spots (3 at the cervical area and 1 at the apex)

All the patients received oral hygiene instruction throughout the study, which was consisted of daily use of free-alcohol oral rinse (Malvatricin Branqueador, Daudt, Divisão Odontis, Brazil), daily dental floss use and correct brushing technique.

LILT equipment, twin laser (MM Optics, Divisão Laser, São Carlos, São Paulo, Brazil), with two therapeutic handpieces, one emitting in the infrared (780 nm) and one in the red band (660 nm) were used (Fig. 1). The 660 nm handpiece with power setting of 25 mW was chosen. The laser beam transversal section was of 4.0 mm^2.

LEDT equipment used in this study was a prototype specifically designed for this experiment (MM Optics, Divisão Laser, São Carlos, São Paulo, Brazil). This device emits at a spectral band of 630±5 nm presenting a constant power of 25 mW (Fig. 2). The spot size of 4.0 mm^2 presents the same size of the low intensity laser system.

Both systems present the same delivery tip being the lens the only difference feature in order to focus the light beam from the laser source to the target tissue. These tips, at the edge of the handpiece, do not present any acrylic or glass nozzles. The delivered power value was measured at the handpiece edge covered by a PVC film (Cristal clear PVC film, Goodyear, Americana, São Paulo, Brazil), using a power meter (Fieldmaster, Coherent, Palo Alto, CA, USA) in order to assure the real output power of 25 mW for the LILT and 25 mW for the LEDT.

3. Dosimetry

For the dose or fluency or energy density (D) [J/cm^2] calculation, the formula shown below, was used where the area (A) [cm^2] corresponded to the laser beam transversal section at the handpiece tip; the power output (P) [W] corresponded to the constant and maximum average power to both of sources (25 mW or 0.025 W); and irradiation time (T) was measured in seconds (10 seconds):

$$D[\mathrm{J/cm^2}] = \frac{P[\mathrm{W}]\,T[\mathrm{s}]}{A[\mathrm{cm^2}]}\,.$$

4. Irradiation protocols

The applications were made on the cervical area of the teeth with hypersensitivity at three cervical points and at the apical region (Fig. 3), following the methodology suggested by E.B. Groth [28] and B.C. Donato and S. Boracks [29]. The irradiation mode was always in contact with the area. The irradiation at the tooth apex had the objective to biomodulate the C fibers, while the irradiation at the cervical area aimed to reach the A-delta fibers of the dentin [18].

Based on previous hypersensitivity studies an air blast was used to evaluate the painful sensitivity. According with M. Brännström [2] the air blast during 3 seconds generates a dentinal tubule fluid dehydration and the nerve fibers and odontoblasts are stretched or turn off. This test has been the most used in dentin hypersensitivity studies.

For the pain measurement procedure a "+" signal was used for pain relieve while a "–" signal for absence of relieve, a "=" was used to characterize absence of response. This was applied to measure the closest personal possible pain reaction from each patient in specific days and moments. Due to the subjective nature of the pain sensation the use of another evaluation form or even a visual analytical scale (VAS) scale widely used amongst several

researchers would be extremely limited and not accurate enough [30–33].

For the placebo group, the irradiation was done with the device off (LEDT) and sound came from the other equipment turned on (LILT) next to patient head. It means that this study was a single-blind study.

As most of the papers [34–37] do not present difference on the obtained results regarding the wavelength used, if red or infrared, more relevant variables were controlled in this present study as the output power, dose or fluency (energy density) and the light source coherence was the tested variable [38].

Irradiation parameters were the same for both sources LILT (660 nm) and LEDT (630±5 nm): 25 mW – 10 sec – 6.0 J/cm^2, 10% less because of the PVC film, resulting in 5.4 J/cm^2, at each irradiation spot for both light sources.

