

# Graphite Application and Different Powers of Neodymium-Doped Yttrium Aluminium Garnet (Nd:YAG) Laser on Dentin Surface Changes: A Scanning Electron Microscopy Study

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## Abstract:

**Introduction:** Various methods have been used for the treatment of dentine hypersensitivity such as dentifrices, sealants and different types of lasers. The aim of this study was to evaluate the effect of Neodimium:Yttrium-Aluminium-Garnet (Nd:YAG) laser in association with graphite on the dentin morphologic changes.

**Methods:** In this experimental in vitro study, 16 freshly extracted third molars were selected. 5 specimens with the dimensions of 2×2×1 mm from root trunk were prepared. Specimens were randomly divided into five groups: group 1 (control, no laser irradiation). Group 2, 3 irradiated by Nd:YAG laser 0.5 and 1W, output power respectively. Group 4, 5 smeared with graphite and then irradiated by Nd: YAG laser 0.5 and 1W output power. Samples were prepared for scanning electron microscopy. Number and diameter of dentinal tubules were determined in different groups and analyzed with the Kruskal-wallis and Mann-Whitney tests (SPSS 16).

**Results:** The number of tubules had significant difference between all groups ( $P < 0.001$ ), except group 1 in comparison with group 2 ( $P > 0.05$ ), and group 3 in comparison with group 4 ( $P > 0.05$ ). Micro-cracks and rupture of melted dentin materials were seen in group 4 and 5.

**Conclusion:** According to the findings of this study, smearing with graphite on dentin surface increase the absorption of Nd:YAG laser energy and reduced the diameter and number of open dentinal tubules.

**Keywords:** hypersensitivity; Nd:YAG; dentinal tubules.

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## Introduction

Increased dentin hypersensitivity is a common

disorder which can occur acutely, without provocation, and usually occurs with sudden onset at one specific area of the mouth. This disorder can result from

provoked and denuded dentin by temperature, tactile, osmotic or chemical alterations (1). Frequently this disorder can be seen as a consequence of periodontal treatments associated with terrible pain and dissatisfaction seen mainly after periodontal therapy. Furthermore, it can severely affect the treatment plan processes as well as cooperation of the patients (2). Studies show that 54-98% of the patients can reveal some degrees of dentin hypersensitivity resulting from periodontal treatments. Therefore treatment of dentin hypersensitivity for patients with periodontal problems is of great importance (3).

In 1935 Grossman determined a treatment plan which is still of central importance. His delineation for dentin hypersensitivity has been focused on a treatment without any destruction of pulp, painless, easy to perform and highly effective over long period of time (4). Since then, different kinds of treatments have been used such as tooth paste, mouth wash, dentinal tubules obstruction materials, destruction of dentinal nerves and so on. Although some of those procedures did not have possibilities of high success according to the mentioned criteria (5). Thus the tendency for dentin hypersensitivity treatment by laser has highly increased since mid 1980s (6).

In 1985 Mastoumoto presented for the first time, the use of Neodymium-Doped Yttrium Aluminium Garnet(Nd:YAG) laser for the patients with dentin hypersensitivity (7). Research in this area has reported various types of results (5). The mechanism of Nd:YAG laser irradiation to remove dentin hypersensitivity is mainly the result of temperature changes caused by laser on dentin surface (8-11).

Many studies have shown that temperature changes caused by Nd:YAG laser on tooth root surfaces can contribute to melted and congealed cementum and root dentin (12,13). This may explain how obturation of dentinal tubules can be beneficial in treatment of dentin hypersensitivity as confirmed in previous studies (6,10,12,14-24).

Essentially Nd:YAG laser irradiation penetrates deeper layers compared to surface hard tissues. On the other hand the wavelength of this laser is appropriately absorbed by pigmented tissues (18-25). Therefore pigmentation of dentin surface can result in increasing Nd:YAG laser absorption.

In 1984 Morioka suggested the use of black ink to increase the surface absorption of Nd:YAG laser (26). Subsequently, in 1987 Launay examined this material for its usefulness in preventing deep penetration of

enamel and dentin which can have hazardous effects on pulp (25,26). Then some researchers used black ink to increase Nd:YAG absorption (20,27-29). Recently other materials such as graphite and erythrosine were used as pigmented smears for this purpose (30,31). Maamary et al investigated the effect of graphite solution on tooth surfaces of patients to remove their dentin hypersensitivity. The results gained from this study showed a significant difference between patients that underwent Nd:YAG laser compared to the control group (30).

