Laser treatment of dentine hypersensitivity

An overview Part II

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_Introduction

More than two decades ago, laser applications in the treatment of dentine hypersensitivity were introduced to dentistry. Many clinical studies using different laser types have been published since. This overview summarises the basic and clinical aspects, including treatment protocols.

In the last issue of laser, conventional approaches towards the treatment of dentine hypersensitivity were discussed with regard to a set of criteria for a successful treatment as proposed by L. I. Grossman (1935). The authors came to the conclusion that, so far, no conventional therapy has been able to meet all the criteria. The authors then moved on to studies on laser treatment. Studies on GaAlAs laser and He-Ne lasers were introduced and analysed. Part I of this article was finished by a comparison between He-Ne lasers and Nd:YAG lasers.

Part II in this issue of laser continues with studies on the application of Nd:YAG lasers in dental therapies as well as an overview on Er:YAG lasers.

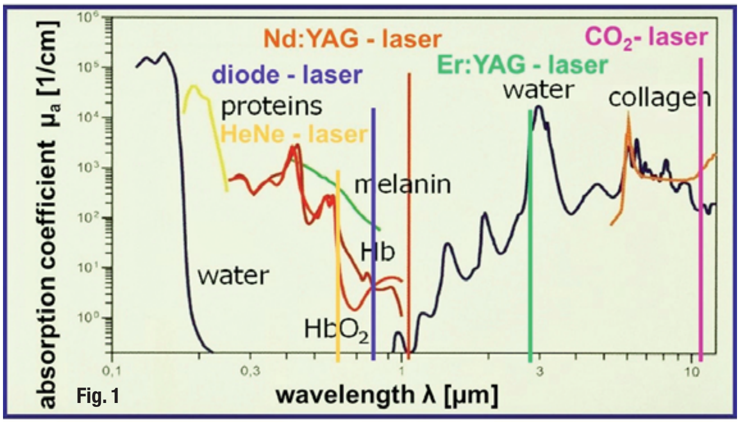

Fig. 1_Laser wavelength and absorption spectrum of the different laser types used for desensitization in human tissues.

_Middle-output power lasers: Nd:YAG laser

The Nd:YAG laser with a wavelength of 1,064 nm belongs to the group of middle-output power lasers. Matsumoto et al. (1985b) referred to the application of this laser type in the therapy of dentine hypersensitivity. Since then, it has been established for the therapy of dentine hypersensitivity in a number of studies (Dilsiz et al. 2009; Yonaga et al. 1999; Kobayashi et al. 1999; Gutknecht et al. 1997; Lan et al. 1996; Renton-Harper et al. 1992; Gelsky et al. 1992; White et al. 1990; Goodis et al. 1989; Matsumoto et al. 1985b).

The energy level used ranges from 0.3 to 10 W, with the most frequent use of 1 or 2 W (Kimura et al. 2000b). The methods of application are highly dependent on the laser energy used and vary according to this, from 0.3 W for 90 seconds in non-contact mode up to 2 W for 0.5 seconds with the application of an absorber in contact mode (Kimura et al. 2000b). In different studies, the efficiency of therapy ranges from 5 to 100 % (Kimura et al. 2000b). Among the middle-output power lasers, the Nd:YAG laser is regarded as exceedingly effective (Dilsiz et al. 2010b; Birang et al. 2007; De Magalhaes et al. 2004; Yonaga et al. 1999). In a comparative *in vitro* study of the ability of Er,Cr:YSGG, Nd:YAG, CO_2 and diode lasers to melt dentinal tubules, all laser types had a statistically significant ability to seal perpendicular dentine and occlude dentinal tubules partially or totally, but the highest reduction in mean tubule diameter resulted from the Nd:YAG laser with 53 % effectiveness (Gholami et al. 2011). Comparable results were also found by Dilsiz et al. (2009), comparing immediate and late therapeutic effects after Nd:YAG (1 W, 10 Hz, 60 seconds, non-contact mode, without cooling) and diode-laser application (25 mW, 9 Hz, 100 seconds). Both were effective in reducing dentine hypersensitivity, but there was a higher success rate after Nd:YAG laser application, especially after immediate application and 60 days after concluding the treatment.

