

# Low and High output power of 810nm Diode Laser: a new combined protocol to treat the Dentine Hypersensitivity evocated in presence of Non-Carious Cervical lesions.

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## Research article

**Keywords:** Dentin Hypersensitivity, non carious cervical lesions, diode laser, LLLT, High power laser therapy

**Posted Date:** August 10th, 2020

**DOI:** <https://doi.org/10.21203/rs.3.rs-49259/v1>

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# Abstract

**Background** The current study evaluates the desensitizing effect of the combination of two different output powers and compares it with single power diode laser.

**Methods** Sixty-nine non carious cervical lesions (NCCLs), responsible of pain by DH after application of test of cold stimulation, were considered for this research. Three study groups were established by analyzing only one lesion in 3 different selected quadrants of the oral cavity in order to obtain a minimum of 3 lesions per patient to treat individually with different therapeutic protocols. All treatment protocols were carried out using a diode laser with different power outcomes used singularly or in combination (810 nm, 5W). The pain by DH was evaluated at baseline, at treatment completion, at 15 days and at 3 months after each laser procedure. Data analysis was performed using Wilcoxon test for paired samples, one-way ANOVA test and unpaired t-test.

**Results** The significant reduction of the mean VAS score has been estimated in each study group immediately, at 15 days and at 3 months' time from the end of treatment and compared with the baseline mean VAS score (p-value < 0.0001). The best result concerning the improvement of DH symptomatology was assessed when a combined protocol of two different output powers of diode laser was used.

**Conclusions** The author offers a new protocol of laser therapy combining two different output powers of the 810 nm diode laser to improve painful symptoms of DH from NCCL in the short and long term.

## Background

An international workshop describes DH as follows: "Dentine hypersensitivity is characterized by short, sharp pain arising from exposed dentine in response to stimuli, typically thermal, evaporative, tactile, osmotic or chemical and which cannot be ascribed to any other dental defect or pathology" [1]. DH is an annoying condition which frequently affects individuals aged 30 to 40 years old and it is often associated with non-carious cervical lesions [2]. DH occurs when dentinal tubules are exposed to the oral environment and this is well explained by the hydrodynamic theory of Brännström[3]. This theory suggests that the abrupt movement of fluids within the dentinal tubules causes the dripping of these fluids into the oral cavity leading to excessive production of new liquid in the same tubules. The movement of the dentinal fluids represents the main factor for the activation of pulpal receptors responsible for pain sensations, therefore the tubules must be both exposed and not occluded for the pain to be stimulated [4]. The severity of symptoms does not depend on the breadth and depth of lesions, but on the number of non-occluded tubules exposed to the oral cavity, consequently the sealing of exposed and patent tubules should reduce or eliminate the pain and discomfort of the patient. Several treatments belonging to the tubule-occluding agent family [5] have been proposed including protein binding and calcium compounds deposition within tubules with casein phosphopeptide[6], peritubular mineral deposition and sodium fluoride (NaF). Unfortunately, these treatments, as well as the use of nerve depolarization therapies (topical potassium nitrate), could be ineffective or might produce short-lived

desensitizing effects [7]. Various studies have also evaluated the use of several lasers with different wavelengths highlighting an equal or better desensitizing effect than fluoride varnish, potassium nitrate gel and Gluma desensitizer. Regrettably, there are conflicting evidences amongst the authors on which laser achieves the best outcome for the treatment of DH. In fact, Yilmaz et al. [8] reported an equal desensitizing effect for diode laser and Er,Cr:YSGG lasers while Dilsiz et al. recommended that Nd:YAG laser is more efficient than diode laser[9].

It is likely that lasers with different output powers ranges impinge on DH with two different mechanisms: high-power lasers melt the surface peritubular dentine while low-power lasers cause anti-inflammatory effects which increases the metabolic activity of odontoblasts causing production of new dentine.<sup>9</sup>

The aim of this study is to evaluate the effectiveness of diode laser on pain caused by DH associated with NCCLs comparing three different laser therapy protocols: high and low power used individually compared to a combined method using before the low and then the high-power laser.

