Lasers Med Sci (2012) 27:813–818
DOI 10.1007/s10103-011-0988-9

ORIGINAL ARTICLE

Effects of Er:YAG and Er,Cr:YSGG lasers on dentine hypersensitivity. Short-term clinical evaluation

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Received: 15 June 2011 / Accepted: 26 August 2011 / Published online: 13 September 2011

Abstract Dentine hypersensitivity (DH) is a painful condition and is a clinical challenge due to the different treatment strategies available. High-intensity lasers have been studied as a possible option. The aim of this randomized, controlled, double-blind clinical study was to evaluate the effects of Er:YAG and Er,Cr:YSGG lasers on DH. The study group comprised 28 subjects who met the inclusion criteria. A visual analogue scale was used to quantify sensitivity before treatment as baseline, immediately before and immediately after treatment, and 1 week and 1 month after treatment. Teeth were assigned to four groups: *group 1* control (no treatment), *group 2* Er:YAG laser treatment (2 Hz/32.4 mJ/5.9 J/cm^2), *group 3* Er,Cr:YSGG laser treatment (0.25 W/4.4 J/cm^2), and *group 4* Er,Cr:YSGG laser treatment (0.50 W/ 8.9 J/cm^2). Data were collected and submitted to statistical analysis for both evaporative (air) and mechanical (probe) stimulation. For both the air and probe stimulation no differences were observed between the pretreatment sensitivities. With the evaporative stimulus, the pain level immediately after treatment was reduced; however, after this the values remained stable. Irradiation with the Er:YAG laser was associated with the lowest level of pain. With the mechanical stimulus, group 4 showed the most pronounced decrease in pain immediately after treatment; however, by the end of the study, pain levels had increased. Groups 1, 2 and 3 showed a reduction in pain that was significantly different from that in group 4 after the 4 weeks of clinical follow up. Based on the results and within the limits of this study, it can be concluded that none of the laser treatments studied was capable of completely eliminating pain, but the Er:YAG and Er,Cr:YSGG lasers are suitable for the treatment of DH.

Keywords Dentine hypersensitivity · Er,Cr:YSGG Laser · Er:YAG laser

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Introduction

Dentine hypersensitivity (DH) is a consequence of a 21st century life-style and increased life expectancy of Western populations who will show functional natural dentition that is prone to tooth wear [1]. Thus, the incidence of DH is likely to become a more frequent dental finding in the future. By definition, DH is a transient tooth pain, characterized by a short, sharp pain arising from exposed dentine in response to a stimulus (thermal, evaporative, tactile, osmotic or chemical) that cannot be ascribed to any other form of dental defect or pathology [2]. It is a relatively common problem encountered in clinical dental practice, and can disturb the patient during eating, drinking and tooth brushing, and sometimes even during breathing.

The essential diagnostic features of DH are: (1) the presence of exposed dentine surfaces, (2) open tubule orifices on the exposed dentine surface, and (3) patent tubules leading to vital pulp. Dentine exposure often occurs as a result of the removal of cervical cementum, gingival recession and removal of enamel associated with different types of tooth wear [3–6]. According to the widely accepted

theory of the mechanism involved in DH, pain is a result of fluid displacement inside the dentinal tubules after stimulation. The displacement of the fluid outside and inside the tubules activates the nerve endings at the pulp–dentine interface resulting in pain [7].

Treating DH can be challenging for the dental professional. Treatments are designed to reduce the flow into the dentinal tubules by occluding them and/or to desensitize the nerves, making them less responsive to stimulation [8, 9]. To date, no single agent or form of treatment has been found effective in all patients, or to have long-lasting effects.

Irradiation with lasers is a new treatment concept and has become an area of research interest over the recent decades. Desensitization seems to depend mostly on the type of laser therapy adopted, and there has been a focus on two different types of laser: low-power and high-power lasers [10]. Low-power laser therapy is an appropriate treatment strategy to promote biomodulatory effects, minimize pain and reduce inflammatory processes. Its use has been widely accepted and approved due to satisfactory results reported in the literature [10, 11]. In contrast, the effects of high-power lasers, such as the carbon dioxide, Nd:YAG, Er:YAG and Er,Cr:YSGG lasers, are related to an increase in surface temperature which can result in the complete closure of dentinal tubules after recrystallization of the dentinal surface. Scanning electron microscopy performed after laser irradiation has shown morphological modifications suggesting that this may be the possible mechanism involved in pain relief [10–13].

