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Effectiveness of Er,Cr:YSGG laser on dentine hypersensitivity: a controlled clinical trial

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Abstract

Aim: Attempts have been made to treat dentine hypersensitivity (DH) with lasers. However, there is limited knowledge on the effects of erbium, chromium-doped:yttrium, scandium, gallium and garnet (Er,Cr:YSGG) laser on DH. The aim of this study was to evaluate the efficacy of Er,Cr:YSGG laser on reduction in DH.

Methods: Forty-two patients (146 teeth) were included. Teeth were assigned to an experimental group and irradiated with the Er,Cr:YSGG laser. In the control group same clinical instrument was used without laser emission. DH was assessed for both groups utilizing the visual analog scale. Plaque index (PI) scores were recorded immediately following treatment, at 1 week, 1 and 3 months.

Results: The results showed that Er,Cr:YSGG laser irradiation had a significantly higher desensitizing effect compared with the placebo immediately after treatment ($p < 0.05$). Intra-group comparisons revealed no statistically significant differences within the placebo group ($p > 0.05$). For the test group, the differences between baseline and all time points following treatment were statistically significant ($p < 0.05$). No significant differences were observed in PI between the test and control groups at any follow-up examination ($p > 0.05$).

Conclusion: Within the limits of this study, it appears that Er,Cr:YSGG laser is effective in the treatment of DH compared with the placebo treatment.

Key words: dentine sensitivity; follow-up studies; laser therapy

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Dentine hypersensitivity (DH) is a common clinical problem originating from exposure of the dentinal tissue and is characterized by a painful sensation after thermal, chemical, mechanical or osmotic stimuli. It is characterized by an acute, non-spontaneous, short or long-lasting pain that appears suddenly in a specific location, which cannot be attributed to any other dental pathology (Holland et al. 1997, Rees & Addy 2002, Que et al. 2010). More than 90% of hypersensitive surfaces are located at the cervical margin on the buccal or labial aspects of the teeth (Orchardson & Collins 1987). Under normal conditions, dentine is protected by enamel or cementum. Hypersensitivity occurs due to the removal of the enamel and/or cementum layer by attrition from either occlusal wear, parafunctional habits, acid erosion, coronal fracture or defective restorations (Corona et al. 2003). Gingival recession, periodontal disease and also improper toothbrushing can expose root surfaces (Wichgers & Emert 1996). It should be noted although that not all exposed dentine may be sensitive. This can be explained by passive mechanisms such as precipitation of salivary proteins and calcium phosphate inside dentinal tubules or adsorption of plasma proteins and saliva constituents. Active mechanisms such as deposit of intra-tubulary crystalline material and formation of secondary, peritubular and irritation (tertiary) dentine can also reduce DH (Ladalardo et al. 2004).

Several theories have been proposed to explain the mechanism of DH (Pashley 1990). According to Brännström's Hydrodynamics Theory (Brännström 1966), various stimuli displace fluid in the dentinal tubules either inwardly or outwardly. Fluid movement activates the nerve endings at the pulp/dentine interface. Therefore, it seems plausible to assume that any substance or technique that reduces dentinal fluid

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movement or dentine permeability should decrease sensitivity. The effectiveness of desensitizing agents is directly related to their capacity to promote the sealing of dentinal tubules or blocking the nerve activity. Desensitizing agents may target various points in the hydrodynamic sequence, which can be interrupted by various actions. The agents most frequently used for the treatment of DH can be classified as follows: protein precipitants, tubule-occluding agents, tubule sealants and nerve activity blockers (Al-Sabbagh et al. 2009, Aranha et al. 2009, Orsini et al. 2010, Pradeep & Sharma 2010).

