Clinical evaluation of Er,Cr:YSGG and GaAlAs laser therapy for treating dentine hypersensitivity: A randomized controlled clinical trial

Hasan Guney Yilmaz a,*, Sevcan Kurtulmus-Yilmaz b, Esra Cengiz c, Hakan Bayindir a, Yasar Aykac d

a Department of Periodontology, Faculty of Dentistry, Near East University, Mersin 10, Turkey
b Department of Prosthodontics, Faculty of Dentistry, Near East University, Mersin 10, Turkey
c Department of Endodontics and Restorative Dentistry, Faculty of Dentistry, Near East University, Mersin 10, Turkey
d Department of Periodontology, Faculty of Dentistry, Ankara University, Ankara, Turkey

ARTICLE INFO

Article history:
Received 25 November 2010
Received in revised form
21 December 2010
Accepted 7 January 2011

Keywords:
Laser therapy
Dentine hypersensitivity
Desensitizing agents

ABSTRACT

Objective: The advent of dental lasers has raised another possible treatment option for dentine hypersensitivity (DH) and has become a research interest in the last decades. The aim of this randomized, controlled, double-blind, split mouth, clinical study was to evaluate and compare the desensitizing effects of erbium, chromium-doped:yttrium, scandium, gallium and garnet (Er,Cr:YSGG) to galium–aluminium–arsenide (GaAlAs) laser on DH.

Methods: Fifty-one patients participated in this study for a total of 174 teeth. DH was assessed for all groups with a visual analog scale. For each patient, the teeth were randomized to three groups. In the diode laser group, sensitive teeth were irradiated with the GaAlAs laser at 8.5 J/cm² energy density. In the Er,Cr:YSGG laser group, sensitive teeth were irradiated with Er,Cr:YSGG laser in the hard tissue mode using a none-contact probe at an energy level of 0.25 W and repetition rate of 20 Hz, 0% water and 10% air. In the control group no treatment was performed. Treatment time was 60 s for GaAlAs laser and 30 s for Er,Cr:YSGG laser.

Results: When compared with the control group and baseline data, in both laser groups, laser irradiation provided a desensitizing effect immediately after treatment and this effect was maintained throughout the study (p < 0.05). No significant differences between Er,Cr:YSGG and GaAlAs laser groups were found at any follow-up examination (p > 0.05).

Conclusion: Based on these findings, it may be concluded that both Er,Cr:YSGG and GaAlAs lasers were effective in the treatment of DH following a single application.

© 2011 Elsevier Ltd. All rights reserved.

1. Introduction

Dentine hypersensitivity (DH) is characterized by an acute, non-spontaneous, short or long-lasting pain originating from exposure of the dentine to thermal, chemical, mechanical, or osmotic stimuli, which cannot be attributed to any other dental pathology. 1,2 Although different theories have been proposed for the mechanism of DH, Brännström's hydrodynamic mechanism 3 is the most widely accepted one. According to this theory, external stimuli cause movement of fluid...
inside dentinal tubules inwardly or outwardly, promoting mechanical deformation of nerve endings at the pulp/dentine interface, which is transmitted as a painful sensation. Under normal conditions, dentine is covered by enamel or cementum and is not sensitive to direct stimulation. DH occurs only with the exposure of the peripheral terminations of dentinal tubules.4 There are various treatment methods for DH and the effectiveness of these methods is directly associated with their capacity to support the sealing of dentinal tubules to prevent dentinal fluid flow or blocking nerve activity.5,6 The agents most frequently used for DH treatment can be classified as follows: protein precipitants, tubule-occluding agents or tubule sealants.5

