

In vitro Evaluation of Dentin Surface Irradiated by Neodymium-doped: Yttrium Aluminum Garnet Laser (Nd: YAG) Using Scanning Electron Microscopy

Original Article

Ali Deghani Nazhvani¹, Hengameh Khosropanah², Mostafa Rezaei³, Mahsa Moradi⁴, Ahmad Moradi⁵

¹Assistant professor, Department of Oral and Maxillofacial Pathology, Biomaterial Research Center, School of Dentistry, Shiraz University of Medical Sciences, Shiraz, Iran.

²Assistant professor, Department of Periodontics, School of Dentistry, Shiraz University of Medical Sciences, Shiraz, Iran.

³Assistant professor, Department of Oral Medicine, School of Dentistry, Shiraz University of Medical Sciences, Shiraz, Iran.

⁴Students' Research Committee, Faculty of Dentistry, International Branch of Shiraz University of Medical Sciences, Shiraz, Iran.

⁵Dermatologist, Private practice, Shiraz, Iran.

Received: Mar 11, 2015

Accepted: Apr 30, 2015

Corresponding Author:

Mahsa Moradi

Address: Students' Research Committee, Faculty of Dentistry, International Branch of Shiraz University of Medical Sciences, Shiraz, Iran

Telephone: +98 711 654 17 18

E-mail: mahsa_mor30@yahoo.com

Fax: +98 711 654 17 18

Abstract

Introduction: Dentinal hypersensitivity (DH) is one of the most painful chronic problems reported in dental offices. Various methods have been applied for the treatment of DH. However, majority of them are either ineffective or last for a short period of time. It has been reported that lasers, particularly Neodymium-doped: Yttrium Aluminum Garnet laser (Nd: YAG), can be helpful in the treatment of this disease. However, systematic reviews have shown that the available evidence for its effectiveness is weak. The aim of this study was to evaluate the Nd: YAG laser-prepared dentine surface with different powers and energies.

Materials and methods: Fifteen extracted human molars were randomly divided into five groups receiving different powers and energies of Nd:YAG laser (Group A: power: 0.7 W, energy: 70 mJ; Group B: power: 0.9 W, energy: 90 mJ; Group C: power: 1.1 W, energy: 110 mJ; Group D: power: 1.3 W, energy: 130 mJ; and Group E: power: 1.5 W, energy: 150 mJ) in three pulse modes. The surfaces of the specimens were then studied using scanning electron microscopy (SEM).

Results: With output power of 0.7 W in single, double and triple radiation modes, sealed dentinal tubules and absence of smear layer were observed. The surfaces prepared by using higher powers of 0.9, 1.1, 1.3, and 1.5 W showed the same features as those prepared with 0.7 W power in single and double pulse modes. In addition, carbonization centers were observed when single pulse mode with power of 1.5 W was employed.

Conclusion: All combinations of power and energy tested in this study were found to have produced sealing of the dentinal tubules. However, 0.7 W power in double and triple radiation modes is suggested to be the best option for the clinician, due to having the lowest energy, fewer side effects and lower risk of physical dangers, as well as decreasing the occurrence of unwanted carbonizations. Experimental and clinical studies, especially randomized clinical trials, comparing the effects of Nd: YAG lasers with conventional methods are recommended.

Key words:

•Lasers •Solid-State •Dentin Sensitivity •Microscopy •Electron •Scanning

Introduction

Lifestyle changes, population aging and a reduction in the loss of teeth caused by caries has resulted in an increased occurrence of non-carious cervical lesions in several parts of the world.^(1,2) Consequently, dentinal hypersensitivity (DH) is a common complaint in adults and it is one of the most painful chronic problems reported in dental offices. Symptoms include a short and sharp pain in response to any thermal, tactile, osmotic, and mechanical stimuli. DH is commonly caused by abrasion, attrition, erosion, abfraction, gingival recession, and improper brushing habits. The most common sites of predilection in descending order are the canines, first premolars, incisors, second premolars, and molars.⁽³⁻⁵⁾

Sensitive dentin is permeable and any decrease in its permeability reduces the movement of the fluid inside the tubules and consequently decreases the pain of dentine hypersensitivity. Various agents have been recommended to partially or completely occlude dentinal tubules. However, majority of the treatments are either ineffective or last for a short period of time.^(4, 6, 7)