When used at subablative energy densities, the area of energy delivery is enlarged and high-power lasers can act as low-power lasers [10–13].

It is hypothesized that the Er:YAG laser used in the treatment of DH is efficient in reducing the diameter of dentinal tubules under some specific conditions, with partial obliteration of dentinal tubules. It is expected that this laser will be shown to be efficient in medical and dental applications because of its thermomechanical ablation mechanism due to the high absorption of its wavelength by water [14]. Through this mechanism, Er:YAG laser irradiation for DH treatment would decrease dentinal fluid by evaporating its superficial layers and partially obliterate the dentinal tubules [15]. However, few published data are available on desensitizing treatment with the Er:YAG laser.

The Er,Cr:YSGG laser has been shown to be effective for soft-tissue surgery as well as for cutting enamel, dentine and bone [16–18]. This laser uses a pulsed-beam system, fiber delivery, and a sapphire tip bathed in a mixture of air and water spray. The system is considered promising for the treatment of DH. However, to the best of our knowledge few studies have been published concerning the clinical aspects of the desensitizing effect obtained with the Er,Cr:YSGG laser. Moreover, there are many unclear parameters that still make this therapy the subject of debate in the literature and it is important to determine strategies and protocols for its clinical use. Thus, the purpose of this study was to investigate the clinical efficacy of irradiation with erbium lasers in reducing cervical DH.

Materials and methods

The research protocol was initially submitted to the Joint Research and Ethics Committee of the School of Dentistry of our institution (protocol 204/03). As the methodology was approved in accordance with the 196/96 Resolution of National Council of Health, patients had to give their verbal and voluntary written informed consent and to be aware of the study inclusion and exclusion criteria, and they were examined before participating in the study.

A detailed medical and dental history was recorded by the examiner to rule out unsuitable participants. Patients were considered suitable for the study if they had sensitive teeth showing abrasion, erosion, abfraction or recession with exposure of cervical dentine. Patients with teeth showing evidence of pulpitis, carious lesions, defective restorations, facets of attrition, premature contact, cracked enamel and active periodontal disease, those who had undergone periodontal surgery in the previous 6 months, those on daily doses of medications or with any factor that could have been responsible for their sensitivity complaint were excluded. Other exclusion criteria were professional desensitizing therapy during the previous 3 months. No pregnant or lactating women were recruited. Differential diagnosis was performed and the vitality of all teeth verified. After clinical examination, 28 patients were selected. Among the teeth, 78.5% were premolars, 14.2% molars and 7.1% canines. All exposed areas were located on the facial surface of teeth. If the subject had two lesions side by side in the same quadrant, only one of the lesions would receive treatment at that time. Thus, all patients would have at least one lesion per quadrant to be treated. Comparisons were made between treatments, considering the tooth as a unit.

In the first screening visit patients were enrolled in an oral hygiene program and received oral hygiene instruction. Toothpaste and a soft toothbrush (both Colgate-Palmolive, São Paulo, Brazil) were dispensed for home use during the study period. Dietary counseling was also provided. Two weeks after the screening visit, and one week before the treatments were performed, patients were standardized concerning visual analogue scale (VAS) assessment and the exposed areas were randomly assigned to groups. DH was assessed by cold air stimulation applied with a dental syringe and slight pressure with a dental probe on the

Table 1 Patient groups and Er:YAG and Er,Cr:YSGG laser parameters

Group		Power (W)	Fluence (J/cm^2)	Repetition rate (Hz)
1 (n=7)	Control	No treatment		
2 (n=7)	Er:YAG	0.64	5.9	2
3 (n=7)	Er,Cr:YSGG	0.25	4.4	20
4 (n=7)	Er,Cr:YSGG	0.50	8.9	20

exposed dentine surface. The subject's response to this stimulation was considered as the baseline measurement according to the VAS for pain.. Each subject was asked to rate his/her perception of discomfort after the application of air with the dental syringe at 45 to 60 psi at a distance of 2 mm from and perpendicular to the root surface for 3 s. Neighboring teeth were isolated by the operator's fingers and cotton rolls during testing. The VAS consisted of a horizontal line 100 mm long, anchored at the left end by the descriptor "no pain" and at the other end by "unbearable pain". Patients were asked to mark position on the scale representing the severity of their hypersensitivity. The distance of this point in millimeters from the left end of the scale was recorded and used as the VAS score. Patients with a VAS score of ≥40 mm were accepted for participation in the study.