## Methods

Four operators, three experienced clinician and a non-clinical researcher, were recruited to avoid bias in carrying out the study and in the interpretation of the results.

The three clinicians were recruited to perform the following functions: enrollment of subjects affected by DH related to NCCLs, evaluation of pain intensity per lesion after cold test and administration of the treatments in analysis. The non-clinical researcher was responsible for determining which NCCLs to treat with DIODE LASER. Lastly, the operator responsible for the enrollment of the subjects also carried out the analysis of the cold test data.

## Selection of lesions

The buccal, lingual and palatal surfaces of the teeth of 172 subjects (88 females and 84 males aged 24 to 70 years old) arrived from January 2017 to July 2019 at the conservative outpatient department of University of Campania “Luigi Vanvitelli”, were examined by the first operator using a probe tip and a x4 magnifying lens. The tip of the probe was held perpendicularly to the tooth surface and inserted to the bottom of the gingival sulcus crossing the cement-enamel junction (CEJ). Any irregularity to cervical enamel and at the CEJ of the teeth were considered as NCCLs. All subjects signed an Informed Consent after verbal and written information on the study were provided.

The procedures of this study were in accordance with the institutional and national ethical standards on human experimentation and the Helsinki Declaration of 1975, as revised in 2000 and it was approved by Ethic committee of AORN of Ospedale dei Colli with N. 1374.

The first operator selected 87 patients (47 females and 40 males aged 24 to 70 years old) who complained of dentine hypersensitivity symptoms related to NCCLs and a total of 372 NCCLs were

selected based on the inclusion and exclusion criteria set for the study.

Inclusion Criteria: (1) presence of NCCLs on the vestibular surface of the tooth; (2) age  $\geq$  18 years old; (3) able to provide Valid Informed Consent.

Exclusion criteria: (1) association of the NCCLs with periodontal pockets or gingival recession; (2) additional presence of a carious lesions on the affected tooth or a pre-existing restoration; (3) evidence of cracks; (4) previous endodontic treatment or exhibited negative cold test; (5) primary teeth and subgingival NCCLs.

The second investigator, blinded to the protocol selection applied for each treated tooth, was employed to examine the intensity of pain sensation elicited by each NCCL using a cold stimuli tests according to the following timeline: baseline (t0), at treatment completion (t1), at 15 days (t2) and at 3 months' time (t3). The intensity of pain was measured using a visual analogue scale (VAS) by which patients can report their perceived pain level with a grade ranging from 0 (the best possible pain status) to 10 (the worst possible pain status).

## **Test of cold stimulation (TCS)**

The degree of tooth sensitivity to cold was determined by an air stimulus defined as a 3-second cold air blast (temperature range of 19 – 20 °C) at a distance of 2–3 mm from the test site. The tooth under examination was isolated using cotton rolls and by shielding the neighboring teeth with the gloved fingers of the operator. All patients were asked to report their degree of pain for each NCCL after TCS using the VAS scale at each point of the timeline previously described.

Only NNCLs associated with DH scoring 6 to 9 on VAS after TCS were included in this study. Three study groups were established by analyzing only one lesion in at least 3 different quadrants of the oral cavity in order to obtain a minimum of 3 lesions per patient to treat individually with different therapeutic protocols.

Allocation to the specific study group for each NCCLs was achieved by the third operator using a randomization software, as Random allocation software [10].

Moreover, all patients with NCCLs associated with DH underwent an anamnestic analysis with the intention to discover and eliminate the causal factors. Instructions were provided on adequate management of oral hygiene to carry out at home and proper dietary requirements.

The selected teeth with NCCLs were flossed and polished before administration of the treatment and cotton rolls were used for isolation.