The use of lasers opens a new dimension in the treatment of DH. Several different theories have been suggested to explain the effect of laser irradiation on dentine, that involve sealing of dentinal tubules by melting and re-crystallization of dentine, evaporation of the dentinal fluid, analgesic effect related to depressed nerve transmission or obliterating the dentinal tubules with tertiary dentine production.7–9 Many lasers, including helium–neon (He–Ne), neodymium-doped:yttrium, aluminium and garnet (Nd:YAG), erbium-doped:yttrium, scandium, gallium and garnet (Er:YSGG), erbium-doped:YAG (Er:YAG) and carbon dioxide (CO2), have desensitizing effects.6–8,10 Recently, the results of gallium–aluminium–arsenide (GaAlAs) diode laser irradiation in DH treatment were successful in clinical trials.5,9,11 Erbium, chromium-doped:yttrium, scandium, gallium and garnet (Er,Cr:YSGG) laser is expected to show efficiency in dental applications.12–14 However, to the best of our knowledge, there are no published data available concerning the clinical outcome of a desensitizing treatment with an Er,Cr:YSGG laser. Therefore, the aim of this in vivo study was to evaluate and compare the desensitizing effects of Er,Cr:YSGG laser and GaAlAs diode laser at 3-month follow-up. The study tested the null hypotheses that laser treatment of dentine had no effect on the level of DH of patients, and that the effect of an Er,Cr:YSGG laser was not different from that of a GaAlAs diode laser.

2. Materials and methods

2.1. Patient selection

Fifty-one patients (22 males and 29 females) with 174 teeth affected by DH between the ages of 18 and 60 (mean age: 44 ± 9.7 years) volunteered for this study. For inclusion in the study the subjects had to have 3 or more hypersensitive teeth in different quadrants. Exclusion criteria included carious lesions on the selected or neighbouring teeth, use of desensitizing toothpaste in the last 3 months, pregnancy or smoking. After having received oral and written information about the intention and the design of the study, and having signed the informed consent form, the subjects were included in the study. Study protocol and related consent forms were approved by our Institutional Review Board.

2.2. Evaluation of dentine hypersensitivity

The vitality of all experimental teeth was controlled at the beginning and end of the trial by means of an electric pulp tester (Digitest, Parkel, NY, USA). For 4 weeks before treatment, all patients were enrolled in an oral hygiene programme and received oral hygiene instructions on two appointments as well as professional tooth cleaning according to individual needs. Prior to the application of lasers in all groups, DH was assessed by an evaporative stimulus. A strong air-blast from a dental syringe was directed to the exposed cervical area for 3 s at a distance of 1 cm and at right angle to the buccal site of the assigned teeth, whilst adjacent teeth were isolated with cotton rolls. Air stimulus time was controlled by a chronometer and the distance was measured by a UNC-15 periodontal probe (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), anchored at each end by the phrases “No pain” and “Unbearable pain”. All stimuli were given by one operator in the same dental chair with the same equipment yielding similar air pressure (55–60 psi) and air temperature (21–22°C) each time.

2.3. Laser treatment

In this split-mouth study, for each patient, selected teeth were randomly assigned to Er,Cr:YSGG laser group, GaAlAs diode laser group or control group by the lottery method. In the diode laser group, sensitive teeth were irradiated with the GaAlAs laser (LaserSmile, Biolase Technology, Irvine, CA, USA) using 810 nm continuous waveform at 8.5 J/cm2 energy density. In the Er,Cr:YSGG laser group, sensitive teeth were irradiated at 2780 nm with Er,Cr:YSGG laser (Waterlase MD, Biolase Technology, Irvine, CA, USA) in the hard tissue mode with the MZ6 sapphire tip (600 μm diameter, 6 mm length) using non-contact mode at an energy level of 0.25 W, repetition rate of 20 pulses/s and pulse duration of 140 μs, 0% water and 10% air. Treatment time was 60 s for GaAlAs laser and 30 s for Er,Cr:YSGG laser by scanning the cervical part in an overlapping pattern. At the control group, no treatment was performed. The patients did not know what kind of therapy each tooth was receiving. All laser irradiations were performed by the same examiner. If any subjects had more than 3 sensitive teeth, all teeth on the same side received the same treatment. The effectiveness of all treatments was assessed at four examination periods; immediately, at 1 week, 1 and 3 months after treatment by one 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.

2.4. Sample size calculation

A minimum clinically significant difference in VAS scores of 0.6 was determined from the available literature on DH.15 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 $\sigma$ of 1.16. On the basis of these data, the number of patients required to be enrolled to conduct this study was calculated as 40.

2.5. Statistical analysis

Mean values of the clinical parameters were calculated for all groups. Normality of the data distribution was checked by the Kolmogorov–Smirnov test. Nonparametric tests were chosen because the data were not distributed normally. Intra-group time-dependent data were analysed by Friedman’s test, and Wilcoxon’s rank sum test was used to evaluate the differences within groups at each time point. Values of $p < 0.05$ were accepted as statistically significant.

