

Desensitizing effects of an Er:YAG laser on hypersensitive dentine

A controlled, prospective clinical study

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Abstract

Aim: The aim of the present study was to evaluate and compare the desensitizing effects of an Er:YAG laser (KEY II[®], KaVo, Germany) and Dentin Protector[®] (Vivadent, Germany) on cervically exposed hypersensitive dentine.

Method: A group of 30 patients showing a total of 104 contralateral pairs of hypersensitive and caries-free teeth was selected and randomly allocated in a split-mouth design to either (1) Er:YAG laser (80 mJ/pulse, 3 Hz), or (2) the application of Dentin Protector[®] (polyurethane-isocyanate 22.5%; methylenechloride 77.5%) whereat one pair served as an untreated control in each patient. The degree of sensitivity to a thermal stimulus was determined qualitatively with an evaporative stimulus defined as a 3-s air blast at a distance of 2 mm from each site to be tested. A qualitative registration of the degree of discomfort was determined according to an arbitrary pain scale in 4 degrees. Recordings were assessed before treatment, immediately after, 1 week, 2 and 6 months after treatment by 1 blinded examiner.

Results: Both treatment forms resulted in significant improvements of discomfort immediately after and 1 week post treatment. After 2 months, the discomfort in the Dentin Protector[®] group increased up to 65% of the baseline score and even up to 90% after 6 months, whereas the effect of the laser remained at the same level that was achieved immediately after treatment. The differences immediately after, 1 week, 2 and 6 months post treatment between both groups were statistically high significant ($p \leq 0.001$; respectively). Compared to the untreated control group, both treatment forms resulted in a significant reduction of discomfort at each follow-up examination.

Conclusion: It was concluded that desensitizing of hypersensitive dentine with an Er:YAG laser is effective and the maintenance of the positive result was more prolonged than with Dentin Protector[®].

Key words: desensitizing effects; Er:YAG laser; dentine hypersensitivity; polyurethane-isocyanate

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Dentine hypersensitivity is one of the most common symptomatic condition which causes complaints of discomfort in patients. The prevalence ranges between 8.9 and 15% in the adult western population (Graf & Galesse 1977, Flynn et al. 1985, Scherman & Jacobsen 1992). So far, there is relatively little known of the etiology of dentine hypersensitivity and the nature of the lesion (Dowell & Addy 1983, 1985, Addy 1990). According to the “hydrodynamic

theory”, movements of fluid within exposed dentinal tubules are responsible for the stimulation of pulpal mechanoreceptors (Brannström 1963, Brannström et al. 1967). The most frequent reasons for exposure of dentine are attrition caused by occlusal disharmony, gingival recession following either a periodontal disease process or periodontal therapy and trauma from tooth brushing. So far, many substances have been tried with varying degrees of suc-

cess in the treatment of hypersensitive dentine. One of the most common used agents is strontium chloride (Blitzer 1967, Hernandez et al. 1972), while clinical trials have shown that concentrated fluoride solutions, in particular sodium fluoride, are also effective (Gedalia et al. 1978). Furthermore iontophoresis with and without a fluoride paste or solution resulted in positive desensitizing effects (Jensen 1965, Schaeffer et al. 1971, Johnson et al. 1982). Today

various laser systems are discussed for a possible use in dentistry. The Nd:YAG (neodymium-doped: yttrium, aluminium and garnet) and CO₂ (carbon dioxide) lasers are limited due to their thermal side effects, whereas the Er:YAG (erbium-doped: yttrium, aluminium and garnet) laser is expected to show efficiency in medical and dental applications because of its thermomechanical ablation mechanism and the high absorption of its wavelength by water (Pick et al. 1985, White et al. 1987, Midda 1992, Aoki et al. 1996). Consequently an Er:YAG laser has a water absorption characteristic approximately 15 times greater than that of the CO₂ and even 20,000 × greater than the Nd:YAG laser (Walsh et al. 1989, Walsh & Cummings 1994). Decreases of dentinal fluid movements would, according to the hydrodynamic theory, directly result in a decrease of dentine hypersensitivity. In this context, the application of an Er:YAG laser would be anticipated to decrease these fluid movements by evaporating the superficial layers of the dentinal fluid. However, until now no published data are available concerning the clinical outcome of a desensitizing treatment with an Er:YAG laser. The purpose of the present study was to evaluate and compare the clinical effectiveness of an Er:YAG laser to that of a commercial product, Dentin Protector®. Untreated hypersensitive teeth served as a control.