Lasers are one of the promising new modalities used for desensitization. Many lasers, including helium–neon (He–Ne), gallium–aluminium–arsenide (GaAlAs-Diode), neodymium-doped:yttrium, aluminium and garnet (Nd:YAG), erbium-doped:YAG (Er:YAG) and carbon dioxide (CO_2), have desensitizing effects (Moritz et al. 1998, Kimura et al. 2000, Schwarz et al. 2002, Aranha et al. 2009). There are several different theories for explaining the effect of laser irradiation on dentine, but the most accepted one indicates sealing or occluding dentinal tubules by melting and re-crystallization of dentine (Aranha et al. 2009). The use of Nd:YAG and CO_2 lasers in DH treatment are limited due to their thermal side effects (Moritz et al. 1998, Birang et al. 2007).

Er:YAG and erbium, chromium-doped:yttrium, scandium, gallium and garnet (Er,Cr:YSGG) lasers are expected to show efficiency in dental applications because of their thermomechanical ablation mechanism and the high absorption of their wavelengths (2.94 and 2.78 nm, respectively) by water (Hossain et al. 1999, Braun et al. 2010). Er:YAG laser irradiation has been demonstrated to be clinically successful in the treatment of DH (Schwarz et al. 2002, Birang et al. 2007). However, to the best of our knowledge, the available data on clinical outcomes of desensitizing treatments with an Er,Cr:YSGG laser are limited. The purpose of this study was to evaluate the clinical effectiveness of Er,Cr:YSGG laser in treating DH.

Material and Methods

Forty-two subjects (146 teeth) with a chief complaint of DH (mean 33.8 ± 12 years old; 24 females and 18 males) were recruited for this study between January and September 2009. Patient recruitment was performed within the Department of Periodontology, Faculty of Dentistry, Near East University. Inclusion criterion included at least one or more (maximum four) contra-lateral pairs of hypersensitive teeth. Exclusion criteria were carious lesions on the selected or neighbouring teeth, restorations, active periodontal diseases and more than 3 mm gingival recession on the selected teeth, any professional desensitizing therapy during the last 6 months, use of desensitizing toothpaste in the last 3 months, having any systemic diseases, being under analgesics/anti-inflammatory drugs at the time of the study, pregnancy and smoking. Following verbal information about the treatment plan, possible discomforts and potential risks, the subjects who signed the informed consent form were included in the study. Study protocol and related consent forms were approved by the Institutional Review Board of Near East University (protocol ID#27.3.3.a). The vitality of all experimental teeth was examined at the beginning and end of the trial by an electric pulp tester (Digitest, Parkel, NY, USA). Each subject received a professional prophy before study and was given oral hygiene instructions at two separate appointments during the 4-week pre-treatment period.

The degree of sensitivity to an evaporative stimulus was determined qualitatively by means of an air blast for 3 s at a distance of approximately 1 cm and at right angle to the buccal site of the assigned teeth, while adjacent teeth were isolated with cotton rolls to prevent false positive results. Air stimulus time was controlled by chronometer and the distance was measured by a periodontal probe (UNC-15, Hu-Friedy, Chicago, IL, USA). Patients were asked to record their overall sensitivity by marking a point on a 10 cm visual analog scale (VAS), which was marked ''No pain'' on the left end and ''Unbearable pain'' on the right end (Holland et al. 1997). All stimuli were given by one operator at the same dental chair with the same equipment yielding similar air pressure (55–60 psi) and temperature (21–22°C) each time. A calibration session was performed to determine intra-examiner consistency. Seven subjects were included for this session and measurements were repeated within 30 min. Calibration for plaque index (PI) evaluation was performed with a periodontal probe (UNC-15, Hu-Friedy) by repeating measurements at mesial and distal half of the tooth surface adjacent to the gingival margin.

For each subject, selected teeth were randomly assigned to the test or the control group by the toss method, and then, half of the sensitive teeth were irradiated with Er,Cr:YSGG laser (Waterlase MD, Biolase, Irvine, CA, USA) on hard tissue mode with a mz6 sapphire tip using non-contact mode at an energy level of 0.25 W and a repetition rate of 20 kHz, 0% water and 10% air. In the placebo group, the same Er,Cr:YSGG laser without laser emission was used. The treatment time was 30 s per surface by scanning the cervical part of the tooth. If any subjects had more than one pair, all teeth on the same side received the same treatment. All active and placebo treatments were performed only at the first visit, by the same clinician. DH was assessed with VAS and PI scores (Silness & Löe 1964) were recorded at four examination periods; immediately, at 1 week, 1 and 3 months after treatment by a single calibrated examiner who was not aware of the type of treatment applied. All patients used a soft toothbrush and toothpaste without any anti-hypersensitivity agent. These products were provided by the researchers. In addition, subjects were asked not to use any mouthrinse and/or fluoride products during the study.