Laser therapy was first introduced as a potential method for DH treatment in the mid-1980s. Since then, the quality, variety and settings of the available lasers have considerably progressed. Improvements have also been made in the evaluation methods that are used for determining the reductions in DH.^(8,9) Neodymium-doped: Yttrium Aluminum Garnet (Nd: YAG) laser is a widely used, effective, Food and Drug Administration (FDA) approved alternative for treatment of DH. Nd: YAG laser penetrates deep into the tooth structure and melts the hydroxyapatite crystals, resulting in closure of the dentinal tubules.^(10,11) Results of previous studies majorly reveal a reduction in DH of Nd: YAG treated teeth. A previous study reported that the Nd: YAG laser is a suitable tool for immediate and successful reduction of dentinal hypersensitivity resulting in better patient satisfaction and shorter treatment time.⁽¹²⁾ However, the results of a systematic review showed that although laser treatment appeared to reduce DH, evidence for its efficacy was weak.⁽¹³⁾ So complementary studies are needed to better assess the effectiveness of lasers in the treatment of DH.

In order to improve the application of Nd: YAG lasers in the treatment of DH, researches on the benefits of irradiation are useful for dental professionals.⁽¹⁴⁾ Therefore, this study aimed to evaluate the dentine surfaces prepared by Nd: YAG lasers with different powers and energies, using scanning electron microscopy (SEM).

Materials and Methods

Fifteen extracted human permanent molars with a mesiodistal diameter of more than 10 mm were collected for the current descriptive study. The teeth were extracted as they were diagnosed with periodontal problems and were considered to be hopeless. Informed consent was obtained from each donor.

Teeth with caries, restorations or fractures were excluded from this study. The specimens were washed under tap water, using a dental curette to eliminate soft and hard tissue remnants. Thereafter, they were stored in distilled water containing 0.4% Thymol to prevent microbial growth.

The specimens were then cut into 5×5×2 mm³ disks using a saw microtome (Leitz 1600, Germany) and were randomly divided into five groups (3 teeth per group), based on the power and energy of Nd: YAG laser (Lumenis LB2600052, USA). All samples were then treated, according to the manufacturer's instructions, with a wave length of 2780 nm and frequency of 20 Hz. A distance of 10 mm between the tip and specimen was maintained during radiations. Irradiated groups were as follows: Group A: power: 0.7 W, energy: 70 mJ; Group B: power: 0.9 W, energy: 90 mJ; Group C: power: 1.1 W, energy: 110 mJ; Group D: power: 1.3 W, energy: 130 mJ; and Group E: power: 1.5 W, energy: 150 mJ. In each group single, double and triple pulse/ms modes were studied.

For SEM, the specimens were fixed in 2.5% glutaraldehyde for 12 hrs (4°C). All samples were then dehydrated using ascending grades of ethanol (25%, 50%, 75%, 90% and 100%). Afterwards, the specimens were dried, gold sputter coated and evaluated with SEM (Cambridge S360, UK).

The study protocol was approved by the Ethics Committee of Dental Faculty at the International Branch of Shiraz University of Medical Sciences.

Results

smooth areas of dentinal tubules which were free of smear layer, with output powers of 0.7 W in single and double pulse/ms modes. However, the dentinal surfaces appeared pebbly with smear particles when triple pulses/ms mode was used. In each of the applied methods, the tubular orifices were seen to have been masked and sealed. Surfaces prepared with powers of 0.9 W, 1.1 W, 1.3 W and 1.5 W also showed the same features as those prepared with 0.7 W power, single and double pulse modes. Moreover, foci of carbonization were observed with 1.5 W power and single pulse mode (Figures 1-3)