On the day of treatment, patients were asked to rate the perception of pain before treatment to check whether the patient could understand the principles of the VAS with both stimuli. Five minutes after this, patients received treatment according to the manufacturers' instructions. The area was isolated with cotton rolls. Patients were randomly assigned to the four treatment groups as shown in Table 1.

In group 1, patients received only dietary counseling and oral hygiene instructions. The irradiation procedure was performed, but the laser display showed zero watts and the power meter showed no power being emitted by the laser.

In group 2, patients were treated with the Er:YAG laser (Key Laser 1243; KaVo, Ulm, Germany) perpendicular to the dentine surface with scanning movements at a distance of 6 mm from the surface, with a defocused bean and with the following parameters: repetition rate 2 Hz, energy setting on the display 60 mJ, actual energy output 32.4 mJ (fiber 50/10 with transmission factor of 54%), energy density 0.46 J/cm^2, mean power 64.8 mW, and peak power 108 W. The surface was irradiated four times for 20 s each time, horizontally and vertically, with a 1-min interval between irradiations, and with air cooling.

In groups 3 and 4, patients were treated with the Er,Cr:YSGG laser (Waterlase, Biolase Technology, Irvine, CA), which had a wavelength of 2.78 μm, perpendicular to the dentine surface with scanning movements, with a 1-mm defocused beam with 0% water and 0% air for 30 s, and with the following parameters: fixed repetition rate 20 Hz, pulse width 140–200 μs, and power 0.25 W (group 3) or 0.5 W (group 4). A Z6 sapphire tip (600 μm diameter, 6 mm length) was used in both groups.

Laser irradiation was performed following the safety protocol in accordance with International Standards. Levels of hypersensitivity with both stimuli (air and probe separately) were quantified 5 min after concluding the procedure. The effectiveness of the therapies was also assessed after 1 week and after 1 month.

Results

For comparing the effectiveness of treatments, teeth were used as statistical units rather than subjects. Means and standard deviations are presented in Tables 2 (air spray stimulus) and 3 (mechanical dental probe stimulus). Data were submitted to the Kruskal-Wallis test and with regard to the air spray stimulus, no differences in the levels of pain between the baseline and pretreatment evaluations were seen showing the standardization of the patients and confidence with the VAS.

To evaluate the differences between groups, an analysis of variance for repeated measures was performed. The Tukey test was used to compare differences between the groups. Figure 1 shows the pain scores at the different evaluation time-points after air spray stimulation. There were decreases in the pain levels in all groups. The decrease

Table 2 Mean (standard deviation) differences in pain levels—air spray stimulus

Group	Immediately after treatment	1 week after treatment	1 month after treatment
1 (control)	1.90 (1.41)	1.23 (2.54)	2.46 (2.36)
2 (Er:YAG laser)	2.94 (1.59)	2.70 (2.38)	3.16 (2.30)
3 (Er,Cr:YSGG laser, 0.25 W)	1.57 (0.92)	0.34 (0.75)	2.26 (0.85)
4 (Er,Cr:YSGG laser, 0.50 W)	1.87 (0.59)	1.93 (0.91)	1.67 (1.27)

Table 3 Mean (standard deviation) differences in pain levels—mechanical probe stimulus

Group	Immediately after treatment	1 week after treatment	1 month after treatment
1 (control)	1.03 (1.08)	1.53 (1.70)	2.59 (3.07)
2 (Er:YAG laser)	0.96 (1.03)	1.59 (1.42)	1.29 (1.61)
3 (Er,Cr:YSGG laser, 0.25 W)	2.44 (2.80)	1.51 (2.07)	2.64 (1.75)
4 (Er,Cr:YSGG laser, 0.50 W)	3.34 (1.64)	2.40 (0.82)	1.67 (1.08)

in mean pain level in group 2 (Er:YAG laser treatment) was significantly greater (Tukey test) than in the other groups.