Abed et al. (2011) compared the sealing ability of Nd:YAG laser application (1 W, 10 Hz, 60 seconds, non-contact mode without cooling) to that of a resin (Seal & Protect®, DENTSPLY DeTrey) applied to exposed human dentinal tubules *in vitro*. Compared with the control group, laser application showed a homogeneous dentinal surface with less exposed tubules and a reduction in the diameter of the exposed tubules of 50 %. Nevertheless, in this study, the resin was much better, with a 90 % sealing ability compared with the control group (Abed et al. 2011).

Effects of Nd:YAG laser application

When using Nd:YAG laser light and black ink as an absorption amplifier, it is recommended that deep penetration of laser light through enamel and dentine be evaded so that excessive harmful effects on the pulpal tissue can be avoided (Launay et al. 1987) and surficial sealing effects can be enhanced (Morioka et al. 1984; Gelsky et al. 1993; Yonaga et al. 1999; Kobayashi et al. 1999). The closure or narrowing of dentinal tubules (Lan & Liu 1995, 1996) and direct nerve analgesia are assumed to be mechanisms of Nd:YAG laser light action (Whitters et al. 1995). In an *in vitro* SEM examination, the melting of dentinal tubule openings and the solidification of the dentine surface with a penetration depth varying between 1 to 7 µm were observed, depending on irradiation parameters (30 mJ, 0.3 W, 7 Hz; 40 mJ, 0.4 W, 7 Hz for 43 seconds with a ten-second interval; De Magalhaes et al. 2004).

In a study by Moriyama et al. (2004), morphological and chemical changes in human dentine surfaces resulting from Nd:YAG laser irradiation with different pulse durations were observed. SEM analysis confirmed a melting and resolidification with larger resolidification structures and a smoother surface after using long pulses. An increased concentration of calcium and phosphorous was also found in all irradiated samples compared with the control group, possibly making it less susceptible to acid dissolution (Moriyama et al. 2004). Laser of a wavelength of 1,064 nm also demonstrates effects upon microcirculation (Funato et al. 1991; Zennyu et al. 1996).

Causes of the analgesic effects of Nd:YAG lasers

A multitude of theories on the way in which the Nd:YAG laser induces its analgesic effect have been suggested (Kimura et al. 2000b). For example, laser energy is thought to interfere with the sodium pump and alter the cell membrane permeability and/or affect the endings of sensory axons (Myers et al. 1991). Not only can Nd:YAG laser application block off the depolarisation of very slow C-fibre afferences, but it can also affect fast-conducting A-ß-fibres (Orchardson et al. 1997). It is also thought that a desensitising effect can be achieved by denaturing the odontoblast process and by overheating dentinal fluid (White et al. 1990; Goodis et al. 1989).

