

Effects of GaAs (904 nm) Low Level Laser Therapy on Dentin Hypersensitivity

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The aim of the study was to investigate the effects of 904 nm GaAs laser irradiation for patients with hypersensitive teeth and to find the possibility of clinical use of this Low Level Laser Therapy (LLLT) for the control of hypersensitive teeth. Eleven patients visited Dept. of Oral Medicine, Dankook University participated in this study. Each patient contributed at least two or more contralateral pairs of hypersensitive teeth with exposed dentine at cervical surfaces. Total number of teeth used from subjects participated in this study was 50: 25 experimental and control teeth respectively. All participants were treated with 904 nm GaAs diode laser every week during 4 weeks. Tactile and cold (ice stick) tests were carried out before LLLT every week during 4 weeks and 1 week later after the last LLLT by measuring visual analogue scale (VAS) of patients and by measuring a score of electrical pulp tester (EPT) simultaneously. The VAS score in tactile test decreased significantly with time, but there was not statistically difference between those of groups. The score of EPT in the experimental group was significantly higher than that of control group, although there was no change with time. In cold test, there was significant difference between two groups and cold sensitivity of the experimental group significantly decreased with time after every LLL irradiation, compared with that of control group. Based on the results, it is suggested that the 904 nm GaAs laser irradiation could be positively used as an effective, reversible method in treating cervical dentine hypersensitivity.

Key words: Dentin Hypersensitivity, GaAs, Low Level Laser Therapy

I. INTRODUCTION

Dentin hypersensitivity(DH) has been defined as

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pain arising from exposed dentine, typically in response to chemical, thermal, tactile or osmotic stimuli, which cannot be explained as arising from other forms of dental defect or pathology.¹⁾ The prevalence ranges between 8.9 and 15% in the adult western population.²⁻⁴⁾

The etiology of DH is multifactorial and not completely understood, although it has been demonstrated (scanning and transmission electron microscopy) by several investigators that the structure of dentine in the affected (sensitive) areas of a tooth is altered, containing a larger number of patent dentine tubules with a wider tubular diameter than unaffected areas (non-sensitive).⁵⁻⁷⁾ Management of DH should be based on a correct diagnosis of the condition by the practitioner.¹⁾ The

dental practitioner should be aware of the importance of a preventive strategy, particularly with a view to the removal of any etiological factors and minimizing the effects of erosion.⁸⁾ The goal of treatment of DH ideally should be the restoration of the original impermeability of the dentinal tubules and the relief of DH experienced by the patient or at least to reduce the level of discomfort to enable the patient's quality of life to be maintained.

Many substances have been tried with varying degrees of success in the treatment of hypersensitive dentine. One of the most common used agents is strontium chloride,⁹⁾ while clinical trials have shown that concentrated fluoride solutions, are also effective.¹⁰⁾ Today various laser systems are discussed for a possible use in dentistry. The Nd:YAG and CO₂ lasers are limited due to their thermal side effects and Er:YAG laser is irreversible method due to its thermomechanical ablation mechanism, although Schwarz et al.¹¹⁾ reported that Er:YAG laser is effective in desensitizing of hypersensitive dentine.

The consensus recommendations for the diagnosis and management of DH by a broadly constituted board of dentists and dental hygienists drawn from general dental practice, specialist practice, academia and research from across Canada, joined by 2 international dentists with subject matter expertise, recommended that depending upon the severity and extent of the condition, reversible procedures should be employed before nonreversible procedures.¹²⁾

Recently, the GaAlAs (790 nm) laser irradiation as a reversible procedure was introduced in treating DH by means of inducing changes in neural transmission networks within the dental pulp, which may stimulate the normal physiological cellular functions. Therefore, at subsequent appointments, the pulpal tissue was less injured or inflamed. In addition, the laser stimulated the production of sclerotic dentin, thus promoting the internal obliteration of dentinal tubules.¹³⁾ The aim of this study was to investigate a low level laser therapy (LLLT) with a different wavelength and diode (904 nm of GaAs) also introduced in treating DH

clinically, using tactile, cold and electrical pulp tests and to determine 904 nm of GaAs LLLT could be effectively used to treat DH as a reversible procedure.

II. MATERIALS AND METHODS

1. Subject

The subjects selected for this study were eleven patients attending the Department of Orofacial Pain and Oral Medicine of Dental Hospital, Dankook University, Cheonan, Korea. The mean age of Six males and 5 females were 50.4 and the range of age was 27 to 66 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: carious lesions on the selected or neighboring teeth, any desensitizing therapy on the selected teeth during the last 6 months, cervical fillings on the selected teeth, cracked or fractured teeth, those continuously taking analgesic medication.¹¹⁾ Total number of teeth used from eleven subjects participated in this study was 50: 25 experimental and control teeth respectively. The study protocol and informed consent documents were submitted and approved by the Ethics Committee of the Dental Hospital, Dankook University (# H-0902/009/002).