3. Results

All 51 patients completed the 3-month study period. Their baseline demographic characteristics are presented in Table 1. Thirty-eight percent of teeth were maxillary or mandibular premolars, followed by mandibular central and mandibular lateral incisors (Table 2). No complications such as adverse pulp effects were observed throughout the study. The response of the patients to the air stimuli throughout the study, and the effects of treatments at the different time points can be seen in Fig. 1. When compared with the control group, in the Er,Cr:YSGG and GaAlAs laser groups, laser irradiation provided a desensitizing effect immediately after treatment that was maintained throughout the study ($p < 0.05$) (Table 3). No significant differences between the laser groups were found at any time points ($p > 0.05$) (Table 3). Intragroup comparisons revealed that the differences between baseline scores and immediately, 1 week, 1 and 3 months after treatment were statistically significant in Er,Cr:YSGG and GaAlAs laser groups (Table 3). In the control group no significant differences were found at the intragroup comparisons (Table 3).

4. Discussion

Traditional DH treatment is based on the application of desensitizing agents, which obliterates the dentinal tubules exposed to the oral environment. Since the use of tubule occlusive agents has some disadvantages such as need for repeated applications, longer treatment time and patient compliance, the need for use of alternative treatment

![Fig. 1](image_url) - Reduction of dentinehypersensitivity in all groups at 3-month follow-up.
modalities has arisen. With the development of laser technology, a new treatment option for DH has occurred in the last decade. Most experimental and clinical studies regarding the effectiveness of low level laser therapy (LLLT) on DH were performed using semiconductor diode lasers with wavelengths in the range of 635–830 nm, and dosages in the range of 2–10 J/cm². GaAlAs laser irradiation at maximum power of 60 mW does not affect the enamel or dentine surface morphologically. However, a small fraction of the laser energy at 830 nm wavelength is transmitted through dental hard tissues to reach the pulp. These lasers’ treatments have an immediate analgesic effect by depressing nerve transmission. According to physiological experiments, this immediate effect of GaAlAs laser is caused by blocking the depolarization of C-fibre afferents.

In this clinical trial an Er,Cr:YSGG laser was also used for the treatment of DH. The Er,Cr:YSGG laser is a relatively new device which can ablate enamel and dentine due to its high absorption in water and its strong absorption by hydroxyl radicals existing in the hydroxyapatite structure. Earlier studies showed that the Er,Cr:YSGG laser could create precise hard tissue removal by the interaction of laser energy with existing water in tissue but also exogenic water for ablation. Since it has been 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. Therefore, the energy settings of the present study were lower than the threshold for carbonization, melting and surface roughness. The high absorption of the Er,Cr:YSGG laser emission wavelength (2.78 μm) in water may result in the deposition of insoluble salts from the exposed tubules by evaporation of the dentinal fluid. Thus, it could be suggested that this deposition is responsible for obturation of the dentinal tubules and reducing DH. Er:YAG laser has similar effects with Er,Cr:YSGG laser since its wavelength (2.94 μm) is very close to that of the Er,Cr:YSGG laser. Schwarz et al. theorized that Er:YAG shows its immediate efficiency on DH using the above-mentioned mechanism. Another possible mechanism of the Er,Cr:YSGG laser on DH is its effect on the neural receptor TRPV1 which is known to be stimulated by heat. Anecdotal reports in dentistry have suggested that the Er,Cr:YSGG laser may assist in local anaesthesia on a short-term basis. Park et al. reported that thermal-sensitive TRPs in dental sensory nerves may serve as tooth pain sensors. Thus, Er,Cr:YSGG laser treatment may cause dental analgesia via TRPV1 inhibition. In a recent paper, Ryu et al. tested the effects of a Er,Cr:YSGG laser (the same as was used in the current study) at energies similar to those used in the current study, on cultured trigeminal neurons and cell cultures overexpressing TRPV1. They used the laser on TRPV1 knockout mice vs. control mice, injected in the hindpaw with 0.33 mM capsaicin, the essence of hot peppers. In normal animals, this substance elicits intense hindpaw linking/shaking responses. When they used the water cooled Er,Cr:YSGG laser to treat the capsaicin-treated site, the mice showed significant reductions in pain-related behaviour. Similar laser treatment of TRPV1 knockout mice did not show any analgesia. The authors speculated that the laser acts directly on the TRPV channel function in sensory neurons rather than by damaging cells. The high bactericidal potential of Er,Cr:YSGG laser is also important since bacteria may secrete inflammatory mediators which cause pain. Er,Cr:YSGG laser irradiation at 0.25 W without water spray reduced micro-organisms on dentine surfaces without signs of carbonization or melting. In this clinical trial, both Er,Cr:YSGG and GaAlAs lasers produced immediate desensitizing effects after a single treatment.