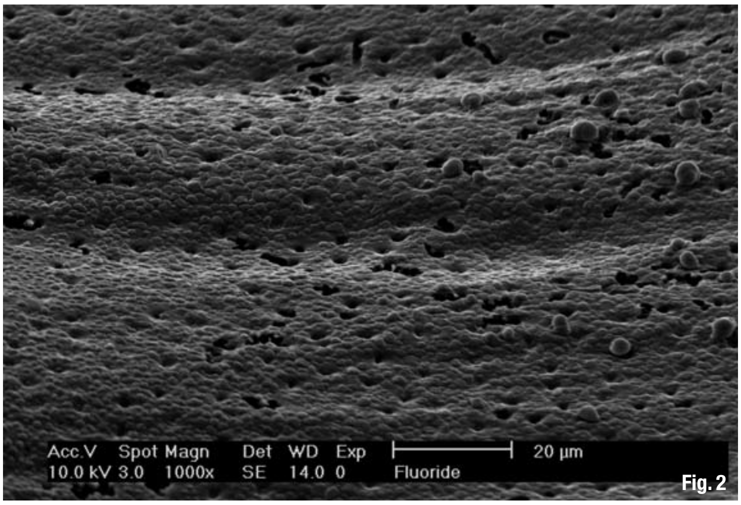

Fig. 2

Fig. 2_SEM examination of a human cervical dentinal surface after removal of the smear layer with 50 % citric acid for one minute to open up the dentinal tubules and simulate hypersensitive dentine and application of Bifluorid 12® (combination of sodium fluoride and calcium fluoride, 1,000 x-magnification). Dentinal tubules are totally or partially closed by fluoride-containing covering layer.

A glazing of the dentine was described after the application of Nd:YAG laser light to the exposed tooth neck (Birang et al. 2007; Lan et al. 2004; Dederich et al. 1984; Halket et al. 1996). The result was a glazed, non-cavernous surface with closure of the exposed tubules and without surface cracks. When using an Nd:YAG laser, the sealing depth is dependent on the chosen parameters and the optical properties of dentine. With the use of 30 mJ/pulse and 10 Hz, the sealing depth is less than 4 µm (Liu et al.1997). In an *in vivo* study by Gutknecht et al. (1997), different laser parameters for Nd:YAG laser application were tested. Roughly the same success rates were detected in each case. It was concluded that Nd:YAG laser light must have been effective even with a low-energy dose. Manton et al. (1992) compared the effect of the Nd:YAG laser with that of an untreated control group. Directly before and after laser application, as well as after three and 28 days, the time it took for teeth to become painful after cold stimuli was measured. Nd:YAG laser light application showed a statistically significant clinical improvement over a period of 28 days. These results were confirmed by a study by Yonaga et al. (1999). Recrudescence occurred after more than two months. After a follow-up period of one year, the effectiveness of Nd:YAG laser application was 85.4 % effective compared with 90 % immediately after the application (Zhang 1990).

Hu (2004) analysed the effect of a pulsed Nd:YAG laser in the therapy of dentine hypersensitivity compared with a control group treated with NaF. The effectiveness immediately after laser application, and one month and six months after was significantly better compared with the control group (Hu 2004). Ciaramicoli et al. (2003) also confirmed the results of the studies described above. The effect of Nd:YAG laser irradiation (2 W, 100 mJ, 20 Hz, 60 seconds, with air cooling) compared with conventional fluoridation (Bifluorid 12®, VOCO, Fig. 2) immediately after and one, two, three and four weeks after application showed a significant improvement in VAS scores to air blast immediately after and one week after laser treatment (Kara et al. 2009). Whereas at weeks two, three and four in the fluoridated group, VAS scores decreased up to nearly 75 to 85 % of the baseline scores, VAS scores remained nearly unchanged in the laser group. Fluoride was applied in three consecutive visits in this study, but laser was only applied once. Nd:YAG laser irradiation thus appears to be a suitable tool for the immediate and successful reduction of pain within a shorter treatment time.

Recurring dentine hypersensitivity

The mechanism of the recurrence of dentine hypersensitivity is unknown (Yonaga et al. 1999), but it is assumed that after laser treatment, a reappearance of symptoms depends on the initial intensity of the dentine hypersensitivity before the application (Yonaga et al. 1999). The irradiation of the cervical region with Nd:YAG laser light under the use of an absorber enhances the efficiency—with this method, a recurrence of the symptoms can be delayed (Yonaga et al. 1999). According to this study, morphological aspects, in addition to analgesic effects, are assumed to be important for the sustainability of treatment effects (Yonaga et al. 1999).