Since the LED-based system presents a coherence wavelength shorter than the laser, the initial hypothesis was that if the power setting used was around 10 times higher than the laser system, then maybe the low coherence could be compensated for therapeutic purpose. In a previous work [22], we did such investigation, however the high power of the LED system [230 mW of average power] generated an increase in temperature in dental crystalline tissue. The composition and morphology of the dentin conducts the light as a wave guide, therefore the heat reaches the pulpal tissue without significant attenuation, and it can cause severe harm and inflammation on pulpal connective tissue.

Throughout the study development, the same devices were used. All the patients signed a consent form for the treatment, describing the risks and benefits of the respective treatments being included in the study the ones who signed and fully agreed with all the statements in the informed consent.

Treatment sessions were in a total of three, every 72 hours (sessions 1, 2, and 3), with three follow-up sessions with intervals of 15 and 30 days from the last application (sessions 4 and 5).

Treatment had the following protocol: prophylaxis with pumice powder and hydrogen peroxide 3%, followed by the sensitivity test with air blast for 3 seconds, irradiation treatment, new sensitivity test (sessions 1, 2, and 3). On the follow up sections a new prophylaxis were performed as aforementioned; the prophylaxis aimed to eliminated any residues form tooth surface that could concealed the results and new sensitivity tests were performed (3 s air blaist) (sessions 4 and 5). The sham illumination group received the same sequence, with the laser off, however without the patients' knowledge.

5. Results

The obtained data concerning the teeth improvement (+), worsening (–), and no change (=) was statistically analyzed using the Poisson model. Chi square test was applied to evidence statistically significant difference.

Comparison among groups (placebo, LEDT and LILT) has shown a significant difference with $p > 0.01$.

Evaluating the likelihood ration (LR) we observed for the "improvement" (+) event, a significant difference at a 1% level among treatments, times (1, 2, and 3 irradiation) and moments (before and after irradiation). Through the analysis of the estimate model parameters we observed that among treatments there was a significant difference among placebo and LEDT and LILT but there was no difference between the two treatments. For the times (first, second and third irradiation) there is a significant improvement between time 1 (first irradiation) and time 3 (third irradiation), and time 2 and 3 were considerate equal. There is a significant improvement between moments (before and after irradiation). There is a significant difference between time (appointments), but there is no difference between treatments and moments (immediately before and after irradiation) for the "unchanged" event (=). Through the analysis of the estimate model parameters we observed that there is no difference between control and experimental groups. For the time variable there is a significant difference between times 1 and 3, and no differences were detected between times 2 and 3. There was an improvement on the first time but the same level of sensitivity was kept. No differences were detected between moments before and after irradiation.

There was no significant difference between treatments, sessions and moments (pre and post-application) for the "worsening" (–) variable. Through the analysis of the estimate model parameters we observed that there is no difference among control and experimental groups. No differences were detected among appointments neither on moments (before and after irradiation).

Evaluating these results, it was possible built some graphs (Fig. 4 – Fig. 7). All graphs show the sensibilities reported by patients just after treatments, long term analysis (compare first to second section for instance) would be too subjective since it is very hard to compare levels of pain in different days and conditions.

Fig. 4 shows results considering measures at the first session. Considering "improvement" event, there is 1% of statistically significant difference between all groups. Indeed, LEDT shows a higher percentage of events in comparison to LILT, but both groups using light were better than control group (Placebo).

Fig. 5 shows results considering measures at the second session (72 hours after the first session), just after treatment. Again, the "improvement" event shows higher values to LEDT and LILT, higher than control group (Placebo). Besides, while "improvement" event increases from Placebo to LILT (evaluating x axis), at the same way, "worsening" event decreases following the same direction, being the highest to Placebo group and the smallest to LILT treatment.

Considering follow up care, we have measured at 15 and 30 days after the third session of treatment.