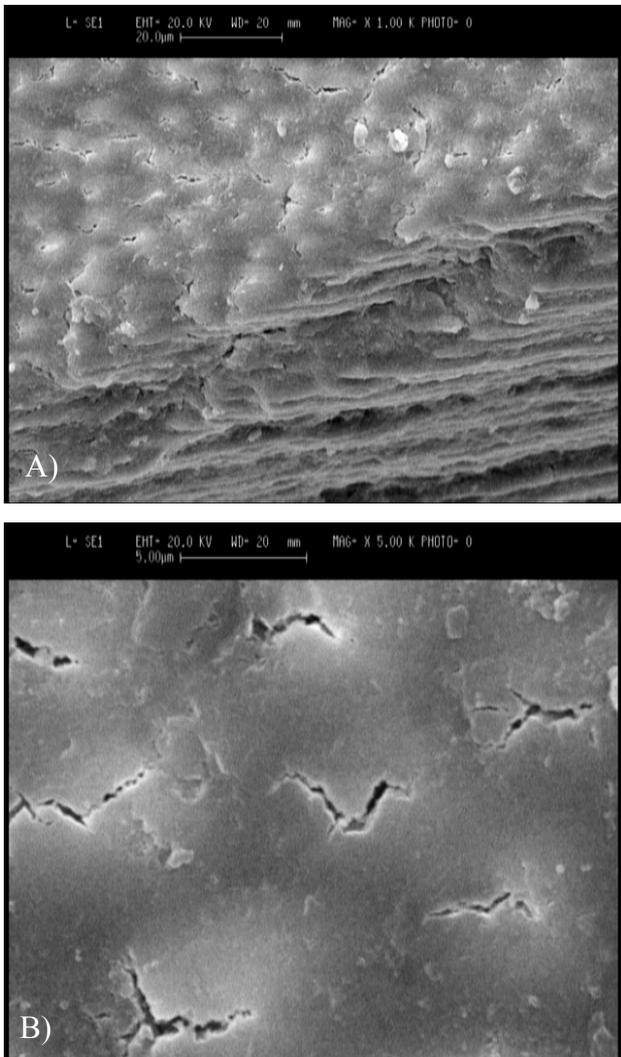


Figure 1. Dentin surface treated by Nd: YAG with 0.7 W power and single pulse/ms showing melted, glassy, smooth areas of dentinal tubules and cleaned smear layer (Original magnification 1000× for A and 5000× for B)

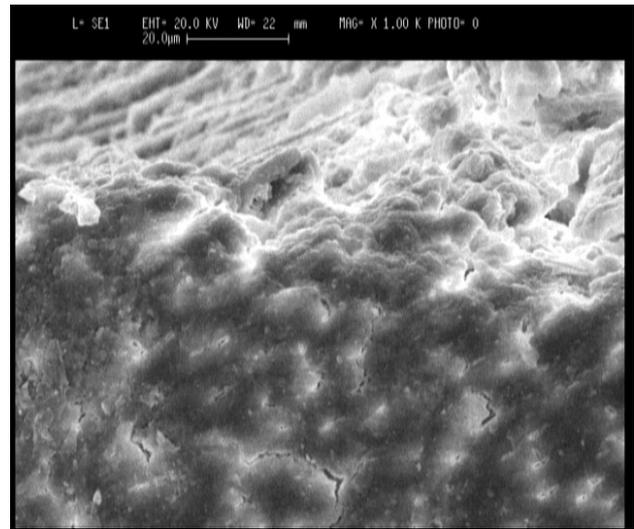


Figure 2. Dentin surface treated by Nd:YAG with 0.7 W power and double pulse/ms. Melted, smooth areas around dentinal tubules can be observed. (Original magnification 1000×)

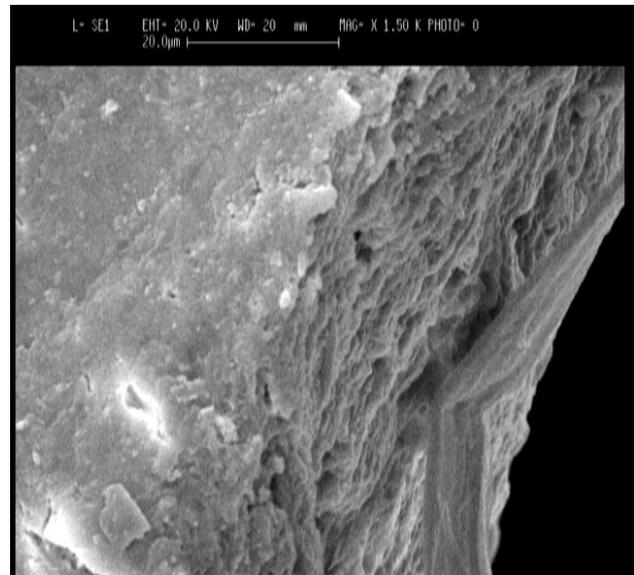


Figure 3. Dentin surface treated by Nd: YAG with 0.7 W power and triple pulse/ms. Melted areas around dentinal tubules with smear layer and absence of glassy appearance can be observed. (Original magnification 1500×)

Discussion

Since hypersensitive teeth exhibit wider diameters of dentinal tubules compared to non-sensitive teeth, it is believed that treatment should focus on decreasing the tubular diameter in order to be effective.⁽⁴⁾ To date, majority of the desensitizing agents attempted to inhibit painful stimuli by either sealing the dentinal tubules with coating mechanisms or by altering tubular contents through coagulation, protein precipitation, or the creation of insoluble calcium complexes. However, the desired long lasting effects were

not reported.^(4, 6, 15) The aim of the current study was to evaluate Nd: YAG laser-prepared dentine surfaces using different powers and energies.