In the present study we aimed to use graphite application on dentin surface to increase the rate of absorption. Two different powers of Nd:YAG lasers were evaluated for their effect on dentin in 2 groups, group 1 including specimens with graphite smear and group 2 including specimens without graphite smear. All alterations were investigated accurately by scanning electron microscope.

## Methods

In this experimental In vitro study, 16 newly extracted third molars were collected from the patients with an average age of 18-25 at University of Isfahan Graduate School Dental Clinic. All extracted teeth were kept in distilled water and a cold environment for 1 week.

In this study, third molar teeth with determined mesiodistal width, long root trunk, without anomaly and decay were included. Five specimens with the dimension of 2×2×1 were obtained from cemento-enamel junction (CEJ) to furcation and root trunk of each tooth. Teeth without above mentioned inclusion criteria were excluded from this study.

The preparation and section of specimens have been done by section device (M300-Servocut, Metkon instrument Ltd, Bursa Turkey). To eliminate smear layer from the surface, specimens were put in Ethylenediaminetetraacetic Acid (EDTA) %17 (PH=7.8) and then in 5 ml sodium hypochlorite for 5 minutes. Finally all specimens were irrigated by distilled water and were divided into 5 groups. Two groups of specimens were smeared by graphite pencil with rectangular section tip. Five groups of specimens included in this study were prepared as follows:

- Group 1 considered as control group.
- Group 2 irradiated by Nd:YAG laser power, 0.5 W output power.
- Group 3 irradiated by Nd:YAG laser power, 1 W

output power.

- Group 4 smeared by graphite and irradiated by Nd:YAG laser power, 0.5 W output power.
- Group 5 smeared by graphite and irradiated by Nd:YAG laser power, 1 W output power.

The frequency of 10 Hz of Nd:YAG laser in 2 stages and over 60 seconds was used for the groups that were irradiated by laser power.

This study utilized Nd:YAG laser of 1064 nm wavelength (Fontana, Ljubljana, Slovenia Fidelis Plus) with an optic fiber of 300 micro millimeter diameter. The distance between the fiber laser tip and dentin surface was adjusted to 2 mm and an orthodontic wire was connected to the end of laser handpiece. All specimens were irradiated by laser power in a horizontal sweeping movement. For Scanning Electron Microscope (SEM) analysis, samples were fixed in 2.5% Glutaraldehyde for 12 hours (4 C), and then dehydrated in ascending grades of ethanol. After that, the samples were dried and sputter-coated with gold. Finally the specimens were investigated by electron microscope (UK-oxford instrument, Cam scan MV 2300) at Tehran University, Faculty of Metallurgy. The photomicrographs were prepared to evaluate micro cracks in magnification of  $\times 100$  as well as craters and dentinal tubules changes in magnification of  $\times 1500$ .

Orifices of all dentinal tubules, in each field were measured by digital caliper (Absolute Digimatic, Mitutoyocorp Japan) and the mean diameter index was reported. In addition, counting of open tubules was conducted to evaluate the number of obstructed tubules. Magnifications of  $\times 1500$  and  $\times 100$  were used to investigate craters and micro cracks in each field respectively. The data were analyzed by SPSS 14.0 (SPSSInc, Chicago,IL, USA), Kruskal-Wallis and Mann-Whitney tests and the significance level was predetermined  $\alpha < 0.05$ .

## Results

Table 1 summarizes the results on dentinal tubules diameter in the 5 groups. Kruskal-Wallis test revealed significant differences between all groups ( $P < 0.001$ ). Results of the Mann-Whitney test revealed a significance difference between all groups except group 3 in comparison with group 4 ( $P = 0.92$ ). Table 2 shows the mean open dentinal tubules indices of the groups used in this study. The results obtained from Mann-Whitney test revealed significant differences between all groups ( $P < 0.001$ ). There are significant

