Lan-Lin Chiou[1,2],
Chun-Pin Chiang[1,2,3],
Po-Chun Chang[1,2]

Effect of 810-nm Diode Laser on Reducing Dentinal Hypersensitivity After Periodontal Treatment

Authors' affiliations:
[1] Graduate Institute of Clinical Dentistry, School of Dentistry, National Taiwan University, Taipei, Taiwan
[2] Department of Dentistry, National Taiwan University Hospital, College of Medicine, National Taiwan University, Taipei, Taiwan
[3] Department of Dentistry, Far Eastern Memorial Hospital, New Taipei City, Taiwan

Correspondence to:
Po-Chun Chang DDS, PhD, Graduate Institute of Clinical Dentistry, School of Dentistry, National Taiwan University, 1 Chang-Te Street, Taipei 10048, Taiwan
Phone: +886-2-2312-3456 extension 67709
Fax: +886-2-2383-1346
E-mail: changpc@ntu.edu.tw

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Abstract:
Background: This study aimed to evaluate the effect of 810-nm diode laser on reducing dentinal hypersensitivity (DH).

Material and Methods: Five human molar teeth without any decay were used in the preclinical study. Each tooth was horizontally sectioned into two dentin blocks which were irradiated by the 810-nm diode laser and then analyzed by a scanning electron microscope (SEM) before and after irradiation. In the clinical investigation, thirteen patients with a total of 45 teeth with DH were included. Each participant received diode laser irradiation and fluoride varnish application on the offending teeth in different quadrants. Visual analogue scale (VAS) was used to assess the extent of DH at the baseline and 15 minutes, 1 day, 7 days, 14 days, 1 month, 2 months, and 3 months after the desensitizing treatment.

Results: The preclinical study showed both the diameter and the surface area of the dentinal tubules were significantly reduced after diode laser irradiation ($p<0.01$ and $p<0.05$, respectively). Clinically, mean VAS scores decreased after desensitizing treatment in both diode laser group and fluoride varnish groups. Compared with the baseline data, VAS did not significantly decrease in the fluoride varnish group but consistently and significantly decreased in the diode laser group over 3 months. The reduction of VAS was significantly greater in the diode laser group than in the fluoride varnish group at days 7 and 14 (both p-values < 0.05).

Conclusion: The 810-nm diode laser is capable of narrowing the diameter of dentinal tubule and has clinical effectiveness on reducing DH over 3 months.

Introduction

Dentinal hypersensitivity (DH) is characterized by an exaggerated sharp pain in response to non-noxious stimuli arising from exposed dentin and it cannot be ascribed to any other form of dental defect or pathology.[1] According to a previous investigation, postoperative pain took place in 78–93% of subjects after periodontal treatment, and 82–90% of them were affected by DH, especially at the sites that underwent osseous surgery or gingivectomy.[2] Approximately 20% of subjects still suffered from DH even after eight weeks of treatment.[2]

It has been widely accepted that DH is mediated by a hydrodynamic mechanism, in which the stimulus leads to increase the fluid transmission in the dentinal tubules and in turn activates the nerve endings in the pulp.[3] Efforts in treating DH have been focused on either occluding the exposed dentinal tubules or depolarizing the sensory nerves.[4,5] The dentinal tubules can be occluded by chemical agents such as resin bonding agents or by deposition of mineral crystals such as hydroxycarbonate apatites.[6] However, most of

these approaches only relieve discomfort temporarily, and effectiveness in long-term desensitization is still questionable.

Lasers have been proposed for treating DH for more than 30 years, and the mechanism is thought to be related to the decrease of dentinal permeability due to occluding or narrowing the dentinal tubules and potentially altering the threshold of sensory axons or fibers.[7] Various lasers with different operating parameters, including Nd:YAG, He–Ne, CO_2, and diode lasers, have been applied clinically and showed 50–100% effectiveness in desensitization.[8] Even though immediate relief took place in most studies, the long-term effect is still rarely investigated.

The present study was to evaluate the clinical effectiveness of a diode laser with a wavelength of 810 nm for treatment of DH over a period of three months, and a preclinical assessment on the dentin slices was performed to verify whether the reduction of DH was due to narrowing of dentinal tubules treated with the diode laser.