Material and Methods

Subject selection

The subjects selected for the study were 30 patients attending the Department of Periodontology and Conservative Dentistry of the University of Saarland, Homburg, Germany. There were 14 males and 16 females, aged between 23 and 56 years (mean age 36 years). Each patient contributed at least two or more contralateral pairs of hypersensitive teeth with exposed dentine at cervical surfaces. Criteria for exclusion from the study were: (a) carious lesions on the selected or neighbouring teeth, (b) any desensitizing therapy on the selected teeth during the last 6 months, (c) cervical fillings on the selected teeth. Other reasons for exclusion were a history of allergy to chemicals used in the study, or the need to continuously take analgesic medication. The vitality of all experimental teeth was checked at the beginning and end of the trial by means of an electric

pulp tester. The purpose and design of the investigation were explained and a consent form was signed. Apart from the provided treatments, the patients received no other concurrent antisensitivity treatment whilst on the trial.

Study design

The study was performed according to a split-mouth design. A total of 60 maxillary and 44 mandibular pairs of contralateral single- and multi-rooted teeth were included. One pair served as an untreated control in each patient. The remaining pairs were randomly treated with an Er:YAG laser or with the Dentin Protector® (Vivadent, Germany) desensitizing system. The distribution of the 2 treatment modalities was equally divided between the right and left sides. All patients were treated by the same experienced operator without local anesthesia.

Oral hygiene

For 4 weeks before treatment, all patients were enrolled in a hygiene programme and received oral hygiene instructions on 2–4 appointments as well as professional tooth cleaning according to individual needs.

Clinical measurements

The degree of sensitivity to a evaporative stimulus was determined qualitatively with an air stimulus defined as a 3 seconds cold air blast (temperature range of 19–20°C) at a distance of 2 mm from the site to be tested. Sensitivity was assessed according to an arbitrary pain scale in four degrees (Table 1). During testing the dentist's gloved fingers shielded the neighbouring teeth. Gingival recessions were recorded from the mid-buccal or mid-oral surface of all teeth, and meas-

Table 1. Pain scale to assess the degree of dentine hypersensitivity

Degree	Description
1	no discomfort during application of the stimulus
2	slight discomfort during application of the stimulus
3	mild discomfort or pain during application of the stimulus
4	severe discomfort or pain during and continuing for longer than 5 s after application of the stimulus

ured in millimetres from the cemento-enamel junction to the gingival margin using a PCP12 periodontal probe (HuFriedy, Chicago, Illinois, USA). Furthermore an unstained plaque index (Silness & Løe 1964) was recorded on the mesial, buccal, distal and lingual surfaces of all experimental teeth.

Recordings were assessed before treatment, immediately after, 1 week, 2 and 6 months after treatment by one examiner who was not aware of which teeth had received the experimental treatments and which teeth served as controls.

Treatments

Immediately before treatment the examiner polished and flossed all teeth of the subjects. An Er:YAG laser (KEY II®, KaVo, Biberach, Germany) was selected for laser treatment, using hand-piece 2051 (KEY II®, KaVo, Biberach, Germany) at an energy level of 80 mJ/pulse, and a repetition rate of 3 Hz with water irrigation according to the instructions given by the manufacturer. The laser beam was handled in a defocused manner and the treatment time was two minutes per tooth by scanning the cervical part in an overlapping pattern. All contralateral teeth received an application of the Dentin Protector® (DP) desensitizing system. DP is an aqueous solution containing 22.5% polyurethane-isocyanate and 77.5% methylenechloride. The application was performed according to the instructions given by the manufacturer. All patients were explicitly instructed to omit tooth brushing during the following 12 h. One untreated contralateral pair of hypersensitive teeth served as a control in each patient.

