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Clinical Research

Clinical Evaluation of Nd:YAG Laser With and Without Dentin Bonding Agent for the Treatment of Occlusal Hypersensitivity

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Clinical Relevance

The use of a Nd:YAG laser (1064-nm wavelength, 30 mJ of energy, 10 pulse/s, 60 seconds, two times) with a self-etch dentin bonding agent could significantly reduce occlusal dentinal hypersensitivity over a longer period of time.

SUMMARY

Purpose: The aim of the present study was to evaluate and compare both the immediate and delayed desensitizing effects of the Nd:YAG (neodymium-doped:yttrium aluminum garnet; Nd^{3+}:$Y_3Al_5O_{12}$) laser with and without dentin bonding agent (DBA) on occlusal dentinal hypersensitivity (DH).

Methods and Materials: Twenty-one patients with a total of 117 chronic occlusal hypersensitive teeth were selected. Each subject had at least three hypersensitive teeth. These teeth were randomly allocated into three groups: group 1, DBA on the occlusal surface; group 2, Nd:YAG laser (1064-nm wavelength, 30 mJ of energy, 10 pulse/s, 60 seconds, two times); and group 3, Nd:YAG laser (1064-nm wavelength, 30 mJ of energy, 10 pulse/s, 60 seconds, two times) with DBA. Pain was assessed using a visual analog scale after stimulation of the sensitive teeth by using the sharp tip of an explorer and an air blast prior to treatment and immediately, one week, one month, and three months after treatment by one blinded examiner.

Results: A significant reduction in occlusal DH occurred at all time points in all of the experimental groups. The three groups showed significant improvements in discomfort immediately after treatment and after one week

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(p<0.001), but the Nd:YAG laser with DBA group had greater efficacy when compared with the other groups. The Nd:YAG laser group and Nd:YAG laser with DBA group had no significant differences at one month and three months after treatment (p>0.05); however, their desensitizing efficacy was superior to the DBA group.

Conclusions: The Nd:YAG laser with DBA may be most effective in the long-term treatment of occlusal DH, although other measures also reduce DH.

INTRODUCTION

Dentinal hypersensitivity (DH), one of the most common dental clinical conditions, is characterized by short, sharp pain arising from exposed dentin in response to thermal, evaporative, tactile, osmotic, or chemical stimuli that cannot be ascribed to any other form of dental defect or pathology.[1,2] It is reported that the prevalence of DH varies from 3% to 98% in the population. The age range of DH is wide, having peak prevalence between 40 and 50 years of age, with females having a slightly higher predilection than males. Maxillary teeth are more commonly affected than mandibular teeth, with a greater occurrence on the buccal/lingual surface than on the occlusal surface.[3] Hypersensitivity in younger patients is often caused by dentin exposure due to erosion, while gingival recession often causes hypersensitivity in older patients due to the exposure of the dentinal tubules in the cervical areas because of periodontal disease and intensified brushing activity.[3]

However, DH on the occlusal/incisal tooth surfaces has also been frequently reported. Occlusal surfaces are more prone to all forms of tooth wear, such as attrition (especially associated with bad habits such as bruxism, biting objects, etc) abrasion, and erosion, all of which cause increased DH when compared with cervical tooth surfaces.[4]

DH has been widely described using the hydrodynamic theory, the most suitable and acceptable theory proposed by Braennstrom and Astroem in 1964.[5] Most pain-producing stimuli, such as thermal, chemical, and mechanical stimuli, disrupt the inward and outward flow of dentinal fluid that activates intradental nerve fibers, via a mechanoreceptor response, resulting in pain. The common stimuli include hot, cold, sweet, and sour foods and drinks as well as cold air.[6,7] DH is due to a combination of any of the previous conditions that exposes the dentinal tubules, such as periodontal pathogens, trauma, dental bleaching, removal of orthodontic fixed appliances, professional oral hygiene, acidic foods and beverages, bad oral hygiene habits, or incorrect oral hygiene causing gingival recession.[8] The exposure of occlusal dentin could occur as a result of attrition from occlusal wear, trauma, dental bleaching, professional oral hygiene, parafunctional habits (such as bruxism), occlusal adjustment, inappropriate tooth brushing, erosion from an acidic diet, or other factors.[9] Desiccation and frictional heat generated during cavity preparation also increase the likelihood of hypersensitivity.[10]

For the treatment of DH, occluding the dentinal tubules is the primary and the most important procedure. Studies have shown that sensitive dentin contains eight times more tubules than nonsensitive dentin, and these tubules are twice as wide.[11,12] Desensitizing agents have been used to occlude the dentinal tubules as a professional measure to treat DH. These agents should be nonirritating to the pulp, relatively painless on application, easily carried out, rapid in action, consistently effective for a long period, and without staining effects, as proposed by Grossman in 1935.[13,14] Many desensitizing agents have been tried with varying degrees of success,[15,16] but most of the therapies have failed to satisfy one or more of these criteria.