Materials and methods

I. Ethical Approval

This research has been approved ethically by the Institutional Review Board of the National Taiwan University Hospital (NTUH) under the protocol no. 201304026RINC for the preclinical assessment, and the protocol no. 201701057RIPA for the clinical investigation. The study was also conducted in accordance with the Helsinki Declaration of 1975, as revised in 2000.

II. Diode Laser

A diode laser apparatus (FOX 810, A.R.C. Laser GmbH, Nurnberg, Germany) with a wavelength of 810 nm and a maximum power output of 8 W was used. The prepared specimens and exposed dentin surfaces were irradiated continuously at 1.5 W output power from an optical fiber (300 μm diameter) under a noncontact mode (the distance between the optical fiber head and the irradiated surface was approximately 1 mm). The fiber was inclined at 15–20 degrees relative to the irradiated surface and was moved by the operator in a single direction at approximately 1 mm/s speed.

III. Preclinical Assessment

Specimens for the preclinical assessment

Five intact human molar teeth without any decay were collected from the patients receiving tooth extraction due to impaction, malposition, or advanced periodontitis in the Department of Dentistry, NTUH. Immediately after extraction, the teeth were cleaned and immersed in distilled water with 0.01% thymol for disinfection. Each tooth was horizontally sectioned using a precision section device (IsoMet™ LS, Buehler, Lake Bluff, IL, USA) to obtain two dentin blocks measuring approximately $2 \times 2 \times 1$ mm^3 in size.

The smear layers on the surfaces of dentin blocks were removed by immersing in 24% EDTA solution (pH 7.4) under constant sonication for 3 minutes at 37℃. The dentin blocks were then dried out and received the laser treatment.

Scanning electron microscopy (SEM) analysis

The dentin blocks were dried out, put on the coverslips without any coating, and analyzed by a scanning electronic microscope (SEM; Model No. JSM 7500F, JEOL, Tokyo Japan) under 1500× magnification, before laser treatment. After laser treatment, the dentin blocks were coated with gold and analyzed using the same SEM under the same magnification. The number of open dentinal tubules, the mean diameter of open dentinal tubules, and the number of dentinal tubules with craters were examined at the centermost 100×100 μm^2 area of each dentin block.

IV. Clinical Investigation

Participants' Recruitment

The participants were recruited from January 2017 to November 2017 from the Department of Dentistry, NTUH. The inclusion criteria were: 1) patients of 20–75 years of age; 2) those being systemically healthy; 3) those with at least 20 teeth present; 4) those having at least one tooth with initial visual analog scale (VAS) ≥ 3 upon cold stimulation test; 5) those without smoking history; 6) those without long-term (>2 weeks) use of medications known to affect periodontal or systemic condition; 7) those not taking antibiotics within the past three months. The cold stimulation was conducted by a three-second cold air blast from a triple syringe and was recorded as a numerical 0–10 cm VAS where the value 0 was connected with no discomfort and the value 10 with utmost discomfort considered as intolerable pain during application of the cold stimulus. All eligible subjects were recruited in the Department of Dentistry, NTUH and signed informed consent prior to participation.

Study Design

A paired (split-mouth) study design was used, and the teeth of the different oral quadrants received different desensitizing treatments. Diode laser irradiation was randomly assigned to the offending teeth of one quadrant of each participant, and fluoride varnish (Duraphat®, Colgate-Palmolive Co., New York, NY, USA) was delivered on those offending teeth in the other quadrant.

Clinical Assessment

The clinical assessments and cold stimulation test were delivered at the baseline, 15 minutes, 1 month, and 3 months after desensitizing treatment. Pocket depth (PD; the distance from the free gingival margin to the bottom of periodontal pocket), gingival recession (REC; the distance from the cemento-enamel junction to the free gingival margin), and clinical attachment level (CAL; the distance from the cemento-enamel junction to the bottom of periodontal pocket), were measured at six surfaces of the teeth, and masticatory mucosa (MM; the distance from the free gingival margin to the muco-gingival junction) was measured at the midfacial aspect of the teeth, using a 10 mm manual periodontal probe (PCP10-SE, Hu-Friedy Co. Inc., Chicago, IL, USA). The cold stimulation was conducted by a three-second cold air blast from a triple syringe and was recorded as a numerical 0–10 cm VAS. The sensitive tooth was isolated from the adjacent teeth with utility wax during the test. In addition, VAS assessments were carried out through telephone communication at 1 day, 7 days, 14 days, and 2 months after desensitizing treatment.