Statistical analysis

For all groups, the mean values of the clinical parameters were calculated. Normal distribution was looked for by the Kolmogorov-Smirnow test. According to the distribution of the data, non-parametric (Wilcoxon signed ranks test) and parametric tests (Student paired *t*-test) were used to determine significant differences between the groups. Values of $p \leq 0.05$ were accepted as statistically significant.

Results

All 30 patients completed the 6 months study period. No complications such as

Table 2. Mean degree of discomfort and standard deviation in all groups over 6 months ($n=30$ patients)

	Before	After	1 week	2 months	6 months
laser	3.6±0.2	1.4±0.3	1.5±0.4	1.5±0.4	1.7±0.5
DP	3.5±0.4	1.6±0.6	2.0±0.5	2.4±0.6	3.2±0.4
control	3.4±0.4	3.5±0.4	3.5±0.4	3.5±0.3	3.6±0.3
laser-DP	n.s.	*	***	***	***
laser-control	n.s.	***	***	***	***
DP-control	n.s.	***	***	***	**

The stars indicate statistically significant differences between groups (Wilcoxon signed ranks test) (n.s. $p \geq 0.05$, * $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$).

Table 3. Mean gingival recessions (\pm SD) in all groups over 6 months ($n=30$ patients)

	Baseline	After	1 week	2 months	6 months
laser	1.4±0.6	1.4±0.5	1.2±0.4	1.3±0.5	1.4±0.8
DP	1.2±0.7	1.2±0.8	1.3±0.6	1.3±0.6	1.3±0.7
control	1.4±0.5	1.4±0.4	1.3±0.5	1.4±0.4	1.4±0.5
laser-DP	n.s.	n.s.	n.s.	n.s.	n.s.
laser-control	n.s.	n.s.	n.s.	n.s.	n.s.
DP-control	n.s.	n.s.	n.s.	n.s.	n.s.

The stars indicate statistically significant differences between groups (paired t -test) (n.s. $p \geq 0.05$, * $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$).

Table 4. Mean plaque index (\pm SD) in all groups over 6 months ($n=30$ patients)

	Baseline	after	1 week	2 months	6 months
laser	1.1±0.4	0.1±0.1	0.6±0.3	0.7±0.3	0.6±0.3
DP	1.0±0.3	0.1±0.1	0.7±0.4	0.9±0.2	0.7±0.3
control	0.9±0.3	0.1±0.1	0.8±0.3	0.7±0.4	0.6±0.4
laser-DP	n.s.	n.s.	n.s.	n.s.	n.s.
laser-control	n.s.	n.s.	n.s.	n.s.	n.s.
DP-control	n.s.	n.s.	n.s.	n.s.	n.s.

The stars indicate statistically significant differences between groups (paired t -test) (n.s. $p \geq 0.05$, * $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$).

detrimental pulpal effects or allergic reactions were observed. How the patients, as a whole, responded to the air stimulus throughout the study as can be seen in Table 2.

Both treatment forms resulted in significant improvements of discomfort immediately after treatment and after one week. At the two months examination the discomfort in the DP group increased up to 65% of the baseline score whereas the effect of the laser stayed nearly unchanged. After 6 months, the mean degree of discomfort in the DP group increased up to nearly 90% of the baseline score whereas only a slight increase occurred in the laser treated group. The differences immediately after, 1 week, 2 and 6 months post treatment between both groups were statistically high significant ($p \leq 0.01$; respectively). The untreated control teeth showed no significant changes of discomfort throughout the study period. Compared to the control group, both

treatment forms showed significant reductions of discomfort at each follow-up examination (Table 2).

The gingival recessions in all groups remained nearly unchanged during the study period. No significant differences were found between and within the groups ($p \geq 0.05$; respectively) (Table 3).

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

Discussion

The results of the present clinical trial demonstrated that desensitizing of hypersensitive dentine with an Er:YAG laser was effective and the maintenance of the positive results was even more prolonged than with Dentin Protector®. The results especially illustrate ef-

fectiveness following evaporative stimulation. However, the laser induced reductions of discomfort were unaltered even 6 months following the initial treatment, whereas the effect of Dentin Protector® showed significant decreases after 2 months.