Desensitizing agents are applied as a long-term treatment option for a preservative method of management of sensitive teeth.[17] Most of the commonly used desensitizing agents in the treatment of DH include anti-inflammatory agents (corticosteroids), protein precipitates (formaldehyde, silver nitrate, strontium chloride hexahydrate), tubule-occluding agents (calcium hydroxide, sodium fluoride, potassium nitrate), and tubule sealants (resins and adhesives) that work by forming a physical barrier in the dentinal tubules to prevent the flow of dentinal fluid and thus block the activation of the mechanoreceptors in the dentinal tubules by forming a protein precipitate, hydroxyapatite crystal deposits, or resin or hybrid tags.[11,12,14,18-20]

The use of lasers in the dental field mostly fulfills the characteristics required by Grossman for the treatment of DH. The use of the neodymium-doped: yttrium aluminum garnet, Nd^{3+}:$Y_3Al_5O_{12}$ (Nd:YAG) laser was found to be more effective when compared with other low- and high-power laser therapy, including CO_2 (10,600), Er:YAG (2940), Er,Cr:YSGG (2780), GaAlAs, and 810-nm diode laser.[8,10,18,21,22] Low-power lasers were found to act only on the nerve level, whereas middle-power lasers such as Nd:YAG produce desensitization by either acting on the internal tubular nerve or obliterating the dentinal tubules. The effect of the Nd:YAG laser on hypersensitive teeth may be due to occlusion of tubules, which may be either through coagulation of proteins inside the dentinal tubules formed due to a photobiomodulating effect on the odontoblasts or melting and recrystallization of hydroxyapatite crystals of the dentinal tubules, preventing the fluid flow inside the dentinal tubules or by acting directly at the nerve level by blocking C and A"β nerve fibers. The Nd:YAG laser produces direct nerve analgesia via destruction of the internal tubular nerve, thus preventing hypersensitivity.[8,14,16,18,21,23-34] Desensitization caused by different lasers depends on multiple factors, such as the type of laser device and various irradiation parameters (eg, power density wavelength, wave mode, pulse frequency, number of repeated applications, and distance from the surface).[30,34-36]

Lasers have been used for the treatment of DH, and some authors report that laser combined with drugs may be a preferable treatment for DH.[24,30,33,36] Treatment with low- and high-power lasers has been shown to display the characteristics proposed by Grossman.[10]

Occlusal hypersensitivity is a serious condition that troubles the dental practitioner. There are few studies on the treatment of occlusal hypersensitivity using an Nd:YAG laser. The purpose of this study was to evaluate and compare the immediate, one-week, one-month, and three-month posttreatment desensitizing efficacy of Nd:YAG laser with and without a dentin bonding agent (DBA) on occlusal DH.

METHODS AND MATERIALS

Study Design

This study was designed as a randomized controlled trial comparing the therapeutic efficacy of the Nd:YAG laser with and without DBA on occlusal DH. A Nd:YAG laser (HSM-III, HTSD, Chengdu, China) and Adper self-etch adhesive liquid (3M ESPE, Seefeld, Germany) as the DBA were used. Subjects who were able to complete the entire therapy and follow-up procedures were selected. Appropriate, approved informed consent was signed from each subject after the nature of the study and the possible discomfort and risks had been fully explained.

Subject Selection

Twenty-one patients (8 men and 13 women; aged 23-69 years, mean age 49.95 ± 13.67 years) with a total of 117 hypersensitive teeth were examined for the presence of occlusal DH at the Characteristic Specialist Clinic on Tooth Sensitivity in the West China College of Stomatology Sichuan University (Table 1). Each patient contributed at least three hypersensitive occlusal surfaces and presented stage 4-7 of occlusal surface wear according to the criteria of Smith and Knight.[37] The degree of occlusal DH was determined qualitatively using a disposable sharp dental explorer stimulus and a three-second cold-air blast from a three-way dental syringe at a distance of 2 mm from each site to be tested. Meanwhile, adjacent teeth were isolated from the air using gauze squares and cotton rolls. All stimuli were performed by one examiner (operator 1) using the same equipment, yielding a similar air pressure each time.