Figure 2 shows the pain scores at the different evaluation time-points after mechanical probe stimulation. The behavior in all groups was similar, and a reduction in pain level was also seen in the control group, indicating a placebo effect. Immediately after treatment the decrease in pain was more pronounced in group 4 (Er,Cr:YSGG/0.5 W) than in group 2 (Er:YAG). For the other time points studied, no significant differences were found.

Discussion

In this preliminary clinical study the effectiveness of erbium lasers in the treatment of DH was analyzed. Patients were treated and followed up for 4 weeks. The treatment of DH is based on the concept of reducing fluid movement inside the dentinal tubules by narrowing or occlusion of tubule openings [19]. In view of this concept, the advent of dental lasers has raised another treatment option [10]. However, the question of how this type of laser acts on DH is still being discussed due to a lack of studies related to the irradiation protocol used and the subjectivity of the evaluation. It has been demonstrated that hypersensitive teeth have significantly greater tubule diameters than nonsensitive teeth. Therefore it would appear that treatment should focus on depolarization of the nerve fibers, and also decreasing the radius of the dentinal tubules is also a prerequisite for effective desensitization [4–6]. The objective in using high-intensity lasers is to seal the dentinal tubules or alter the tubule contents by means of coagulation, protein precipitation, or the creation of insoluble calcium complexes [10, 12, 13].

Previous clinical studies have demonstrated that the Nd:YAG laser effectively reduces DH to cold air stimulation [20–22]. As well as the Nd:YAG laser, erbium lasers have also often been suggested for the treatment of DH. However, there are few data available concerning the effects of the Er:YAG laser on dentinal tubules and dentinal fluid flow. The high absorption of the Er:YAG laser emission wavelength in water may result in evaporation of the dentinal fluid and the smear layer [14, 15]. Recently, Badran et al. [23] described the use of the Er:YAG laser in tooth desensitization and found it to be promising for the clinical management of DH. In the present study both the Er:YAG and the Er,Cr:YSGG laser reduced pain levels after 1 month. All teeth retained vitality of their pulp after irradiation. However, the Er:YAG laser showed the best performance in clinical evaluations. These results are in agreement with those obtained by Schwarz et al. [15] who concluded that treating DH with the Er:YAG laser at the settings proposed is effective, and the positive results were unaltered even 6 months after the initial treatment.

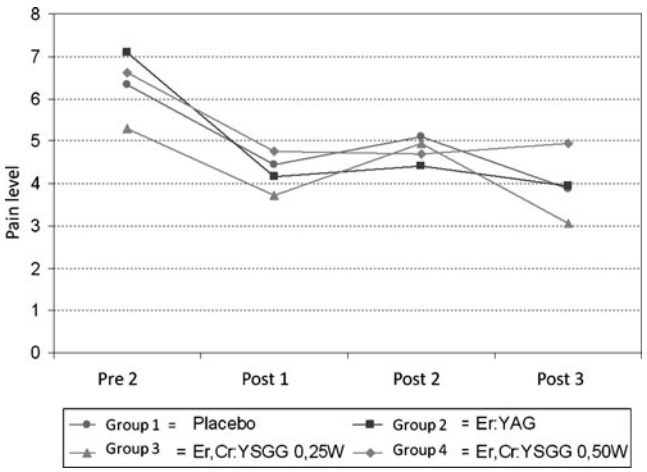

Fig. 1 Levels of pain with the air spray stimulus at the different evaluation time-points

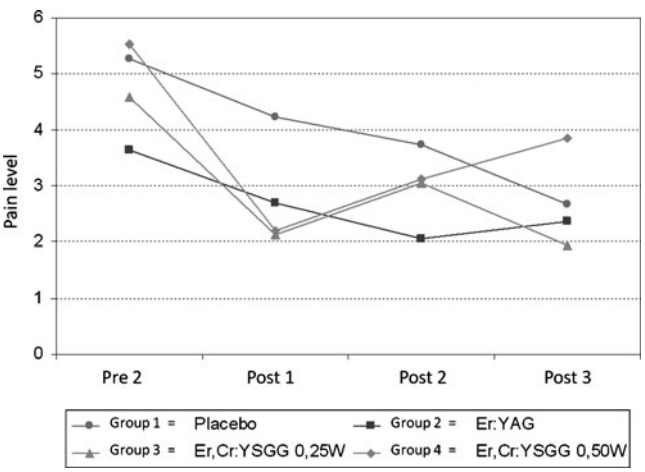

Fig. 2 Levels of pain with the mechanical probe stimulus at the different evaluation time-points