So far, no published data are available concerning the clinical effectiveness of an Er:YAG laser in the treatment of dentine hypersensitivity, whereas the use of lasers has often been propagated for this indication. In previous clinical studies it has been demonstrated that the pulsed Nd:YAG laser is also an effective tool in reducing dentine hypersensitivity to cold air stimuli. It produced an immediate effect to a greater or lesser extent on almost all sensitive teeth (Renton-Harper & Midda 1992, Gelskey et al. 1993, Gutknecht et al. 1997). It was presumed that dentine may be fused during Nd:YAG laser irradiation (Renton-Harper & Midda 1992, Gelskey et al. 1993). Similar results have also been found with the CO₂ laser (Moritz et al. 1996). Its effectiveness is probably due to an occlusion or narrowing of dentinal tubules (Moritz et al. 1995). If dentine hypersensitivity results from the movements of fluid in the tubules, fusing the tubules should result in a predictable elimination of dentine hypersensitivity. In this context it is important to mention that hypersensitive teeth demonstrate tubular diameters that are significantly wider (2×) than those of non-sensitive teeth, so it would appear that treatment focused at decreasing the radius is a prerequisite for effective desensitisation (Rimondini et al. 1995). The energy settings of 80 mJ/pulse at 3 Hz, used in the present study, are lower than the ablation thresholds of dental hard tissues. The high absorption of the Er:YAG laser emission wavelength in water may result in an evaporation of the dentinal fluid and the smear layer. In a recently published comparative study the Er:YAG laser was the most effective tool in removing the smear layer from the root-canal walls (Takeda et al. 1999). Thus, it could be suggested that a deposition of insoluble salts in the exposed tubules are responsible for an obturation of the dentinal tubules. Furthermore bacteria also seem to play an important role in sensitivity of teeth. The pain threshold of the nerve fibers seems to be lowered in presence of inflammation mediators (Johnson & Brannström 1974, Olgart et al. 1974). In this context it is important to point to the results of previous studies

which have shown that the Er:YAG laser has also a high bactericidal potential (Ando et al. 1996, Hibst et al. 1996).

The used Dentin Protector® is an aqueous solution containing 22.5% polyurethane-isocyanate and 77.5% methylenechloride. So far, the clinical effectiveness of polyurethane-isocyanate, as the active substance, has not yet been examined. This agent will probably lead to the creation of a peripheral intrinsic barrier within the lumen of the dentinal tubules. In this context the removal of the smear layer would be advantageous for this phenomenon to happen. Especially the pre-treatment with an Er:YAG laser could be favourable for the penetration of the resin-adhesive within the dentinal tubules. The combination of the two methods could be an area for future studies. One possible explanation for the decreasing effectiveness after 2 months may be the removal of this peripheral intrinsic barrier by tooth brushing.

A well-known difficulty and common feature of many clinical studies on dentine hypersensitivity is an improvement in all treatment groups, including the control (Addy & Dowell 1983). This phenomenon may be a placebo effect, but just as likely is spontaneous improvement, or regression to the mode. These findings could not be supported by the present study. The untreated control teeth showed constantly high degrees of discomfort at each control session.

In conclusion, the present study has demonstrated that the Er:YAG laser seems to be a suitable tool for successful reduction of dentine hypersensitivity, especially while the 6 months results of this treatment modality are promising. Further studies are needed in order to evaluate the long-term stability of the obtained positive results. Especially the mechanism of the laser-induced desensitisation should be investigated in following studies.

Zusammenfassung

Desensibilisierungswirkung des Er:YAG-Lasers auf überempfindliches Dentin. Eine kontrollierte, prospektive klinische Studie

Ziel: Das Ziel der vorliegenden Studie war es, die Desensibilisierungswirkung eines Er:YAG-Lasers (KEY II®, KaVo, Deutschland) und des Dentin Protectors® (Vivadent, Deutschland) auf zervikales exponiertes überempfindliches Dentin zu vergleichen.