Sample size calculation

A minimum clinically significant difference in VAS scores of 0.6 was determined from available literature on DH (Yates et al. 2004). The power analysis was conducted based on this minimum clinically significant difference in VAS scores, using alpha at level 0.05, at 80% power and a σ of 1.16. On the basis of these data, the number of patient required to be enrolled to conduct this study has been calculated as 40.

Statistical analysis

For comparing the effectiveness of the Er,Cr:YSGG laser irradiation to placebo treatment, patient was used as a statistical unit rather than tooth. Mean values of the clinical parameters were calculated for all groups. The normal distribution of all scores was assessed using the Kolmogorov–Smirnov test. To evaluate the changes over time within the groups, one-way repeated analysis of variance was used. Post hoc comparisons were performed using the Tukey test, when significance was detected. The paired *t*-test was used for comparison between groups at the each time points. Values of $p < 0.05$ were accepted as statistically significant.

Cohen's κ was used to describe the reliability of discrete values for an objective evaluation of PI. Based on the duplicate evaluations, the κ value for PI evaluation was 0.92 ± 0.05. The range of mean errors for VAS assessment was 0.21–0.28 and indicated stable reliability during the evaluation period.

Results

All 42 patients completed the 3-month study period. Teeth included in this study can be seen in Table 1. Forty-nine per cent of teeth were maxillary or mandibular premolars, followed by maxillary canines and mandibular lateral incisors (Table 1). No complications such as adverse pulp effects were observed. The baseline VAS score for each subject following the air stimuli is presented in Table 2. Although few patients were low responders (baseline VAS < 5), the baseline difference between test and placebo sides was not statistically significant for the same subject (Table 2). The effects of treatment at the different time points can be seen in Table 3. Er,Cr:YSGG laser irradiation provided a significantly higher desensitizing effect compared with placebo immediately after treatment and was maintained throughout the duration of the study ($p < 0.05$). Intra-group comparisons revealed no statistically significant differences within the placebo group ($p > 0.05$). When the test group was considered, post-treatment VAS scores were lower than baseline VAS scores ($p < 0.05$). There were no statistical significance between the following intervals ($p > 0.05$). Figure 1a,b indicate the median and quartiles VAS values over 3 months in test and placebo groups. Higher variations observed at baseline were decreased throughout the study for test sides (Fig. 1a) compared with placebo sides (Fig. 1b).

The mean plaque scores at baseline indicated a high standard of oral hygiene in all groups during the study period. No significant differences between the groups were found at any follow-up examination ($p > 0.05$) (Table 4).