**Table 1.** Indices of dentinal tubules diameter in different groups (micron)

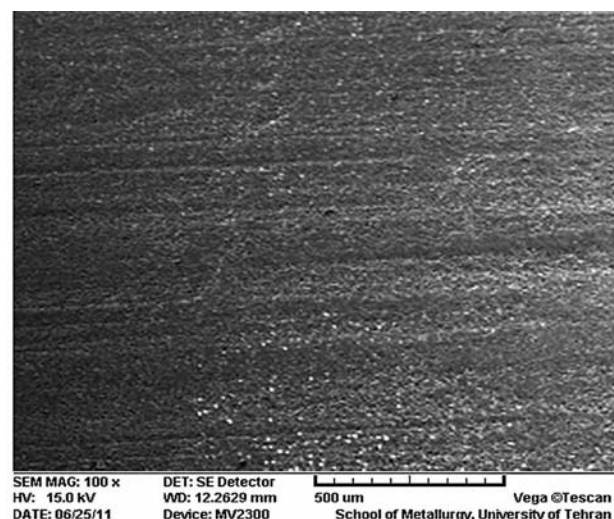
Groups	Dentinal tubules diameter			
	n	min	max	mean $\pm$ SD
Control	16	3/21	5/2	4/06 $\pm$ 0/59
0.5 w Nd:YAG	16	2/01	3/4	2/94 $\pm$ 0/28
1w Nd:YAG	16	1/11	2/42	1/8 $\pm$ 0/36
Smeared 0.5 w Nd: YAG	16	1/17	2/2	1/17 $\pm$ 0/27
Smeared 1 w Nd: YAG	16	0/65	0/8	0/72 $\pm$ 0/04

**Table 2.** Indices of open dentinal tubules numbers in different groups (micron)

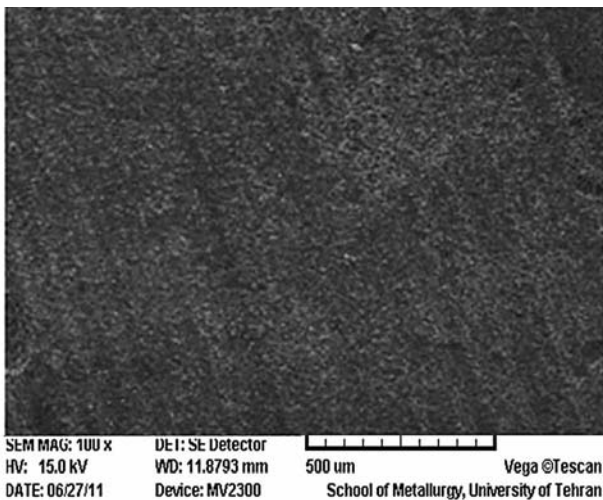
Groups	Dentinal tubules numbers			
	n	min	max	mean $\pm$ SD
Control	16	35	68	52 $\pm$ 11
0.5 w Nd:YAG	16	30	55	46 $\pm$ 8
1w Nd:YAG	16	10	25	17 $\pm$ 5
Smeared 0.5 w Nd: YAG	16	10	25	16 $\pm$ 5
Smeared 1 w Nd: YAG	16	1	13	9 $\pm$ 3

differences between all groups except between group 1 in comparison with group 2 ( $P = 0.11$ ) and group 3 in comparison with group 4 ( $P = 0.78$ ).

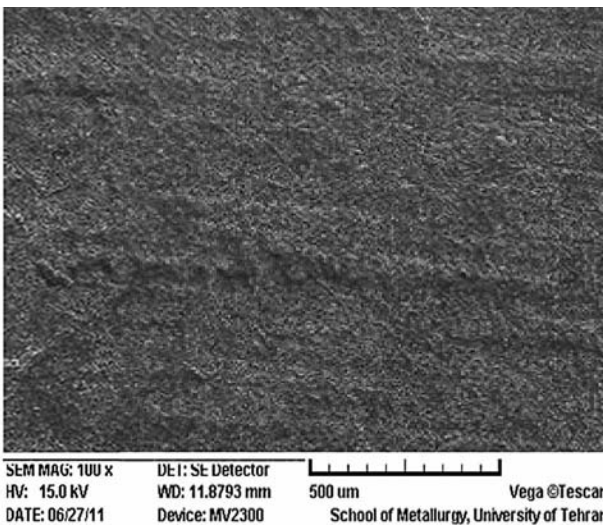
Evaluation of SEM photomicrographs of specimens without graphite smear under magnification of  $\times 100$ , exhibited no micro cracks or any other problems in comparison with control group (Figures 1-3), but some surface globules were observed in graphite smear specimens of groups 4 and 5 (Figures 4,5). Under magnification of  $\times 1500$ , specimens of groups 2 and 3 showed reduction in the diameter and number of dentinal tubules comparing to the control group (Figures 6-8). But, this reduction in group 3 is significantly more