The long-term duration of desensitizing effects is as critical as the rapid reduction of DH. Previous studies reported that the effects of many topical desensitizing agents, dentifrices, and products containing ferric aluminium and potassium oxalates are not permanent, because they do not adhere to the dentine surface. However, histological studies have reported that when the diode laser is used with correct parameters, besides the immediate analgesic effect, pulpal hard tissue formation is enhanced as a reaction to laser light in the dental pulp over a long time period. Stimulation of odontoblasts, production of reactionary irregular dentine and obliteration of dentinal tubules provoked by diode laser may be reasons for the prolonged suppression of pain in DH. Er,Cr:YSGG laser light is more highly absorbed by OH ions than water molecules so Er,Cr:YSGG laser can cause a rise in surface temperature and thus change the mineral content of enamel and dentine. Recently, de Freitas et al. indicated that low power laser irradiation with the Er,Cr:YSGG laser at 0.25 W or 0.5 W can be an alternative to the use of fluoride for the caries preventive treatment. They stated that, this irradiation was claimed to make the surface more resistant to acid as a result of chemical alterations in the enamel structure. Thus, the authors speculate that Er,Cr:YSGG laser reduces DH in long-term due to the caries preventive and solubility reducing effects on dental hard tissues. The current study demonstrated that,

### Table 3 – Mean degree of VAS scores and standard deviation in all groups over 3 months.

<table>
<thead>
<tr>
<th>Group</th>
<th>Baseline</th>
<th>Immediate</th>
<th>Week 1</th>
<th>Month 1</th>
<th>Month 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Er,Cr:YSGG</td>
<td>7.2 ± 1.4</td>
<td>1.5 ± 1.4*</td>
<td>1.2 ± 1.1*</td>
<td>1.1 ± 1.2*</td>
<td>1 ± 1.1*</td>
</tr>
<tr>
<td>GaAlAs</td>
<td>7.1 ± 1.3</td>
<td>1.7 ± 1.3*</td>
<td>1.6 ± 1.3*</td>
<td>1.2 ± 1.2*</td>
<td>1.1 ± 1.1*</td>
</tr>
<tr>
<td>Control</td>
<td>6.9 ± 1.4</td>
<td>6.6 ± 1.6</td>
<td>6.5 ± 1.5</td>
<td>6.6 ± 1.4</td>
<td>6.4 ± 1.4</td>
</tr>
</tbody>
</table>

* Post treatment VAS scores were lower than baseline VAS scores at Er,Cr:YSGG group, p < 0.05, Friedman’s test.
# Post treatment VAS scores were lower than baseline VAS scores at GaAlAs group, p < 0.05, Friedman’s test.
* The differences at immediate, 1 week, 1 and 3 months after treatment were statistically significant between laser groups and control group, p < 0.05, Wilcoxon’s rank sum test.
positive results of irradiation of both lasers were maintained for 3-months without any side effects.

5. Conclusion

Both the Er,Cr:YSGG laser and the GaAlAs diode laser irradiation seem to be suitable for routine clinical treatment for DH, due to the rapid and 3-months clinical effectiveness without adverse reactions. Also laser treatment seems to be more comfortable and faster than traditional DH treatment, since the time consuming procedures such as isolation of operation field and repeated applications were eliminated. Further studies are necessary to evaluate the morphological alterations of the dentine surfaces under scanning electron microscopy after Er,Cr:YSGG laser application for DH treatment.

REFERENCES