Discussion

Although there is a great variety of therapeutic methods, DH is still a chronic dental problem due to the difficulty of qualification of pain, selection of treatment method and uncertain prognosis. The conventional treatment of DH can be classified according to the use of chemical and physical agents or periodontal plastic surgery (PPS). Traditionally, PPS is utilized in cases of DH caused by gingival recession as it allows root coverage in Miller I and II defects. Among the available procedures, free gingival graft, laterally or coronally positioned flaps, semilunar flap, guided tissue regeneration and subepithelial connective tissue grafts have been routinely performed (Roccuzzo et al. 2002, Chambrone et al. 2009, 2010). However, the outcome of PPS is not always predictable, particularly, in cases with severe root exposure where complete root coverage is not possible (Al-Zahrani & Bissada 2005, Chambrone et al. 2008, 2009, 2010). In this study, a physical agent (Er,Cr:YSGG laser) was evaluated for desensitizing efficacy. The Er,Cr:YSGG laser is a relatively new device, which has been reported to ablate dental hard tissues with minimum injury to the pulp and surrounding tissues (Eversole et al. 1997). This laser can ablate enamel and dentine effectively, due to its high absorption in water and also strong absorption by the hydroxyl radicals present in the hydroxyapatite structure (Eversole et al. 1997, Hadley et al. 2000). Earlier studies have shown that Er,Cr:YSGG laser can create precise hard tissue cuts through the interaction of laser energy with atomized water droplets on the tissue interface resulting in the ablation of the tissue (Eversole & Rizoiu 1995, Hossain et al. 1999, Olivi et al. 2010). Beside the existing water in tissue, the Er,Cr:YSGG laser uses exogenous water for ablation (Ekworapoj et al. 2007). Because Meister et al. (2006) reported that the exogenous water has a greater affect than endogenous water on the dentine ablation, in the present study Er,Cr:YSGG laser was used without water. Ting et al. (2007) applied Er,Cr:YSGG laser to extracted single-rooted tooth surfaces with and without water at different power outputs and

Table 1. Types of teeth included in the study

Types of teeth	Number of teeth included in study
Maxillary central incisors	8
Maxillary lateral incisors	10
Maxillary canine	14
Maxillary premolars	30
Maxillary molars	6
Mandibular central incisors	12
Mandibular lateral incisors	14
Mandibular canine	4
Mandibular premolars	42
Mandibular molars	6

Table 2. Baseline VAS scores for each patient

Patient number	Test	Control
1	8.7	8.5
2	6.5	7
3	4	4.5
4	7.5	8
5	6.5	5.9
6	3.8	4.9
7	7	6.4
8	3.5	4.9
9	10	8.8
10	6.4	6.5
11	5.5	5.7
12	4.8	5.2
13	4	5.9
14	4.5	5
15	8	7
16	7.2	7.1
17	6.5	6.3
18	5.9	5.9
19	9.2	9.5
20	8.7	8.5
21	9.8	9.5
22	8.5	8.9
23	8.2	7.8
24	9.4	9.7
25	9.4	8.9
26	5	6.8
27	7.3	7.3
28	5.5	5.6
29	5.2	6.4
30	6.7	7.1
31	6.8	7.6
32	6.5	4.7
33	5.9	3.8
34	9.2	7
35	8.7	6.2
36	8	6
37	8.5	7
38	8	7.2
39	8.2	8.7
40	9.8	9
41	5	5.8
42	7.3	7.2

VAS, visual analog scale.

Table 3. Mean degree of discomfort and standard deviation in all groups over 3 months

Group	Baseline	Immediate	Week 1	Month 1	Month 3
Test	7.02 ± 1.82	1.47 ± 1.08*†	1.59 ± 1.22*†	1.32 ± 0.99*†	1.35 ± 1.07*†
Control	6.89 ± 1.5	6.13 ± 2.05	6.12 ± 2.01	6.14 ± 2.02	6.10 ± 2.06

*Post-treatment VAS scores were lower than baseline VAS scores, $p < 0.05$.
†The differences at immediate, 1 week, 1 month and 3 months after treatment were statistically significant between test and control group, $p < 0.05$.
VAS, visual analog scale.