## **Laser treatment session**

The third operator carried out all treatment protocols using a fiber of 400  $\mu$ m diode laser (Soft Touch, Creation Medical Laser; 810 nm, 5W) with a distance of 1–2 mm from the dental surface and vertical and

horizontal movements to cover the entire surface of NCCL of each tooth evaluated in order to avoid the production of thermal effects within the tooth. Three different laser treatments (LTs) were used: low and high output powers used individually and a combined method using before the low and then the high-power laser.

The set parameters of each LT for the study groups were:

SG1: 0.2 Watt in continuous emission (CW) for 60 seconds and treatment repeated after 24 hours (Low Level Laser Therapy, LLLT);

SG2: 2 Watt in pulse mode for 60 seconds and treatment repeated after 24 hours (High-power laser therapy: HPLT); SG3: NCCLs were treated with combined diode laser therapy. In details, the same lesion was exposed to a first stage of laser treatment following the LLLT protocol with the same parameters used for the SG1. After 24 hours, the same lesion underwent a second session of irradiation applying the HPLT protocol as the one used in SG2-HPLT (Low-High combined Laser Therapy: LHLT).

## Statistical analysis.

The mean and the error standard of the VAS score at each time point (t0, t1, t2, t3) were estimated for each study group. Data analysis was conducted using the Wilcoxon test for paired samples to assess for significant differences among the averages observed at time t1, t2 and t3 time compared to the time t0 in each study group. The mean of VAS scores obtained at t0 for each patient were compared among the three study groups applying a one-way ANOVA test. An unpaired t-test was applied to compare the averages of VAS scores for the pairs: SG1 vs SG2, SG1 vs SG3, SG2 vs SG3.

All the statistics used for the data analysis are implemented in GraphPad Prism V 6.0. Values of  $p < 0.05$  were accepted as statistically significant.

Moreover, in each study group the mean residual pain ( $P_i$ ) was estimated evaluating the mean VAS score at t1, t2 and t3 times against the mean VAS scores of t0. The formula applied was:

$$\text{Formula [1]:} \quad \text{for } i=0, 1, 2, 3 \quad P_i = \frac{(\text{Mean VAS score})_{t_i}}{(\text{Mean VAS score})_{t_0}} \times 100$$

Then, the improvement of DH symptomology was obtained as difference between 100, the best possible result, and the mean residual pain ( $P_i$ ) estimated at t1, t2 and t3 times. The formula applied was:

$$\text{Formula [2]:} \quad \text{for } i=0, 1, 2, 3 \quad I_i = 100 - P_i$$

## Results

The study sample used for our analysis is composed of 69 NCCLs associated with DH and belonging to 23 patients, of which 15 are females and 8 males and with a mean age of 41.4 years. Only the NCCLs that observed the Inclusion and Exclusion criteria, reported in the Material and Methods section, and that shown a VAS score ranged between 6 and 9 in at least 3 different quadrants of mouth for each patient, were selected for the analysis. Finally, thanks to a randomization software the 69 NCCLs were assigned to the 3 study groups each consisting of 23 NCCLs and treated with a different laser therapy. In the same patient one lesion per selected quadrant was included in a different study group.

The values of mean and error standard of the VAS scores for each study group are shown in Table 1 for each time point of the therapeutic protocol: baseline (t0), at treatment completion (t1), at 15 days (t2) and at 3 months' time (t3).

Table 1  
The mean and the error standard of the VAS score are shown at each time point (t0, t1, t2, t3) for each study group.

Study groups	t0	t1	t2	t3
SG1	7,04 ± 0,20	3,57 ± 0,27	3,83 ± 0,21	4,39 ± 0,23
SG2	7,04 ± 0,20	2,87 ± 0,17	4,26 ± 0,16	4,65 ± 0,17
SG3	7,09 ± 0,20	2,83 ± 0,15	3,09 ± 0,15	3,52 ± 0,12

A significant reduction of the mean VAS score was estimated for each study group at time t1, t2 and t3 of the laser treatment timeline compared with the mean VAS score assessed at t0 (p-value of Wilcoxon test < 0.0001 for each tested pair and for each study group).