Statistical Analysis

The sample size was calculated by power analysis based on the result from a controlled clinical trial on DH,[9] and a minimum clinically significant difference in VAS was set as 0.6, at $\alpha = 0.05$, 80% power, and $\sigma = 0.7$. On the basis of these data, the number of participants in this study was 13 per treatment group. Mean and standard deviation (SD) of the parameters were calculated for all groups. The normal distribution of all VAS scores was assessed using the Shapiro–Wilk test. The paired t-test was used to evaluate the change of VAS over time within the same group and the difference of VAS between examined groups at the same time point. The Mann–Whitney U test was used to evaluate the change of VAS difference between examined groups over time.

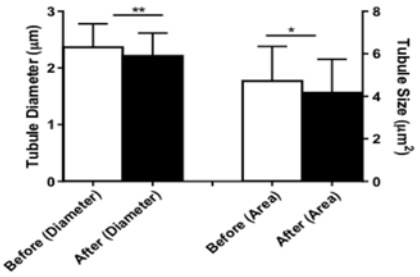

*Fig.1 The diameter and area of dentinal tubules before and after diode laser irradiation. (*p<0.05, **p<0.01)*

Results

I. The Preclinical Assessment

The dentinal tubules became narrower after irradiation with the diode laser. As shown in Figure 1, the diameter and the surface area of the dentinal tubules were reduced significantly after irradiation ($p < 0.01$ & $p < 0.05$).

II. The Clinical Investigation

Thirteen patients (3 males and 10 females; aged from 24 to 76 years) with a total of 45 teeth with dentinal hypersensitivity were analyzed. The number of the affected teeth in the control group was 10 in maxillary arch and 11 in mandibular arch, while that in the test group was 13 in maxillary arch and 11 in the mandibular arch. Two patients were lost to follow-up after 14 days, and all other participants completed the full course of assessments. No major adverse effect was reported.

The results of clinical parameter assessments are shown in Table 1. There was no significant difference in any

Table 1. Means and standard deviations (SD) of clinical parameters

	Mean (SD)					
	Baseline		1 m		3 m	
	Control	Test	Control	Test	Control	Test
PD	2.068 (0.2797)	2.125 (0.3175)	1.973 (0.3413)	2.098 (0.3165)	1.893 (0.2861)	2.024 (0.2194)
REC	1.084 (0.764)	1.215 (0.8311)	1.175 (0.717)	1.281 (0.7834)	1.372 (0.8197)	1.378 (0.6926)
CAL	3.151 (0.6475)	3.341 (0.8346)	3.149 (0.6431)	3.377 (0.7627)	3.265 (0.7677)	3.402 (0.7035)
MM	2.778 (1.567)	2.833 (1.371)	2.6 (1.311)	3 (1.528)	2.531 (1.502)	2.682 (1.309)

PD: Probing depth. REC: Gingival recession. CAL: Clinical attachment level. MM: Masticatory mucosa.

Table 2. Mean VAS scores and standard deviations (SD) for the test and control groups at baseline and different time points.

	Mean VAS score (SD)							
Group	**Baseline**	**0 day**	**1 day**	**7 days**	**14 days**	**1 month**	**2 months**	**3 months**
Control	3.692 (2.097)	2.692 (1.932)	2.154 (2.304)	2.692 (2.78)	2.909 (2.737)	3.045 (3.070)	3.727 (3.133)	2.727 (3.467)
Test	5.692 (1.750)	3.385 (2.142)	2.154 (2.410)	1.846 (2.478)	2.091 (2.773)	3 (1.673)	3.545 (1.864)	3.455 (2.622)
P-value	0.0031**	0.2006	>0.9999	0.2963	0.3702	0.9589	0.8130	0.1039