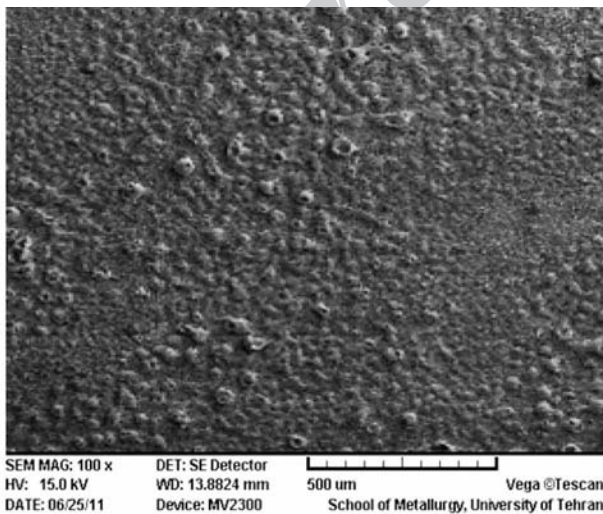
**Figure 1.** Scanning electron micrograph of specimen in control group ( $\times 100$ )



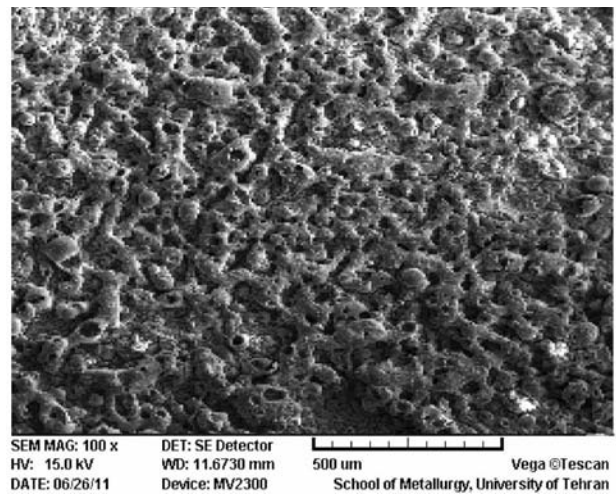
**Figure 2.** Scanning electron micrograph of specimen using Nd:YAG 0.5 W ( $\times 100$ )



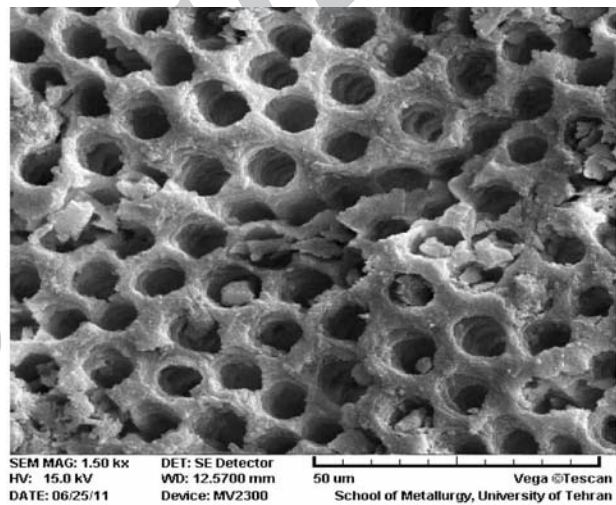
**Figure 3.** Scanning electron micrograph of specimen using Nd:YAG 1 W ( $\times 100$ )



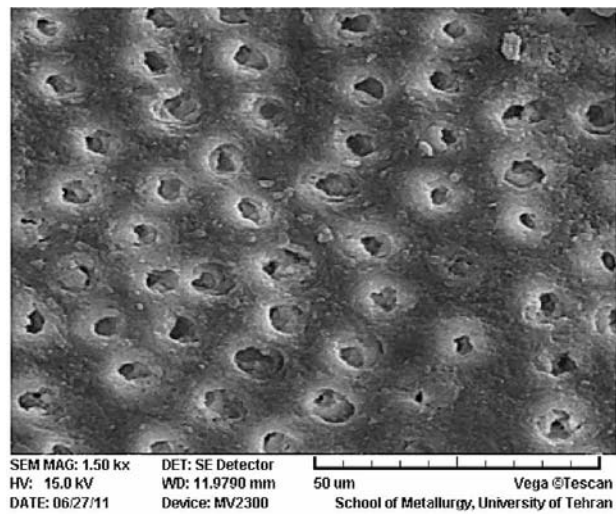
**Figure 4.** Scanning electron micrograph of specimen using Nd:YAG 0.5 W with graphite smear ( $\times 100$ )