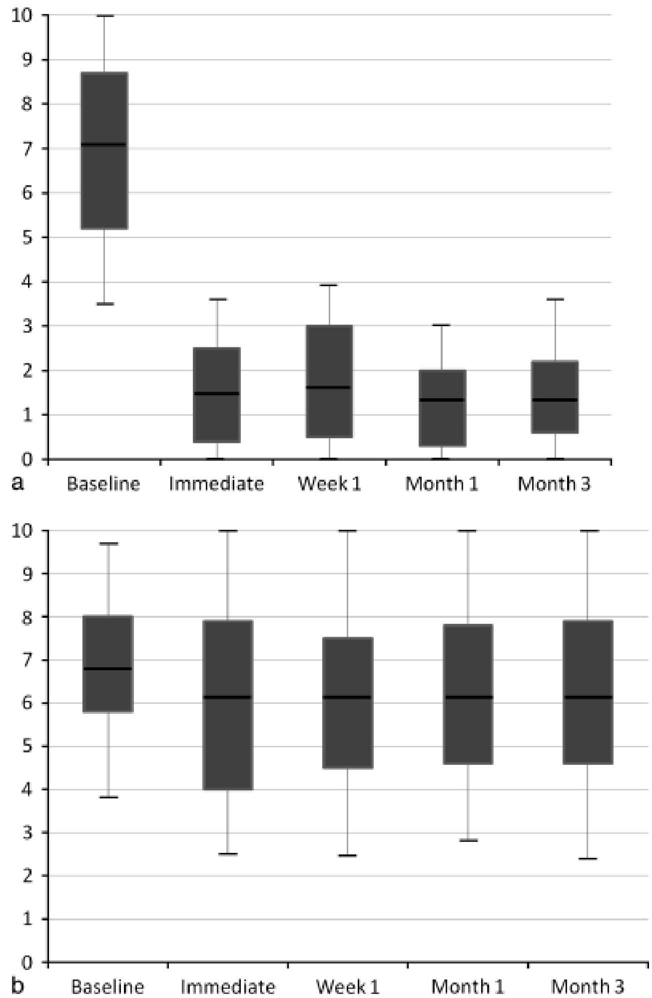

Fig. 1. a. Median, maximum, minimum values and interquartile ranges of visual analog scale (VAS) values for test group ($n = 42$). b. Median, maximum, minimum values and interquartile ranges of VAS values for control group ($n = 42$).

Table 4. Mean plaque index and standard deviation in all groups over 3 months*

Group	Baseline	Immediate	Week 1	Month 1	Month 3
Test	0.6 ± 0.2	0.1 ± 0.2	0.8 ± 0.4	0.9 ± 0.3	0.6 ± 0.3
Control	0.7 ± 0.2	0.1 ± 0.1	0.9 ± 0.3	1.0 ± 0.1	0.7 ± 0.2

*No significant differences between the groups were found at any follow-up examination, $p > 0.05$.

examined the morphologic alterations after irradiation. The results of the study showed that in the no water group, carbonization occurred, even at 0.5 W. With regard to this result, the energy settings of the present study were lower than the threshold at which carbonization, melting and surface roughness could occur. A rough root surface may create a niche for plaque accumulation and may cause caries and hypersensitivity (Quirynen & Bollen 1995). In the current study, because there were no differences observed in PI compared with the baseline, it can be considered that this approach does not alter the tooth surface that might result in plaque retention.

The high absorption of the Er,Cr:YSGG laser emission wavelength (2.78 μm) in water may result in an evaporation of the dentinal fluid and the smear layer. Thus, it could be suggested that a deposition of insoluble salts in the exposed tubules are responsible for obturation of the dentinal tubules. Er:YAG laser has similar effects with Er,Cr:YSGG laser because the wavelength (2.94 μm) is very close to Er,Cr:YSGG laser (Hossain et al. 1999). Schwarz et al. (2002) reported that Er:YAG laser may treat hypersensitivity with the aforementioned mechanism. However, Er,Cr:YSGG laser is more highly absorbed by OH ions than water molecules so that Er,Cr:YSGG laser can cause a higher rise in surface temperature than the Er:YAG laser. As a result, more chemical surface alteration occurs and also the mineral content of enamel and dentine changes (Harashima et al. 2005). Thus, it may be suggested that Er,Cr:YSGG laser has more solubility-reducing effect on enamel and dentine. High bactericidal potential of Er,Cr:YSGG laser (Arnabat et al. 2010) should be also emphasized because bacteria seem to play an important role in sensitivity of teeth by causing the synthesis of inflammation mediators and thereby lowering the pain threshold of the nerve fibres (Olgart et al. 1974).