**$p<0.01$

Table 3. The change of VAS over time

	Control		Test		Control vs Test
Follow-up time	Mean of difference	P-value	Mean of difference	P-value	P-value
0 day	-1	0.1827	-2.308	0.0055**	0.1096
1 day	-1.538	0.0908	-3.538	0.0005***	0.1130
7 days	-1	0.2484	-3.846	0.0004***	0.0213*
14 days	-0.9091	0.3508	-3.636	0.0052**	0.0196*
1 month	-0.7727	0.4146	-2.727	0.0006***	0.0831
2 months	-0.09091	0.9326	-2.182	0.0097**	0.1310
3 months	-1.091	0.2721	-2.273	0.0401*	0.3330

*$p<0.05$, **$p<0.01$, ***$p<0.001$

clinical parameter between the control and test sites or among different time points. The mean VAS score is shown in Table 2. At the baseline, the mean VAS score was significantly lower ($p < 0.01$) in the control group (3.692 ± 2.097) than in the test group (5.692 ± 1.75). The VAS score in both groups decreased after treatment, and no significant difference between groups was noted at any time point after treatment.

Table 3 shows the difference of VAS score compared with the baseline. In general, VAS score in both groups decreased after treatment. Comparing with the VAS score at baseline, there was no significant difference in the control group at 15 minutes after the application of fluoride varnish, whereas the test group showed a significant decrease of VAS after diode laser irradiation ($p < 0.01$) (Table 3). During the follow-up period, the test group demonstrated significant improvement of dentinal hypersensitivity after 1 day ($p < 0.001$), 7 days ($p < 0.001$), 14 days ($p < 0.01$), 1 month ($p < 0.001$), 2 months ($p < 0.01$), and 3 months ($p < 0.05$), and the greatest improvement was observed at day 7. On the other hand, the change of VAS in the control group showed no significant differences at all times. Comparing the effectiveness of fluoride varnish and diode laser for treatment of dentinal hypersensitivity, the improvement of dentinal hypersensitivity in the test group was greater than that in the control group. Significant differences between the two methods were noted at days 7 ($p < 0.05$) and 14 ($p < 0.05$).

Discussion

DH is one of the most common problems in clinical dental practice. For treatment of DH, occlusion or narrowing of dentinal tubules has been proposed. In the preclinical assessment, the diameter and area of dentinal tubules significantly decreased after diode laser irradiation (Figure 1). This result was in agreement with the findings from previous studies conducted by Umana et al.[10] and Liu et al.[11] With the use of 810 and 980 nm diode lasers at 0.8 and 1 W, Umana et al. demonstrated the partial occlusion of dentinal tubules with ≤ 2 ℃ pulp temperature change.[10] Liu et al. used a 980 nm diode laser at 2.0W, showing no significant influence on the vitality of odontoblasts.[11] Clinically, the conducted investigation showed the improvement of DH at sites treated with fluoride varnish and a diode laser, but significant reduction in VAS was only observed at the sites treated with a diode laser (Table 3). These data, including ours, indicate the effectiveness of using diode laser irradiation for treatment of DH.

Different types of lasers have been used for the treatment of DH. Based on a meta-analysis, laser treatment was able to achieve an improvement in a mean VAS score of 3.09 relative to placebo or no treatment.[12] The lasers used can be divided into the low-power lasers (He–Ne laser and GaAlAs laser) and middle-power lasers (Nd:YAG laser, CO_2 laser, and Er:YAG laser).[8] The underlying mechanisms for reducing DH include the occluding effect on the dentinal tubules, blocking the depolarization of C and A δ fiber afferents, and/or temporarily altering the ending of the sensory axons.[7,13]