Erbium lasers are known for their ability to remove hard tissue in a process called ablation. Ablated tissue shows a surface without a smear layer, open dentinal tubules and rough surfaces without demineralization [14]. It should be emphasized that ablation is not suitable for the treatment of DH. Therefore, in the present study, the protocols used with both types of laser were below the ablation threshold. How can we explain why low-intensity laser treatment acts directly on the surface without altering the surface? One hypothesis for the satisfactory results of the effect of erbium lasers in reducing pain levels is the mode of action of high-intensity lasers which, with some parameters and in defocused mode, are able to act in the same way as low-intensity lasers. Clinically, no effect on the morphology of the dentinal surface could be observed. Er:YAG irradiation has an analgesic effect on pulpal nerves and this could explain the immediate decrease in pain scores, similar to the effects of low intensity laser.

The literature is in agreement that the mechanisms proposed for the effects of low-intensity laser treatment require serious consideration. It can be stated that the diode laser is an effective method for the treatment of DH, and the treatment is considered predictable, reliable and simple [23, 24]. However, information on the neurophysiological mechanism is not conclusive. It is postulated that low-intensity lasers and defocused high-intensity lasers mediate an analgesic effect related to the depolarization of C-fiber afferents. This interference in the polarity of cell membranes, by increasing the amplitude of the action potential of the cell membranes, can block the transmission of pain stimuli in hypersensitive dentine [25].

Considering the decrease in pain observed in all groups in the present study, a possible hypothesis could be that the defocused protocol used with the Er:YAG laser is adequate for the treatment of DH. The Er,Cr:YSGG laser was not defocused but the parameters were below the ablation threshold, meaning that the energy density used was not capable of altering the morphology of the dentinal surface, but was capable of altering the nerve fibers and promoting a reduction in pain caused by DH. Up to now, there have been few studies on the use of the Er,Cr:YSGG laser in the treatment of DH. One recent study compared the effects of a low-intensity laser and the Er,Cr:YSGG laser, and concluded that both types of laser are effective in the treatment of DH after a single irradiation [25]. The authors agreed that a lower energy setting is required and that deposition of insoluble salts from the tubules exposed by dentinal fluid evaporation could be responsible for obliterating the dentinal tubules and reducing DH [25].

In the present study, although the Er,Cr:YSGG laser at 0.5 W showed more pronounced immediate effects than the Er:YAG laser, no difference was found at 4 weeks, showing the similarity of these types of laser. Yilmaz et al. [26] showed an immediate dentine desensitization effect with the Er,Cr:YSGG laser in a clinical study, concluding that this laser seems to provide a suitable routine clinical treatment for DH due to the rapid and effective clinical results lasting for up to 3 months.

The results of this study indicated that both lasers used as dentine desensitizing methods were effective in reducing the level of sensitivity. It should be considered that the evaluation of treatments for DH is not simple due to the interference of the placebo effect, as well as the natural desensitization of dentine, the mechanical occlusion of dentine tubules by the smear layer and secondary dentine production [27]. Because it is a painful and subjective phenomenon, the pain coming from the cervical lesion may be modified by the subject's emotional status.

More double-blind randomized controlled clinical studies should be conducted in order to find the most suitable protocol for the treatment of DH. Comparative data between low- and high-power lasers and their association are required for further discussion.

Conclusions

Clinically, all the laser treatments evaluated were capable of reducing pain levels at the 1-month follow-up. All teeth retained vitality of their pulp. The Er,Cr:YSGG laser at a power of 0.25 W showed the best performance in the clinical evaluations.

Acknowledgments This investigation was supported by the State of Sao Paulo Research Foundation (grant 03/10001-0) and the Special Laboratory of Lasers in Dentistry at the University of São Paulo, Brazil.

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