According to the results of the present study, Nd: YAG laser was effectively sealed dentinal tubules with output power of 0.7 W, particularly in triple radiation pulses. These were in line with previous reports by Kara et al⁽¹²⁾, Kumar et al⁽¹⁶⁾, and Moghareh Abed et al⁽¹⁰⁾ who also found Nd: YAG laser to be a suitable alternative for the treatment of hypersensitive teeth. Kumar et al used laser energy of 30 mJ for 2 min, while Moghareh Abed et al and Kara et al applied energy of 100 mJ for 60 s.^(10, 12, 16) These differences reveal a lack of a standard model for treatment of DH.

Despite conflicting results, a recent systematic review revealed that laser therapy had a slight clinical advantage over topical medicaments as they resulted in higher patient satisfaction in the treatment of dentine hypersensitivity.⁽¹⁷⁾ Another study compared the short-term desensitizing effects of Nd: YAG laser, 5% sodium fluoride varnish and a combination of both. The authors concluded that Nd: YAG laser was superior to fluoride varnish in treating DH.⁽¹⁶⁾ The results of another systematic review revealed that laser treatment can reduce dentinal hypersensitivity related pain.⁽⁸⁾ However, the evidence for its effectiveness is weak, and the possibility of a placebo effect must be considered.⁽⁸⁾

In addition to being effective, the safety of laser application is an aspect that should be highlighted. None of the previous studies described any detrimental pulpal effects, allergic reactions, or clinically detectable complications post laser application.⁽¹⁷⁾

On reviewing the literature, we found several studies reporting the effects of Er: YAG laser on DH. Nokhbatolfoghaie et al investigated the effects of Er: YAG lasers on dentinal tubules in a descriptive study. The authors concluded that Er: YAG laser as an alternative technique for surface treatment was as safe as other conventional methods.⁽¹⁸⁾ A recent study in Taiwan investigated the effects of Er: YAG lasers on 20 patients with cervically exposed hypersensitive dentine in caries-free teeth. The results of this study showed that treatment with Er: YAG laser seemed to be a suitable tool for successful reduction of dentine hypersensitivity up to 90% after 4 weeks fol-

low up.⁽¹⁹⁾ Another similar study showed a fairly equal improvement in cervical DH after clinical application of a glutaraldehyde-based desensitizing system and an Er: YAG laser.⁽²⁰⁾

To date, because of its low cost effectiveness and unclear mechanism, acceptance of lasers in the treatment of DH is still having some limitations.⁽¹³⁾ The mechanism is hypothesized to be the occlusion of exposed dentinal tubules by partial melting. Another hypotheses regarding the instant desensitization effects can include the analgesic effect of laser irradiation on pulpal nerves and the placebo effects.⁽¹⁹⁻²¹⁾ {1.1 [EN] Please check the change}. Studying different powers and energies of Nd: YAG laser using three different modes helped us to better understand the best treatment modes of the device for dentinal hypersensitivity. Certainly, 0.7 W power in double or triple pulses/ms is recommended since it has the minimum energy and side effects.

Conclusion

All of the different powers tested in our study produced sealing of the dentinal tubules. However, 0.7 W power in double and triple radiation modes appears to be the best option for the clinician. This is mainly because it has minimum energy, less side effects, lower risk of physical danger and decreased occurrence of unwanted carbonizations. This phenomenon can also draw the attention of researchers to the possible effects of radiation modes (pulses/ms). It appears that Nd: YAG lasers are safe alternatives for the treatment of DH. Experimental and clinical studies and in particular randomized clinical trials comparing the effects of Nd: YAG lasers with other conventional methods are recommended.

Declaration

The authors have no financial support or relationships that may pose a conflict of interest.

Acknowledgments

This paper has been extracted from Ms Mahsa Moradi's DDS thesis, which was conducted under supervision of Dr Ali Dehghani Nazhvani. The study was approved, registered with ID 8692053, and supported by the International Branch of Shiraz University of Medical Sciences.