Compared with other types of lasers, diode lasers are available in a

broad wavelength spectrum and can be applied to a variety of treatment procedures.[12] As reported by Umana et al., diode lasers with wavelengths of 810 and 980 nm are able to seal dentinal tubules.[10] In addition, diode lasers with near-infrared wavelengths are absorbed primarily by melanin and hemoglobin and can be used in many soft-tissue procedures.[10,14] An in vitro study demonstrated that Nd:YAG, CO_2, and diode lasers are all effective for sealing dentinal tubules. However, compared with Nd:YAG and CO_2 lasers, diode lasers show less ability to occlude dentinal tubules.[15] The desensitizing effect of a diode laser may be attributed to the laser-induced changes to neural transmission networks within the dental pulp[16] or the activation of the metabolism of the odontoblasts that consequently obliterate the dentinal tubules.[17] Although the mechanisms are still unclear, the effectiveness of diode lasers for treatment of DH has been investigated clinically for years. Sicilia et al. reported that a diode laser significantly reduced DH in 15 minutes after irradiation, and the improvement persisted until day 60.[18] Femiano et al. used a diode laser to irradiate the affected tooth sites three times a week and observed a significant reduction (47.2%) of VAS score after 6 months.[19]

Fluoride varnish is a conventional approach for the treatment of DH because fluoride assists the precipitation of calcium fluoride crystals in the dentinal tubules and in turn reduces dentinal permeability.[20,21] Ritter et al. showed that fluoride varnish effectively reduces cervical DH and the application of fluoride varnish leads to significant reduction of VAS score after 24 weeks regardless of air or ice stimulus.[21] Yilmaz et al. compared the desensitizing effects of diode laser and fluoride varnish on DH and reported that both treatments significantly reduce VAS score throughout the 6-month study period. However, there was a significant increase in VAS score after 3 months compared with an early stage in the fluoride varnish treatment group.[17] Corona et al. further evaluated the effectiveness of low-level laser and fluoride varnish in the treatment of cervical DH and showed that fluoride varnish does not significantly improve DH during the 30-day study period.[20] In this study, fluoride varnish served as the control group, and the mean VAS score did not significantly decrease after the application of fluoride varnish. Compared with the sites treated by fluoride varnish, the reduction of VAS score was consistently greater in those teeth treated by a diode laser. These data suggest that the diode laser is a more effective device to overcome DH.

However, this study has several limitations. First, it was difficult to evaluate the degree of DH objectively because the VAS score was inherently subjective. Second, due to the ethical concern, there was no placebo group in the present study, and the participants were not blinded from the study design. The placebo effect was not evaluated. Third, VAS scores obtained at 1 day, 7 days, 14 days, and 2 months were through communication without attendance in the clinic. The assessments were not well-controlled, and the record could be more subjective in these time points. Last but not least, the sample size in this study was moderate, and the observation period was relatively short. Further comprehensive large-scale and long-term clinical investigations in treating DH are still necessary.

Conclusion

Notwithstanding the limitations, we conclude that diode lasers in the continuous irradiation mode with an output power of 1.5 W are capable of narrowing dentinal tubule and are effective devices for treatment of DH.

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中文摘要

本研究旨在評估 810-nm 二極體雷射對於減低牙本質敏感的效果。臨床前實驗採用 5 顆完整無缺損之人類大臼齒，每顆牙齒水平方向切為兩個牙本質塊，以 810-nm 二極體雷射照射，並使用掃描式電子顯微鏡在雷射照射前後作分析。臨床試驗包含 13 位患者及總數 45 顆具牙本質敏感的牙齒，每位患者在不同象限的患齒分別接受二極體雷射照射和氟漆的治療；牙本質敏感的程度在治療前及去敏感治療後 15 分鐘、1 天、7 天、14 天、1 個月、2 個月、3 個月以視覺類比量表 (VAS) 作評估。臨床前實驗結果顯示二極體雷射照射後的牙本質小管直徑 ($p<0.01$) 及面積 ($p<0.05$) 皆有顯著地減少。

臨床試驗結果顯示在二極體雷射和氟漆治療後，VAS 的平均分數皆有下降；但與治療前相比，氟漆組的敏感程度沒有顯著性降低，而二極體雷射組則有持續且顯著地差異；治療後第 7 天及 14 天時，VAS 的下降程度在二極體雷射組顯著高於氟漆組 (皆為 p<0.05)。基於上述結果結論，810-nm 二極體雷射可以縮小牙本質小管直徑，並具降低牙本質敏感且持續三個月以上的臨床效果。

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