Immediate alleviation of pain is important in the treatment of DH. Equally important is the long-term duration of effects in the reduction of DH. Many studies have shown effective results with observation periods between 4 and 24 weeks (Pillon et al. 2004, Kumar & Mehta 2005, Dilsiz et al 2009, Ipci et al. 2009). Pesevska et al. (2010) treated scaling and root planing induced DH with low-level diode laser and topical fluoride. Both of the treatments were found to be effective. However, a decrease in the pain was observed after the second and third treatment visit and patients were not followed-up in long term. Frechoso et al. (2003) investigated the immediate efficacy of two types of potassium nitrate (NKO_3) gels (5% and 10%) in the treatment of DH and evaluated the frequency of appearance of adverse effects of these treatments. They founded that a greater reduction of DH was observed after 48 h of treatment in the NKO_3 10% group compared with the NKO_3 5% group and placebo group. Also, they reported that there were small irritations in the area of the NKO_3 10%-treated tooth. Recently, Orsini et al. (2010) compared the desensitizing efficacy of a new dentifrice containing carbonate/hydroxyapatite (CHA) nanocrystals and a sodium fluoride/potassium nitrate dentifrice. The investigators reported that nanostructured CHA microparticles may significantly reduce painful stimuli when compared with the control group at 8 weeks. The results of the present clinical trial demonstrated that desensitizing of the hypersensitive dentine with Er,Cr:YSGG laser was effective at a single visit and the positive results of laser irradiation compared with placebo treatment at control site was maintained for 3 months without any side effects.

The most common stimuli for assessing DH are thermal and tactile stimuli. Air blast has been used in the majority of studies as a means of combining thermal and evaporative stimulation of sensitive dentine (Ide et al. 2001). In this study, air blast was used because thermal methods have been demonstrated to be more effective (Gillam et al. 2002). Although it has been recommended by some authors to use more than one stimulus (Duran & Sengun 2004), a single stimulus, an air blast was chosen because this is a clinically relevant measure (Ide et al. 2001, Schwarz et al. 2002). Despite various methods for assessment of pain, VAS was preferred in this study because it is a widely used and adequate tool for the evaluation of pain, because it is easily understood by patients, sensitive in discriminating among the effects of various types of treatments and thus it is suitable for evaluating the pain response seen in studies of DH (Gillam & Newman 1993, Holland et al. 1997, Ide et al. 2001).

Grossman (1935) suggested a number of requirements for treatment of DH, which are still valid today. Therapy should be non-irritant to the pulp; relatively painless on application; easily carried out; rapid in action; effective for a long period; without staining effects; and consistently effective. To date, most of the therapies have failed to satisfy one or more of these criteria. In our study, none of the laser-treated teeth showed secondary effects, which confirms the safety of this type of treatment. However, inappropriate laser usage could result in thermal lesions on the radicular surface, gingival tissues, dental pulp and adjacent bone (Schwarz et al. 2008). The practitioner must read thoroughly the safety and efficacy documentation of the laser protocol that she/he wants to apply.

In conclusion, the present study demonstrated that the single application of Er,Cr:YSGG laser has shown efficacy in rapid DH reduction compared with placebo treatment. This effect has become apparent immediately, and it remained stable for a 3-month examination period. There is a need to compare the effectiveness of Er,CR:YSGG laser on DH with currently available treatment modalities conventionally used to treat DH. Nevertheless, Er,Cr:YSGG laser provides a simple approach for both patient and the clinician with promising treatment outcomes. Further studies are necessary to understand the possible mechanism(s) involved at the cellular level.

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Clinical Relevance

Scientific rationale for study: Lasers are used in the treatment of DH; however, information on the clinical application of Er,Cr:YSGG laser for DH is limited.
Principal findings: Er,Cr:YSGG laser application has shown an immediate reduction of DH compared with placebo. These positive results of laser irradiation were maintained for 3 months.
Practical implications: The use of Er,Cr:YSGG laser at 0.25 W without water has shown efficacy in DH reduction compared with placebo treatment. However, additional studies are necessary to compare Er,Cr:YSGG laser treatment with conventional applications used to decrease DH.