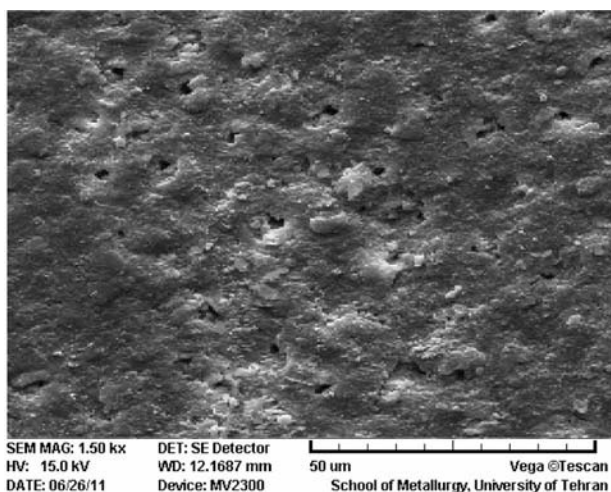
**Figure 5.** Scanning electron micrograph of specimen using Nd:YAG 1 W with graphite smear ( $\times 100$ ).



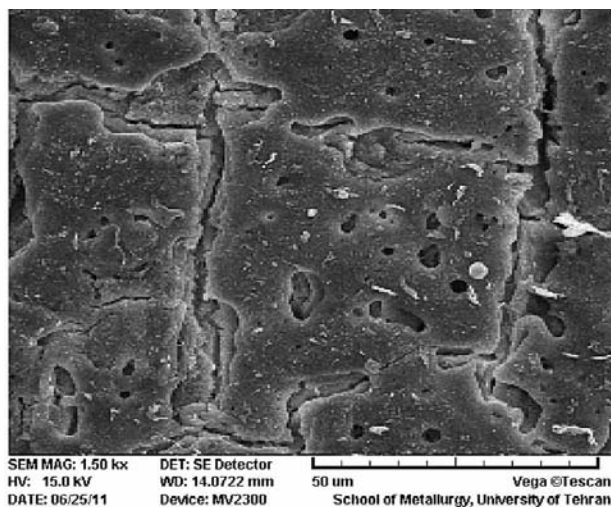
**Figure 6.** Scanning electron micrograph of specimen in control group ( $\times 1500$ )



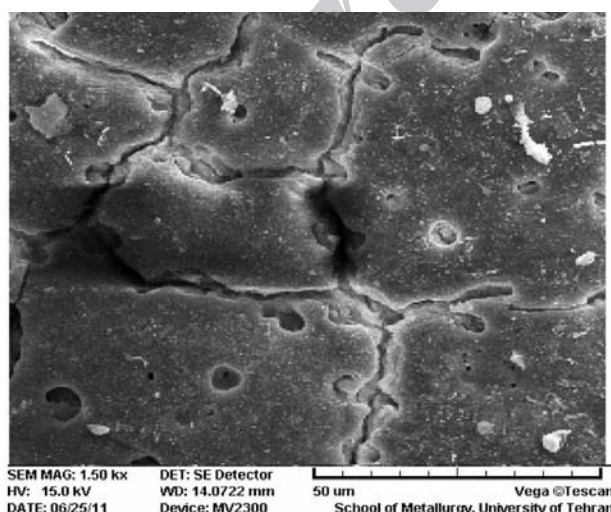
**Figure 7.** Scanning electron micrograph of specimen using Nd:YAG 0.5 W ( $\times 1500$ )



**Figure 8.** Scanning electron micrograph of specimen using Nd:YAG 1 W ( $\times 1500$ )



**Figure 9.** Scanning electron micrograph of specimen using Nd:YAG 0.5 W with graphite smear ( $\times 1500$ )



**Figure 10.** Scanning electron micrograph of specimen using Nd:YAG 1 W with graphite smear ( $\times 1500$ )

than that of group 2. Laser irradiation of the groups smeared with graphite (groups 4,5) led to nearly complete obstruction of dentinal tubules' orifices which were associated with micro cracks and rupture of melted dentin (Figures 9,10). Furthermore, the number and depth of ruptures were higher in group 5, when compared with group 4. This increase was associated, in some areas, with open dentinal tubules.