References

1. Bartlett DW, Shah P. A critical review of non-carious cervical (wear) lesions and the role of abfraction, erosion, and abrasion. *J Dent Res* 2006; 85(4): 306-12.
2. Bagramian RA, Garcia-Godoy F, Volpe AR. The global increase in dental caries. A pending public health crisis. *Am J Dent* 2009; 22(1): 3-8.
3. Lopes AO, de Paula Eduardo C, Aranha AC. Clinical evaluation of low-power laser and a desensitizing agent on dentin hypersensitivity. *Lasers Med Sci* 2015;30(2):823-9. doi: 10.1007/s10103-013-1441-z.
4. Aranha AC, Eduardo Cde P. In vitro effects of Er, Cr: YSGG laser on dentine hypersensitivity. Dentine permeability and scanning electron microscopy analysis. *Lasers Med Sci* 2012; 27(4): 827-34.
5. Bartold PM. Dentinal hypersensitivity: a review. *Aust Dent J* 2006; 51(3):212-8.
6. Bamise CT, Esan TA. Mechanisms and treatment approaches of dentine hypersensitivity: a literature review. *Oral Health Prev Dent* 2011; 9(4):353-67.
7. West NX, Lussi A, Seong J, Hellwig E. Dentin hypersensitivity: pain mechanisms and aetiology of exposed cervical dentin. *Clin Oral Investig* 2013; 17: S9-19.
8. Sgolastra F, Petrucci A, Gatto R, Monaco A. Effectiveness of laser in dentinal hypersensitivity treatment: a systematic review. *J Endod* 2011; 37(3):297-303.
9. Kimura Y, Wilder-Smith P, Yonaga K, Matsumoto K. Treatment of dentine hypersensitivity by lasers: a review. *J Clin Periodontol* 2000; 27:715-21.
10. Abed AM, Mahdian M, Seifi M, Ziaei SA, Shamsaei M. Comparative assessment of the sealing ability of Nd: YAG laser versus a new desensitizing agent in human dentinal tubules: a pilot study. *Odontology* 2011; 99(1):45-8.
11. Ishikawa I, Aoki A, Takasaki AA. Potential applications of erbium: YAG laser in periodontics. *J Periodontal Res* 2004; 39:275-85.
12. Kara C, Orbak R. Comparative evaluation of Nd: YAG laser and fluoride varnish for the treatment of dentinal hypersensitivity. *J Endod* 2009; 35(7): 971-4.
13. He S, Wang Y, Li X, Hu D. Effectiveness of laser therapy and topical desensitising agents in treating dentine hypersensitivity: a systematic review. *J Oral Rehabil* 2011; 38(5):348-58.
14. Franke M, Taylor AW, Lago A, Fredel MC. Influence of Nd: YAG laser irradiation on an adhesive restorative procedure. *Oper Dent* 2006; 31(5):604-9.
15. Cummins D. Dentin hypersensitivity: from diagnosis to a breakthrough therapy for everyday sensitivity relief. *J Clin Dent* 2009; 20(1):1-9.
16. Kumar NG, Mehta DS. Short-term assessment of the Nd: YAG laser with and without sodium fluoride varnish in the treatment of dentin hypersensitivity - A clinical and scanning electron microscopy study. *J Periodontol* 2005; 76:1140-7.
17. Blatz MB. Laser therapy may be better than topical desensitizing agents for treating dentin hypersensitivity. *J Evid Based Dent Pract* 2012; 12(3 Suppl):229-30.
18. Nokhbatolfighahaie H, Chiniforush N, Shahabi S, Monzavi A. Scanning electron microscope (SEM) evaluation of tooth surface irradiated by different parameters of Erbium: Yttrium Aluminium Garnet (Er: YAG) laser. *J Lasers Med Sci* 2012. 3(2):51-5.
19. Yu CH, Chang YC. Clinical efficacy of the Er: YAG laser treatment on hypersensitive dentin. *J Formos Med Assoc* 2014; 113(6):388-91.
20. Ehlers V, Ernst CP, Reich M, Kämmerer P, Willershausen B. Clinical comparison of gluma and Er: YAG laser treatment of cervically exposed hypersensitive dentin. *Am J Dent* 2012; 25(3):131-5.
21. Colucci V, do Amaral FL, Pécora JD, Palma-Dibb RG, Corona SA. Effects of water flow on ablation rate and morphological changes in human enamel and dentin after Er: YAG laser irradiation. *Am J Dent* 2012; 25(6):332-6.