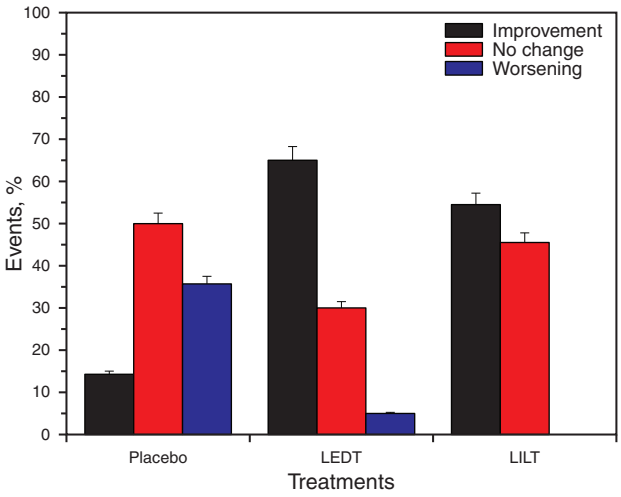

Figure 4 (online color at www.lphys.org) Results considering measures at the first session, just after treatments done

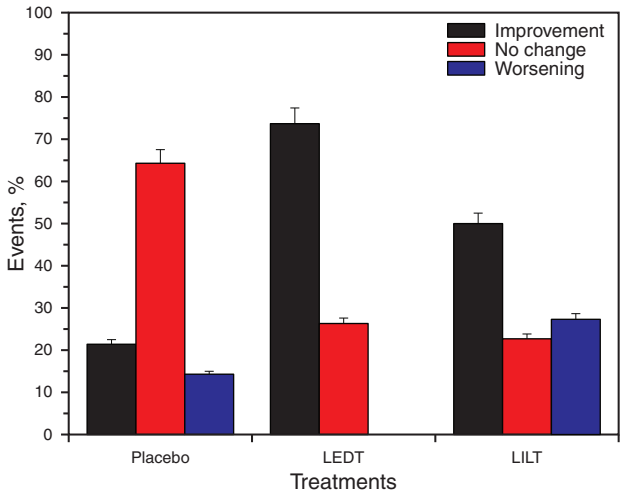

Figure 6 (online color at www.lphys.org) Results considering measures at follow up care 15 days after the second session

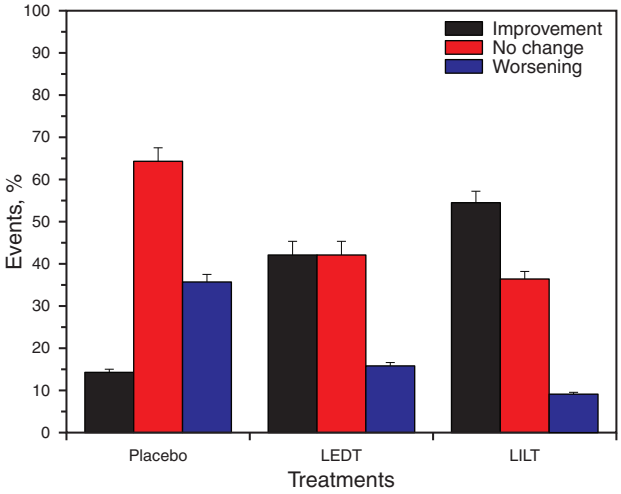

Figure 5 (online color at www.lphys.org) Results considering measures at the second session (72 hours after the first session), just after treatment

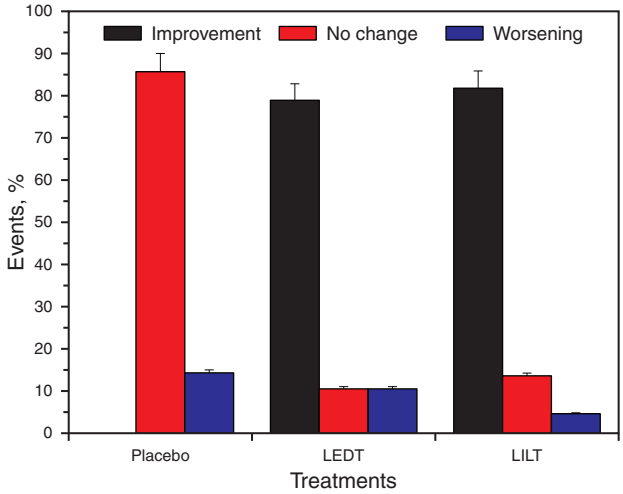

Figure 7 (online color at www.lphys.org) Results considering measures at follow up care of 30 days after the second session

6. Discussion

The doses applied in this study were established in previous works and they are not dangerous to the dental structure, during the course of this study all teeth had their vitality preserved.