The patients were required to have had more than one month of DH and to have not used other desensitizing methods, such as fluoridated toothpastes or tubule sealers, to decrease the degree of DH. Meanwhile, we excluded pregnant and lactating women and those with chronic or debilitating diseases to avoid probable side effects of laser treatment. Teeth that were nonvital, cracked, carious, or had deep restorations, crowns and abutments, pulpitis, periapical periodontitis, or active periodontal disease were also excluded.

In addition, subjects were asked to use a standardized toothbrush and toothpaste without any desensitizing agent for the three-month trial period. All participants completed the study and reported 100% compliance.

Treatments

After a baseline pain assessment, the teeth were randomly assigned to group 1 (DBA treatment), group 2 (Nd:YAG laser treatment), or group 3 (Nd:YAG laser with DBA treatment).

Prior to therapy, all hypersensitive teeth received cleaning and disinfection with 75% alcohol. A few patients experienced pain for a short time period but were able to endure the procedure. Since pumice residues may remain in the dentinal tubules, which may affect laser treatment, we used alcohol, which is easy to apply, volatile, and leaves no residue in the dentinal tubules.[30] The region being treated was isolated using gauze squares and cotton rolls, and the occlusal surface was dried with gauze before each treatment session. The vitality of all experimental teeth was checked with an electric pulp tester before and after each treatment session. The

Table 1: *Age, Gender, Stage of Wear, and Tooth Type in the Patient Population*

Variable	n	Group1 n	Group2 n	Group3 n
Age, y				
11-30	3	1	1	1
31-50	7	2	3	2
51-70	11	4	3	4
Gender				
Female	13	4	5	4
Male	8	3	2	3
Stage of wear				
4	21	6	8	7
5	46	18	14	14
6	37	11	12	14
7	13	4	5	4
Tooth type				
First molar	66	24	22	20
Second molar	40	12	13	15
Third molar	11	3	4	4

patients were blinded as to what type of therapy each tooth was receiving.

Group 1 was treated with DBA, which was applied at the sensitive site on the occlusal surface and allowed to sit for 15 seconds. The DBA was then reapplied, allowed to sit for 15 seconds, and light cured for 20 seconds.

Group 2 was subjected to treatment with Nd:YAG laser (1064 nm) set at 30 mJ and 10 pps for 60 seconds, using a sweeping motion and without coolant (the duration was changed because of the size of tooth wear) after black ink was applied. The laser beam was applied using a 320-mm optical fiber. The distance between the end of the optical fiber and the occlusal surface was maintained at 2 mm with the help of an orthodontic wire. Protective eyewear was worn by both the investigator and the patient while using the laser.

Group 3 was treated with a combination of the Nd:YAG laser with DBA. The therapy methods and clinical parameters were the same as in groups 1 and 2. The therapy was performed by the same investigator (operator 1).

Pain Assessment

A visual analog scale (VAS) was used to document occlusal hypersensitivity caused by a disposable sharp dental probe and a three-second air blast from each site to be tested. The VAS was administered in a standard manner, with the initial explanation given by the same clinician to all participants. All patients were asked to define their level of hypersensitivity on a VAS scale ranging from 0 to 10 (a 10-cm line). On this scale, 0 and 10 represented *no pain/no discomfort* and *worst pain/severe discomfort*, respectively. All pain assessments were performed in the morning in the same clinic, in an area free of noise, music, or conversation. All stimuli were applied by a single investigator in the same dental chair with the same equipment. Evaluation of pain was scheduled before treatment, immediately after treatment, and at one week, one month, and three months posttreatment. The treatments were performed by operator 1, and the pain was assessed by the other examiner (operator 2).

Statistical Analysis

Statistical analysis was performed using SPSS 16.0 software for Windows (Statistical Program for Social Sciences Inc, Chicago, IL, USA). The statistical significance of data for all clinical and VAS scores within and between groups was determined by using one-way analysis of variance. Least significant difference post hoc test for multiple comparisons was used to determine the differences in the VAS scores within groups at different times. Changes with p values <0.05 were considered statistically significant.