Side-effects

The thermal impacts of laser light on the pulpal tissue constitute a problem for using Nd:YAG laser *in vivo*. Compared with other laser types, the Nd:YAG laser beam has deep penetration into dentine, bone and soft tissue (Dederich 1993; Zennyu et al. 1996). Exposure of dentine beyond the safety threshold can cause thermal damage to the pulpal tissue (Yonaga et al. 1999; Zhang 1990; Matsumoto et al. 1988; Zach et al. 1965). However, clinical studies state that despite the danger of thermal damage, no side-effects were found (Yonaga et al. 1999).

Other clinical studies examined a partial oxygen saturation of pulpal blood in anterior hypersensitive teeth after Nd:YAG laser irradiation (1 W, 10 Hz, 60 seconds, non-contact mode, without cooling) as a possible indicator of pulpal damage. A slight but significant increase in the oxygen saturation of the pulpal blood was observed immediately and one week after laser application compared with the control group. However, partial oxygen saturation of pulpal blood in laser-treated teeth had gained its pretreatment level at follow-up measurement after one month, thus maintaining the teeth vitality and indicating no irreversible damage in the dental pulp after laser application within the limit of desensitisation parameters (Birang et al. 2008).

The additional use of an absorber defines the depth effect of Nd:YAG laser light and reduces the possibility of side-effects. Zapletalova et al. (2007) tested different dye solutions for topical application in combination with Nd:YAG laser energy and found erythrosin to be the best agent to avoid damage to the dentinal structure. Sealing of tubules occurred after four doses of 30 mJ pulses (total energy density 33 J/cm^2).

Concerning efficiency and simplicity, the application of Nd:YAG laser light is a relevant treatment method for clinical practice (Yonaga et al. 1999). The great variances in the different studies can be explained by morphological differences that inevitably occur on account of intra- and inter-individual variation of the dentine structure and depend, among others, on the age and clinical history of the teeth (Moriyama et al. 2004). For example, in their SEM examination of the occluding ability of Nd:YAG laser on exposed human dentine compared with a resin, Abed et al. (2011) discovered that the number and diameter of dentinal tubules vary significantly from tooth to tooth even for different sections of the same tooth. This confirms most of the clinical findings morphologically.

Combined treatment with Nd:YAG laser and fluoride

The clinical application of the Nd:YAG laser and NaF varnish, as well as Nd:YAG laser light alone, showed significant improvement in dentine hypersensitivity in each case (Kumar et al. 2005). However, the combination of the Nd:YAG laser and NaF varnish showed a greater efficiency compared with either of these used alone (Kumar et al. 2005). SEM examinations confirm the clinical results. A reduction in the number of open tubules was combined with an improvement in the efficiency of the therapy (Kumar et al. 2005). The study by Ciaramicoli et al. (2003) supports the above results. Hsu et al. (2006) also hypothesised the improved desensitising effect of a combined treatment. A fluoride-containing dentine desensitiser was first applied and this was followed by Nd:YAG laser irradiation (1,062 nm, 33 mJ, 50 pulses/second [pps] for two minutes in slight contact) resulted in long-lasting acid and brushing resistance. The posttreatment was carried out very briefly and the integration of fluoride into the dentinal surface was not confirmed by structural analysis. This confines the validity of this study. Qualitative microanalysis of ions and ultrastructural changes in dentine exposed to Nd:YAG laser (1.5 W, 100 mJ, 15 Hz, 60 seconds, energy density 125 mJ/cm^2, with black ink as dye solution) and flouride solutions (10 % SnF_2 for 30 minutes; 10 % $SrCl_2$ for 30 minutes) proved the capability of the Nd:YAG laser to alter the dentinal structure by melting and resolidification of the surface with an occluding effect on exposed dentine and additionally altering the absorption of ions, leading to a better infiltration into the dentinal structure (Glauche et al. 2005). After the combined use of the Nd:YAG laser and 10 % SnF_2, Sn_2+ could be detected up to 250 µm in EDX analysis compared with 100 µm without laser application. The combined use of the Nd:YAG laser and 10 % $SrCl_2$ resulted in an uptake of Sr_2+ up to 500 µm compared with 23 µm without laser irradiation (Glauche et al. 2005).