No significant difference in the mean of VAS scores at time t0 was appraised among the three study groups (p-value of one-way ANOVA test 0.9846; mean values shown in the Table 1).

The comparison of the means of VAS scores at time t1, t2 and t3 between each pair of study groups reveals:

a statistically significant difference for the pair SG1 vs SG3 at each tested point of the laser treatment timeline; for the comparison SG2 vs SG3 the difference is extremely significant only at time t2 and t3 and finally for the pair SG1 vs SG2 a significant difference was observed only at t1 time (the p-values are shown in the Table 2).

Table 2

Comparison of the mean values of VAS estimated at time t1, t2 and t3 of the laser treatment timeline for the three pairs of study groups: SG1 vs SG2, SG1 vs SG3, SG2 vs SG3. \*=p-value < 0,05; \*\*\*= p-value < 0,005

Study groups	t1	t2	t3
SG1 vs SG2	0.0326*	0.0993	0.3740
SG1 vs SG3	0.0194*	0.0060*	0.0019***
SG2 vs SG3	0.8485	0.0001***	0.0001***

The improvement of DH symptomology was registered for all study groups as shown in Fig. 1. The SG2 (HPLT) and SG3 (LHLT) present the best results, 59% and 60% respectively, immediately after the laser treatment (t1) against an improvement of DH of 49% for SG1 (LLLT). On the other hand, SG1 (LLLT) and SG3 (LHLT) reveal a similar trend in reduction of improvements which is more gradual over time than SG2 (HPLT) that instead has a rapid decrease at t2 (59% at t1 vs 39% at t2) but shows unvaried values from t2 to t3.

## Discussion

The most widely accepted theory for DH is the hydrodynamic theory proposed by Brännström. This theory postulates that temperature, physical or osmotic changes can disturb the fluids within the dentinal tubules stimulating the baroreceptor on the plasmalemma of the odontoblasts which leads to neural discharge [3].

Different systems have been proposed in order to block or reduce the DH symptomatology. Some of these act by producing occlusion of the dentinal tubule either by precipitation of calcium salts [11, 12] or by coagulation of proteins contained in dentine fluid[13], others act by causing depolarization of the membrane of the nerve endings reducing the nerve transmission of pain[14].

Finally, the ability of different types of lasers in sealing patent dentinal tubules have been evaluated, but the studies carried out on which laser achieves the best outcome for the treatment of DH showed discordant evidences which could be explained considering several factors such as: types of lasers, fibers, power outcome, exposure time and radiation frequency[14].

Several studies have showed the efficiency of diode laser [8, 15–18] and of its different wavelengths (780, 900 and 810 nm) in the treatment of DH [19].

In the present study we have appraised the effectiveness of three different treatments based on the use of diode laser (LLLT, HPLT and combined LHLT) focusing on the different percentage of pain reduction and on the persistence of the effect over time.

Our results underline that more immediate improvements, obtained with a single output power, are not long-lasting while others that can be achieved in a longer loss of time are more persistent [9, 20].

The effectiveness of each laser therapy was gauged by estimating the improvement of DH symptomatology on 3 different NCCLs comparing the mean VAS score obtained at the end of treatment (t1), after 15 days (t2) and after 3 months (t3) with the mean VAS values at baseline (t0).