RESULTS

All 21 patients completed the three-month study period. Each tooth was tested for pulp vitality before treatment, immediately after treatment, and one week, one month, and three months after treatment. There were no adverse reactions reported nor any clinically detectable complications, and all experimental teeth responded normally to the vitality test. Because of the randomization procedures, the three groups were well matched in demographics, including age, sex, stage of wear, and tooth type (Table 1). The response of the patients to the probing or air blast throughout the study and the mean VAS values at the different time points are presented in Table 2. The results of the probing and air blast were similar. The initial mean hypersensitivity scores were well matched in the three groups ($p>0.05$), although the treatment in the three groups resulted in significant improvements in discomfort immediately after treatment and after one week ($p<0.001$). Group 3 had a higher degree of desensitization when compared with the other groups. At the one- and three-month evaluations, there was a statistically significant difference between groups 1 and 2 and between

Table 2: *Comparison of the Mean ± Standard Deviation VAS Scores of Patients' Perceptions in the Three Treatment Groups*

	Group 1	Group 2	Group 3	p^a
Hypersensitivity after provoking with probe				
Before the treatment	7.03 ± 1.15	7.06 ± 1.20	7.01 ± 1.08	0.981
After the treatment				
Immediate	2.56 ± 1.02	1.63 ± 0.97	1.20 ± 0.78	<0.001*
One week	2.58 ± 0.97	1.56 ± 0.94	1.16 ± 0.69	<0.001*
One month	2.93 ± 1.06	1.45 ± 0.78[b]	1.41 ± 0.84[b]	<0.001
Three months	3.71 ± 1.16	1.51 ± 0.76[c]	1.47 ± 0.87[c]	<0.001
Hypersensitivity after provoking with air blast				
Before the treatment	6.41 ± 0.96	6.43 ± 0.79	6.40 ± 0.69	0.987
After the treatment				
Immediate	2.41 ± 0.92	2.03 ± 0.85	1.02 ± 0.68	<0.001*
1 week	2.40 ± 0.98	2.01 ± 0.97	1.16 ± 0.69	<0.001*
1 month	2.71 ± 0.93	1.23 ± 0.79[d]	1.30 ± 0.72[d]	<0.001
3 months	3.35 ± 0.98	1.31 ± 0.76[e]	1.24 ± 0.72[e]	<0.001

[a] *The differences between groups immediately posttreatment and at one week, one month,, and three months after treatment were tested by one-way analysis of variance.*
[b] *Significant difference after one month by provoking with probe in group 2 and group 3.*
[c] *Significant difference after three months by provoking with probe in group 2 and group 3.*
[d] *Significant difference after one month by provoking with air blast in group 2 and group 3.*
[e] *Significant difference after three months by provoking with air blast in group 2 and group 3.*
* *Statistically significant differences in the multiple comparison using least significant difference method.*

groups 1 and 3 ($p<0.001$). There was no statistically significant difference between groups 2 and 3 ($p>0.05$). However, the desensitizing efficacies of groups 2 and 3 were superior than group 1.

DISCUSSION

DH is one of the most difficult and frequent conditions in the dental clinic for both patients and dental practitioners. DH causes sharp pain that disturbs patients' normal dental activity, and because long-term relief by preservative professional treatment is difficult to achieve, DH presents a great challenge for dental practitioners. The required treatment depends on the etiology, degree of discomfort, and extension and depth of the lesions.[10]

According to the hydrodynamic theory for DH, exposed dentinal tubules cause inward and outward flow of dentinal fluids under the given stimuli, activating intradental nerve fibers and causing sharp pain on the teeth. Occlusion of the exposed dentinal tubules and/or blockage of nerve activity are the treatment choices for DH. Freshly exposed coronal dentin is more sensitive than cervical dentin. This may be due to the higher conduction velocity or structural differences in dentinal innervations and in the dentin structure itself.[34]

Preservative treatment of occlusal DH is difficult because the occluded layer formed by desensitizing agents is typically very thin and can be worn out by physical forces such as brushing, occlusion, and acidic food.[18,19] The combined effects of laser and drug therapy have been found to provide improved desensitization and long-term efficacy.[10,12,19,30,33,36] Therefore, in this experiment, the long-term desensitizing effect of the combination of an Nd:YAG laser and DBA was compared with that of DBA and laser alone. The Nd:YAG laser can be used to reduce hypersensitivity without detrimental thermal effects on the pulp.[29,30,32] Nd:YAG laser is a near infrared laser with a primary wavelength of 1064 nm. It is nonionizing in character and is therefore nonmutagenic.[18] However, exposure to Nd:YAG laser energy leads to morphological changes of the dentin surface, characterized by a glazed, melted resolidified surface with the occasional formation of globules and cracks.[38]