The low intensity laser effect is well report in literature. LILT after biofilm removal promoted, as observed in our study, an increase in the pain threshold and a biostimulation, which should have accelerated the cell activity. One of the mechanisms purpose is an initial enhancement on the inflammation process on pulpal tissue, this event may take place on the first session allowing a more efficient production of secondary dentin by the target odontoblasts on the irradiated area, which was already demonstrated in previous study [39].

The notorious point is the uncovered dentin on the cervical area receiving continuous aggressions which leads to a painful sensitivity. This process will lead to a restart on the inflammation process as a normal physiological response. The central goal is to understand the length of the effect of the irradiation, and it can act until a new inflammatory event is installed.

It is important to highlight that for the Placebo group the exposed dentin prophylaxis may had act as a stimulus

that might had contributed to secondary dentin production [40]. However, it was not sufficient to be significantly different to others tested conditions. Placebo group kept percentage events of worsening during the entire study, giving us consistent support to think that LEDT and LILT are efficient to treat dentin hypersensitivity.

It is important to emphasize that on the same appointment, no statistically significant differences were found among the 3 treatments (Placebo, LILT, and LEDT), considering the three different events: improvement, unchanged or worsening. Therefore, the importance of an appropriate follow up (at least 30 days) is enhanced, and crucial to the precise evaluation of any given treatment.

Analyzing the "improvement" event, which is the main goal of the clinical research, both light sources presented a better performance than control group, but they were considerate equal to each other, therefore LILT and LEDT present the same capability on pain control in dentin hypersensitivity. Besides, the results showed that the two first appointments were enough to achieve the desire outcome, which was maintained on the third appointment, this result is in accordance with previously published work [22] that suggested that two irradiation appointments were adequate for this type of pathology. It is possible to observe on Figures 4 and 5 that the irradiation with both light sources always promoted an improvement, meanwhile on the control group there is 50% increase on worsening.

On the 30 days follow up we observed that 85% of the data on the control group presented an unchanged outcome, thus it is quite obviously that the placebo treatment did not promote any alterations on dentin hypersensitivity, even thought a professional cleaning had been done, as part of the clinical protocol, to obtain the sensibility measurements. On the other hand, on the 15 days follow up as well as on the 30 days records both light sources, LILT and LEDT presented at least a 50% of improvement. On the 15 day analysis the LEDT presented a better performance than LILT with a 23% rate, though on the thirtieth day analysis both light sources had a similar performance with an 80% rate on "improvement".

Concluding, since the "improvement and "unchanged" events were the major response compare with the "worsening" event, for LILT as well as for LEDT, the results of the present study indicate that both light sources, on the spectral range from 625–660 nm, with the applied parameters, under low power density (25 mW) are capable of reducing pain on the dentin hypersensitivity pathology, and the mechanism underlying this action may be the reactional dentin stimulation towards the tooth external surface, promoting an physiological sealing in a non aggressive way.

7. Conclusions

The model used as well as the parameters applied in the present study suggested that LILT and LEDT are equally efficient treatments for cervical dentin hypersensitivity, it means that the more important parameters could be power output, fluency or dose and spectral band, not coherence. A 3rd treatment session was not necessary/two sessions were enough.

More studies are paramount to prove to real effectiveness of the LEDT for this kind of treatment, considering different spectral bands and total energy.

Acknowledgements We would like to acknowledge CePOF/IFSC-USP and FAPESP, for the financial support; to MM Optics Ltda., for building and donating LED prototype system to our Biophotonics Laboratory at IFSC-USP.

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