2. Methods

The study was performed according to a randomized split-mouth design. A total of 12 maxillary and 13 mandibular pairs were included. A tooth was used as an experimental tooth and irradiated with 904 nm GaAs laser. A contralateral tooth served as a pseudoirradiated control in each patient. All patients were treated by one experienced operator every week for 4 weeks and evaluated by the other one every week before LLL irradiation for 4 weeks and one week later after last irradiation.

A GaAs laser (DENS BIOS LASER[®], TNC, Seoul, Korea) was used for laser treatment at a mean

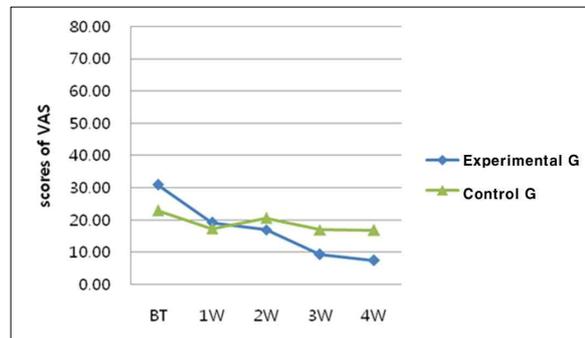
Table 1. Means and standard deviations of VAS score measured using a tactile test according to time after laser irradiation and results of repeated measures 2-way ANOVA

Group	Time						P value
		BT	1W	2W	3W	4W	
Experimental	M±Sd	30.92±26.605	19.20±22.716	17.00±19.257	9.40±13.254	7.50±8.165	0.456
	decreasing rate	100.000	37.904	45.019	69.599	75.744	
Contral	M±Sd	23.00±27.003	17.28±21.398	20.60±28.807	17.00±24.281	16.80±25.367	0.297
	decreasing rate	100.000	24.870	10.435	26.087	26.957	
P value		0.010					0.297

energy level of 2.2 mJ and a repetition rate of 1,000 Hz according to the instructions given by the manufacturer. The laser beam was handled in a non-contact manner about 5 mm away from a target area. The diameter of probe emitting laser was 5 mm and the area irradiated 5 mm apart from a probe of laser system used in this study was about 32 mm² (4×8 mm). The treatment time was 3 minutes per tooth by irradiating both cervical and apical areas of tooth buccally (experimental group). The irradiated energy per tooth was 0.40 J and the energy density was 1.24 J/cm² in this study. The treatment was also performed identically to all contralateral teeth (control group) except focusing laser beam on the cheek side.

To apply mechanical stimuli for tactile test, scratching the dentine surface with a sharp dental probe was used.^{9,14-20} The degree of sensitivity to a cold stimulus was determined qualitatively through an ice stick contact to cervical dentine for 3 seconds (temperature range 7-8°C). Ice stick was made by filling with water in an empty lidocaine ample and freezing it. Sensitivity for mechanical and thermal stimuli was assessed using a visual analogue scale.²¹ Pulp vitality tester (Parkell Inc., Edgewood, Network, USA) was used for evaluate the sensitivity to an electrical stimuli. These 3 tests were performed in the order of above description.

The data obtained were analyzed statistically using repeated measures analysis of variance (ANOVA). The level of significance for statistical analysis was set at $p < 0.05$.

**Fig. 1.** A linear gram showing a change of VAS by a tactile test with time after laser irradiation.

III. RESULTS

Table 1 shows the results of the tactile evaluation from 25 paired teeth. The examiner found that the VAS score in tactile test decreased significantly with time, although there was not statistically difference between those of groups (Fig. 1). It is thought that this result should be due to a remarkable decrease of the VAS of LLL irradiated group against a weak change of control group and due to relatively large standard deviation.

The results of thermal(cold) evaluation can be seen in Table 2. There were significant differences between groups with time. The experimental group showed that cold sensitivity significantly decreased after every LLL irradiation compared with that of control group (Fig. 2).