DH is a pain sensation that is difficult to quantify. However, a VAS is widely used to assess DH, as it is easily understood by patients, sensitive in discriminating among the effects of various types of treatment and change in pain, and has advantages of being a continuous scale. Thus, the VAS scale was found to be suitable for evaluating the pain response in DH studies.[10,21,26,30,35]

The present study provides information about the clinical effectiveness of the Nd:YAG laser with and without DBA in the treatment of occlusal hypersensitivity. It showed that the mean hypersensitivity score was well matched in the three groups. However, immediately after treatment and at one week, one month, and three months posttreatment, the adhesive group and the other two groups were significantly different ($p<0.001$). It is possible that using adhesive alone was unable to occlude the dentinal tubules and that problems arise when the adhesive breaks away, resulting in exposure of the tubules.[15] Since the purpose of applying resin is to occlude dentin orifices, the loss of occluded resin due to physical forces such as mastication and brushing would result in reduced effectiveness.[33] In addition, there are greater chances of dislodging or breaking the adhesives on the occlusal surface due to occlusal forces.

However, there was no significant difference between groups 2 and 3 immediately posttreatment or at one week and three weeks after treatment ($p>0.05$). Some scholars have found microcracks, carbonization of tooth surfaces or open tubules, and a consequent increase in intrapulpal temperature with some teeth when using Nd:YAG laser irradiation.[10,21,28] In this study, no microcracking, carbonization, or pulpal damage was detected, which may be due to the management of the parameters and continuous motion of the laser over the treatment surface during the procedure.

It is possible that the two treatments tested in this study may reduce DH by different mechanisms. DBA reduces DH by the formation of protein precipitates traversing the septa in the deeper part of the tubules and formation of resin tags near the surface, thereby blocking fluid flow across dentin.[18,20,33] Whereas the mechanism of Nd:YAG may affect the occluding or narrowing of the dentinal tubules by melting and recrystallization of dentin, evaporation of the dentinal fluid, or direct nerve analgesia.[8,14,16,18,21,23-34] The use of an Nd:YAG laser before the application of a desensitizing agent modifies the dentin surface, increasing the adhesion property of the desensitizing agent while occluding the open dentinal tubules, which are not affected by laser therapy. The effectiveness of laser therapy before or after the use of a desensitizing agent shows no statistical significance. After application of a desensitizing agent, the Nd:YAG laser incorporates the desensitizing agent within the dentin during melting or recrystallization.[19,24] The most important issue in laser therapy is to determine the right parameters to use in order to achieve optimal results, without inducing detrimental pulpal effects or causing fractures or carbonization.[28,38]

Some scholars have shown that Nd:YAG laser irradiation (30 mJ, 10 pps, two minutes) can be used to seal exposed dentinal tubules without the dentin surface cracking and detrimental pulpal effects.[31,39,40] That study found that laser use with 1-mm dentinal thickness causes pulpal disruption while a dentin thickness of greater than 1 mm provides no such effect. Dentin without ink negligibly absorbs or scatters the laser. The use of black ink enhances the amount of melting and recrystallization of the stained dentin, which results in the closure of dentinal tubules.[28] Black ink also prevents the laser beam from penetrating excessively into the tooth structure and therefore protects the pulp from excessive effects.[32] In the present study, the laser was applied for two minutes, and the remaining ink layer from the tooth surface was wiped out with warm water.

The current results indicate that the application of laser with or without dentin bonding agent is better than the single use of a DBA. As DH is due to multifactorial causes, it cannot be concluded that blockage of exposed dentinal tubules is the only option for successful long-term treatment. Other predisposing factors, such as parafunctional habits, must be treated simultaneously to decrease the relapse rate. We suggest using laser with DBA for a synergistic effect as well as proper sealing of opened tubular dentin. The operation is simple, does not require special equipment, is suitable for patients with occlusal dentin sensitivity, and can be popularized in clinical application.

CONCLUSIONS

Because of the short duration of the present experiment and difficulty in monitoring the personal habits of the subjects, such as brushing technique or type of food intake, it is difficult to conclude how long the effects of the Nd:YAG laser will be effective. We cannot determine whether the dislodgement of resin tags formed with DBA or the fracture of recrystallized tubules causes relapse. Further microscopic studies are necessary to determine the cause of relapse of occlusal DH.

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Regulatory Statement

This study was conducted in accordance with all the provisions of the local human subjects oversight committee guidelines and policies of approval of the Department of Operative Dentistry and Endodontics, West China School of Stomatology, Sichuan University, Chengdu, China.

Conflict of Interest

The authors certify that they have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this article.

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