## Discussion

There is a close relationship between dentin hypersensitivity and open dentinal tubules located on denuded dentin surfaces. Usually sensitized dentin areas are affected by higher number of open dentinal tubules with bigger diameter (32-34). Yet, different methods such as irradiation of laser power, particularly Nd:YAG laser, have been used to obstruct dentinal tubules orifices in order to remove dentin sensitivity. Deep penetration of this laser wavelength, leading to overheating, can result in unfavorable effects on pulp and dentin surface due to tendency of Nd:YAG laser wavelength to be absorbed by pigmented tissues, the use of pigmented smears to increase surface absorption has been recommended (6,14,20,25-31).

In this study, dentin morphologic changes such as alteration in number and diameter of dentinal tubules and hazardous effects like cratering and micro cracking were evaluated in Nd:YAG laser irradiation following graphite smear application. The correlation between smeared surfaces and suggested parameters was further investigated.

The results of this study show the diameter of dentinal tubules in group irradiated by Nd:YAG 0.5 and 1W (group 2, 3) were significantly reduced in comparison to the control group. There was a significant difference between groups 2, 3 as well. Moreover the number of open tubules was significantly lower in group 3 compared to group 1. Therefore evaluation of dentinal tubules obstruction, based on diameter changes and number of obstructed dentinal tubules, showed that irradiation of Nd:YAG was highly effective in obstruction of dentinal tubules. In addition an increase in laser output energy from 0.5 to 1W have increased the rate of dentinal tubules obstruction as well. Thus the findings of this study are in accordance with previous researches (10,14-24).

The results of this study show that the number of dentinal tubules has no significant difference between groups 1 and 2, while diameter of dentinal tubules

does show significant difference between those groups. The diameter changes and number of dentinal tubules reveal a significant difference between groups 2 and 3. These results confirm previous studies indicating that Nd:YAG laser 0.5 W output power decreased dentinal tubules diameter resulting in reduction of hypersensitivity (20,21,35). Irradiation of Nd:YAG laser 1 W output power reduced dentinal tubules diameter in addition to obstruction of buried dentinal tubules which can possibly remove higher ratings of dentin hypersensitivity compared to a situation that is only associated with reduced dentinal tubules diameter. This point is of great importance showing that higher output powers of Nd:YAG laser at the same time, can increase hazardous side effects on pulp and dentin surfaces such as craters and micro cracks, phase changes as well as dentinal rupture (36).

The diameter changes and number of open dentinal tubules show a significant difference between groups smeared with graphite (4,5), and the control group (group 1). The number and diameter of dentinal tubules have a significant difference between group 2 and group 4 and between group 5 and other groups. This part of results are in accordance with other studies specially Maamary et al who have investigated the effect of graphite smear in increasing Nd:YAG absorption (20,25-31).

Evaluation of SEM photomicrographs of specimens irradiated by laser power with graphite smear on dentin surfaces shows more micro cracks and ruptures of melted materials and open dentinal tubules; specially in specimens with 1W output power, compared to other groups, while specimens without graphite smear exhibit few micro cracks only on areas irradiated by Nd:YAG laser 1W output power. This result is possibly caused by concentration of higher laser irradiation on those areas (37).

Laser energy absorbed by tooth surfaces should be carefully under control to prevent hazardous effects such as micro cracking and phase change (36). To minimize heat concentration on dentin surface the following precautions are recommended: pulsating laser, minimal effective output power, retaining appropriate distance between fiber tip and dentin surface and continuous sweeping movement of fiber on dentin surface (16).

The results gained from this study show that irradiation of Nd:YAG laser, 0.5 and 1W output powers, generally can cause dentinal tubules diameter and dentinal tubules number reduction, which can be

effective in removing dentin hypersensitivity. Laser irradiation with the same output powers on dentin surface smeared with graphite revealed higher rating of dentinal tubules obstruction and buried dentinal tubules. Specimens smeared with graphite and irradiated by Nd:YAG laser 0.5W output power exhibited the same results regarding dentinal tubules obstruction compared to specimens irradiated by Nd:YAG 1W output power. This finding confirms that the use of graphite smear resulted in higher absorption of Nd:YAG laser on dentin surface. Therefore, dentin surface smeared with graphite and irradiated by Nd:YAG with less output power (even less than 0.5 W) can lead to improved and more favorable treatment results.

## Conclusion

Based on overall results of this study, it can be concluded that graphite smear on dentin surface can increase surface absorption of Nd:YAG and ultimately pathologic effects on pulp or tooth surface can be avoided by reduction of irradiation energy used to remove dentin hypersensitivity.

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