_Middle-output power lasers: Er:YAG laser

Today, there are only a few clinical studies on the application of the Er:YAG laser (2,940 nm) in the therapy of dentine hypersensitivity. A possible explanation for the desensitising effect of the Er:YAG laser is its high absorption in water; thereby an evaporation of dentinal fluid and the retention of the smear layer with a deposition of insoluble salts in the exposed dentinal tubules are assumed (Moritz et al. 2006). Another possible explanation for the Er:YAG laser effects in the treatment of dentine hypersensitivity is an analgesic effect on the pulpal nerves, which would explain the immediate effect and the progressive increase of symptoms after irradiation over time (Badran et al. 2011).

SEM analysis of human dentine after Er:YAG laser irradiation (300 mJ, 10 pps, ten seconds; up to 700 mJ, 10 pps, ten seconds, with and without water cooling) demonstrated that laser energy of 500 mJ/pulse at 10 pps for ten seconds was sufficient for inducing melting and recrystallisation of dentine crystals (Lee et al. 2004). At irradiation parameters of 60 mJ, 2 Hz, without air/water-cooling on human dentine in vitro for 30, 60 or 120 seconds, a partial reduction in tubule diameter (30 seconds), an almost complete obliteration of exposed tubules with visible signs of melting (60 seconds) and complete occlusion with a rugous melted dentinal surface were observed (Badran et al. 2011). A decrease in dentine permeability in 26.05 % was also achieved at 60 mJ and 2 Hz for four applications of 20 seconds *in vitro* (Aranha et al. 2005). The use of water-cooling is important for the reduction of thermal effects (Lee et al. 2004). Firoozmand et al. (2008) proved that the *in vitro* use of an Er:YAG laser (250 mJ, 4 Hz, 80 s, 19 mJ/cm^2, non-contact mode, with constant water-cooling) for cavity preparation on bovine dentine did not exceed the critical temperature of 5.5 °C.

Clinical investigations of Er:YAG laser application (100 mJ, 3 Hz, two applications of 60 seconds) have found an acceptable therapeutic effect with reduction in pain over a period of up to six months (Birang et al. 2007).

Comparative studies of Er:YAG lasers

Schwarz et al. (2002) compared the efficiency of Er:YAG laser application (80 mJ/pulse and 3 Hz) and a conventional treatment and observed a significant improvement in symptoms directly after the application of both of the two treatments and after six months compared with the control group. However, at two and six months, the group treated with fluoride varnish showed an increase in dentine hypersensitivity compared with the group treated with laser. The latter had the same level as directly after the laser treatment.

Another comparative *in vivo* study evaluating the effect of the Er:YAG and CO_2 lasers and the combination of these laser types with fluoride application (NaF) proved the efficiency of the two treatment options. With the use of Er:YAG laser light at energy levels of 60 mJ at 30 Hz for 10 seconds without water/air spray alone or in combination with fluoride, the clinical improvement in discomfort determined by a cold-air blast and VAS score was significantly reduced one week, one month and six months after treatment compared with a control group treated solely with fluoridation. No significant differences between Er:YAG laser application and CO_2 laser application as a single dose or as a combined treatment were observed (Ipci et al. 2009).

Similar results in an *in vitro* study that compared the occluding ability of the Er:YAG laser (60 mJ, 30 Hz, ten seconds) and CO_2 laser (1 W, cw, one second) application alone or in combination with 2 % NaF gel corroborated the clinical findings mentioned above. A melted appearance along with the occlusion of the dentinal tubules could be found in all irradiated groups, but in terms of number and diameter of open tubules, no significant differences between the laser only and the combination group were found (Cakar et al. 2008)._

Editorial note: To be continued in our next issue of laser. A complete list of references is available from the publisher.

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