Methode: Es wurde eine Gruppe von 30 Patienten mit insgesamt 104 kontralateralen Zahnpaaren, die überempfindlich und kariös-

frei waren ausgewählt und nach einem Zufallsprinzip einem Splitmouth-Design zugeordnet. Es wurde entweder der Er:YAG-Laser angewendet (80 mJ/Puls, 3 Hz) oder Dentin Protector® (Polyurethan-Isocyanat 22.5%; Methylenchlorid 77.5%) appliziert und ein Paar bei jedem Patienten diente als unbehandelte Kontrolle. Der Empfindlichkeitsgrad bezüglich eines thermischen Stimulus wurde qualitativ bestimmt, indem jede Stelle aus 2 mm Entfernung mit einem Luftbläser für 3 Sekunden getrocknet wurde. Entsprechend einer Schmerzsкала mit Einteilung nach vier Graden wurde eine qualitative Beurteilung des Grades der Beeinträchtigung vorgenommen. Die Befunde wurden vor der Behandlung, direkt anschließend, sowie eine Woche, 2 und nach 6 Monate nach der Behandlung durch einen bezüglich der Therapie blinden Untersucher erhoben.

Ergebnisse: Direkt nach der Behandlung und eine Woche danach hatten beide Behandlungsarten eine signifikante Verbesserung der Beeinträchtigung zur Folge. Nach zwei Monaten erhöhte sich in der Dentin Protector®-Gruppe die Beeinträchtigung auf Werte bis zu 65% der Ausgangswerte und sogar auf bis zu 90% nach sechs Monaten, während die Wirkung des Lasers auf dem gleichen Niveau wie direkt nach der Behandlung blieb. Die Unterschiede direkt nach der Behandlung, sowie 1 Woche, 2 und 6 Monate danach waren zwischen beiden Gruppen statistisch hoch signifikant ($p \leq 0.001$). Beide Behandlungsarten hatten im Vergleich zur unbehandelten Kontrollgruppe bei jeder Nachuntersuchung eine signifikante Reduktion der Beeinträchtigung zur Folge.

Schlussfolgerung: Es wurde die Schlussfolgerung gezogen, dass die Desensibilisierung von überempfindlichem Dentin mit einem Er:YAG-Laser effektiv ist und die Aufrechterhaltung der positiven Ergebnisse länger anhält als mit Dentin Protector®.

Résumé

Effet de désensibilisation de dents hypersensibles par le laser Er:YAG. Une étude clinique prospective contrôlée

But: Le but de cette étude a été d'évaluer et de comparer les effets désensibilisateurs d'un laser Er:YAG (KEY II®, KaVo, Allemagne) et du Dentin Protector® (Vivadent, Allemagne) sur la dentine hypersensible exposée au niveau du collet.

Méthode: Un groupe de 30 patients avec 104 paires contralatérales de dents hypersensibles non-cariées a été sélectionné et étudié selon un modèle de bouche divisée soit (1) dans le groupe Er:YAG (80 mJ/impulsion, 3 Hz), ou (2) par l'application de Dentin Protector® (isocyanate polyuréthane 22.5%; chlorure de méthylène 77.5%), une paire servant de contrôle non-traité chez chaque patient. Le degré de sensibilité à un stimulus thermique a été déterminé qualitativement à l'aide d'un stimulus d'évaporation défini à 3 s de soufflé à une distance de 2 mm pour chaque site testé. Un enregistrement qualitatif du degré

d'inconfort a été déterminé suivant une échelle de douleur arbitraire de 4 degrés. Les enregistrements ont été effectués avant le traitement, immédiatement après ainsi qu'une semaine, 2 et 6 mois après le traitement par un examinateur aveugle.

Résultats: Les deux types de traitement se sont accompagnés d'une diminution de l'inconfort immédiatement après et 1 semaine après le traitement. Après 2 mois, l'inconfort dans le groupe Dentin Protector® atteignait 65% du score initial et même 90% après 6 mois tandis que l'effet obtenu par le laser demeurerait au même niveau que celui atteint juste après le traitement. Les différences immédiates, 1 semaine, 2 et 6 mois après le traitement entre les deux groupes étaient très significatives ($p \leq 0.001$). Comparées au groupe contrôle non-traité, les deux traitements résultaient en une réduction significative de l'inconfort lors de chaque examen.

Conclusion: La désensibilisation dentinaire avec le laser Er:YAG est efficace et le maintien de son résultat positif plus prolongé qu'avec le Dentin Protector®.

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