A clear improvement, both in the short and long term from therapy, has been documented for all the NCCLs in all study groups with the best results obtained in SG-3 (LHLT). In the short term, immediately after the end of treatment (t1), the HPLT and the LHLT showed the same improvement of DH symptomatology compared to the LLLT (59.29% and 60,12

% vs 49.38%). In fact, no significant difference was estimated between the mean VAS score of SG2 (HPLT) and SG3 (LHLT) at time t1, while both averages resulted statistically different from the mean VAS score of SG1 (LLLT) for the same time point. In the long term, after 15 days or after 3 months from the end of treatment, the effectiveness of the LHLT, applied in the SG3, was still greater (56.44% and 50.62% respectively) than the laser treatments based on the use of a single output power (LLLT and HLT), applied in the SG1 and SG2 respectively. This result was supported by the evidence that the averages of VAS scores both for comparison SG1 vs SG3 and SG2 vs SG3 were statistically different.

The rationale behind the use of two different outcome powers of the diode laser is based on the different interaction that each intensity of laser has with the tissues: photo-thermo effect with thermodynamic behavior of tissue water content and bio-stimulant effects on dental tissues.

**In the HPLT (SG2 group)** the lasers with high power can improve the symptomatology of DH mainly with the photo-thermal effect that melts the hard tissue on the surface with the smear layer occluding the tubules. In this way the laser blocks the movement of the fluids in the dentinal tubules, which is the fundament of the hydrodynamic theory of DH pain. The studies of Lopes and Aranha demonstrate that the sealing of dentinal tubules, obtained with the use of high-power laser, represents an effective treatment strategy in reducing dentine hypersensitivity [21]. The photo-thermal effect is reported by Liu et al. also for the Nd:YAG laser which allows to have a sealing depth of approximately 4 microns due to the melting of dentin and the closure of exposed dentinal tubules[22]. The short-term efficacy of high-power laser can be precisely correlated to the rapidity with which the physical-thermal effect closes the patent dentinal tubules, but this haste can also expose to an early relapse and a failure of the therapy if the causal factors persist (i.e.: mechanical abrasion or microbial action) which could induce a possible loss of superficial layer of dentine[22].

**In the LLLT (SG1 group)** the desensitizing action of the low-power laser on DH compared to action of desensitizing paste containing 8% arginine-calcium carbonate has been demonstrated by Bal et al [23].

The efficiency of the low-power laser seems to be greater when lasers with high tissue penetration are used, such as the 810 nm diode laser and Nd: YAG. Whitters et al. and Femiano et al. (2018) verified the

analgesic effect of low-power using either a Nd:YAG laser (1.1 Watt) or a diode laser (0.1 Watt) during routine dental restoration procedures for carious lesions with the recovery to baseline values of pain threshold after 60 min[24, 25].

This output power could show an analgesic effect on the pulp tissue due to the possible depolarizing effect of C- and A $\delta$ - nervous fibers [14] and an anti-inflammatory effect due to the bio-stimulation of the pulp tissue that could activate the odontoblasts to counter with the production of an irregular secondary dentine. The action on the inner layer of dentine with the activation of odontoblasts could explain the slower action of low-power laser on pain reduction associated with DH and, at the same time, the longer-lasting effect compared with the action of high power laser that is restricted to the external surface of dentine[26].

**In the LHLT (SG3 group)**, a combined and definite sequence of two different output powers of diode laser was used on the NCCLs associated with DH. This approach dictated the use a low power first and subsequently a high-power set in order to have a prompt improvement of pain that also lasts over time. The rationale of this clinical evidence is based on the hypothesis that the mechanical effect, induced by high-power laser, creates a barrier on the external side of the tubules which protects the internal environment. In this way the odontoblasts, already activated by the biological effect and induced by the low-power laser, have a greater chance of organizing the defense in the internal side of the tubules and elicit the production of secondary dentine. On the other hand, the sealing of the external side of dentinal tubules, induced by mechanical action, consents to have an immediate improvement of the DH symptomatology. The opposite sequence of the use of output powers should not have the same efficiency in the long term, because, if the external sealing is induced by high-power laser before the bio-stimulation of the internal side of the dentine is achieved, it could create a barrier that prevents the low power laser from reaching the most inner layer and thus activating the odontoblasts.

## Conclusion

In conclusion, considering the results obtained, we propose a new laser therapy protocol combining two different output powers of the diode laser to treat the DH when its symptomatology is evocated in presence of NCCLs to achieve a more lasting pain control.

## Abbreviations

Non carious cervical lesions, NCCLs;

Dentine hypersensitivity, DH;

Cement-enamel junction, CEJ;

Visual analogue scale, VAS;

Test of cold stimulation, TCS;

Low Level Laser Therapy, LLLT;

High-power laser therapy, HPLT;

Low-High combined Laser Therapy, LHLT.

## Authors' Contributions

Femiano Felice: conception and design of the work; interpretation of data; writing of the manuscript

Femiano Rossella: selection of the patients

Femiano Luigi: administration of therapy

Scotti Nicola: revision of the manuscript.

Sorice Rossella: analysis of data; writing and revision of the manuscript.

## Declarations

**Ethics approval and consent to participate:** the procedures of this study were in accordance with the institutional and national ethical standards on human experimentation and the Helsinki Declaration of 1975, as revised in 2000 and it was approved by Ethic committee of AORN of Ospedalidei Colli with N. 1374. All subjects signed an Informed Consent after verbal and written information on the study were provided.

**Consent to publication:** All subjects gave their consent for the publication of data for scientific purposes.

**Availability of data and material:** all raw data are available for consultation and for a collaboration request at the following email address: [femiano@libero.it](mailto:femiano@libero.it)

**Competing interests:** Not applicable

**Funding:** Not applicable

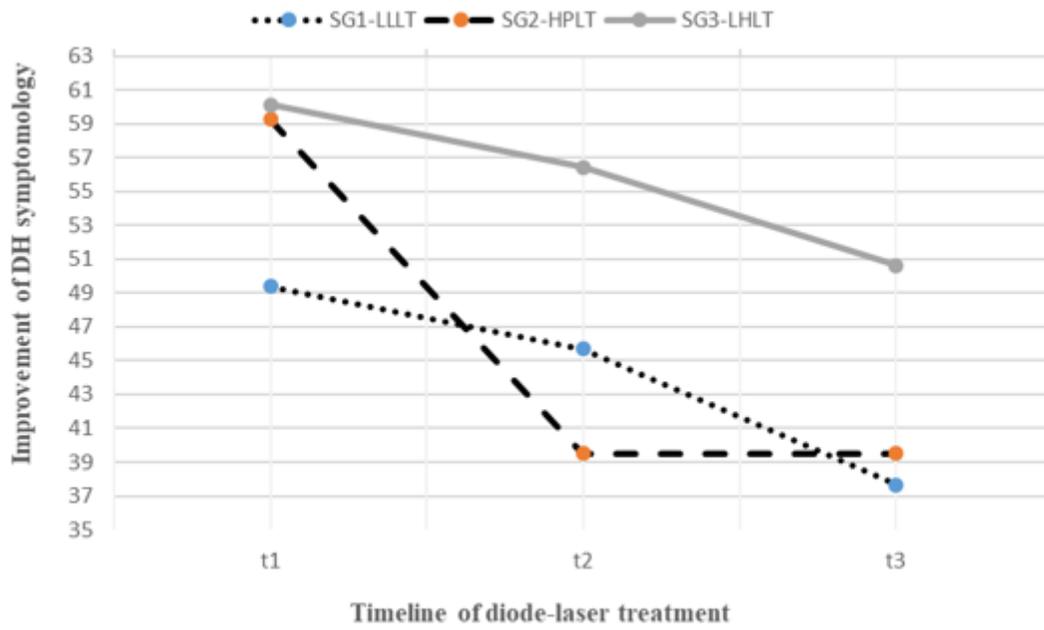
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## Figures



**Figure 1**

Trend of DH symptomatology. The figure shows the trend of the improvement of DH symptomatology estimated at treatment completion (t1), at 15 days (t2) and at 3 months' time (t3) for each study group.