Table 3 and Fig. 3 showed the results of an electrical pulp test in this study. There was a

Table 2. Means and standard deviations of VAS score measured using a cold test according to time after laser irradiation and results of repeated measures 2-way ANOVA

Group	Time	Time					P value
		BT	1W	2W	3W	4W	
Experimental	M±Sd	68.80±15.800	69.00±25.166	42.40±24.028	22.20±17.916	15.50±12.500	0.038
	decreasing rate	100.000	-0.291	38.372	67.733	77.471	
Contral	M±Sd	56.40±14.967	61.00±20.716	47.80±19.207	45.00±25.941	34.88±23.129	0.000
	decreasing rate	100.000	-8.156	15.248	20.213	38.156	
P value		0.0010					0.000

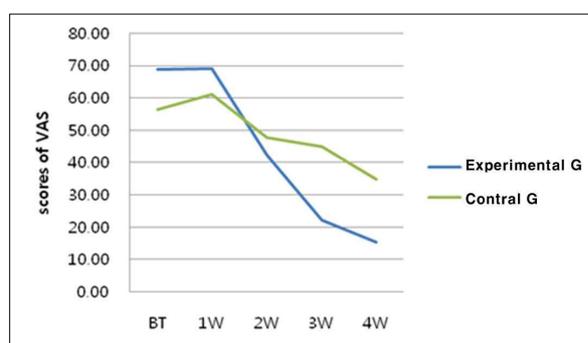


Fig. 2. A linear gram showing a change of VAS by a cold test with time after laser irradiation.

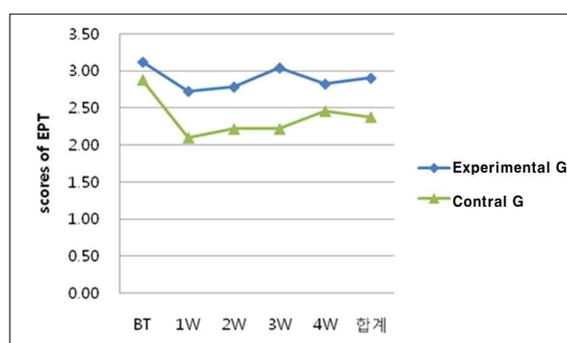


Fig. 3. A linear gram showing a change of EPT scores with time after laser irradiation.

significant difference between the experimental and the control groups, but was no change with time. The value of EPT in the experimental group was higher than that of control group ($p = 0.018$). The initial EPT score (before treatment) of experimental group was slightly higher than that of control

group, but the EPT score of control group after 1 week decreased significantly, compared with that of experimental group. The decrease of EPT score in both groups after 1 week is thought to be due to patient's fear to a discomfort for electrical stimulus having experienced at the first EPT test.

Table 3. Means and standard deviations of EPT score measured according to time after laser irradiation and results of repeated measures 2-way ANOVA

Group	Time	Time					P value
		BT	1W	2W	3W	4W	
Experimental	M±Sd	3.12±1.900	2.72±2.170	2.78±1.904	3.04±2.086	2.82±1.520	0.018
	decreasing rate	100.000	12.821	10.897	2.564	9.615	
Contral	M±Sd	2.88±1.641	2.1±1.534	2.22±1.242	2.22±1.331	2.46±1.664	0.929
	decreasing rate	100.000	27.083	22.917	22.917	14.583	
P value		0.495					0.929

IV. DISCUSSION

To apply mechanical stimuli for tactile test in this study, scratching the dentine surface with a explorer probe was used.^{9,14-18,20)} Explorer probe use to evaluate sensitivity has been criticized. A mechanical probe introduces variability in pressure. Ideally, one would require the same tactile pressure to be exerted on all test teeth at all time intervals during a given clinical trial.²²⁾ The use of a sharp probe may also scratch the dentine surface. According to a previous report²³⁾ pressure, even from a gentle force of 5-10g, is sufficient to overcome the elastic limit of dentine, leading not only to compression and smear layer creation under the explorer tip, but also to permanent (microscopic) deformation of dentine (scratch development). This deformation of dentine may cause displacement of tubular fluid inwardly at a rapid rate, which activates mechanoreceptors, thereby triggering a pain impulse. The examiner in this study was an experienced dentist for these tests and a tactile force of the examiner was in the range of 20-30 g. This tactile force can be thought to be sufficient to deform dentine according to previous report. The authors, however, did not investigate a deformation of dentine in this study and further research is required to determine whether this large tactile force had an effect on this study.

The scratching of the dentine may also remove a therapeutic agent deposited during a clinical trial, but this does not seem to substantially influence pain threshold.²⁴⁾ In this study, the teeth, which had dentine hypersensitive but had not been treated, were selected.

Several investigators have applied cold water to exposed cervical dentine.^{14,25,26)} Minkov et al.¹⁵⁾ applied cold water (7°C) from a syringe, while Uchida et al.¹⁷⁾ used 15 ml of cold water (7°C) utilized 20°C cold water. Flynn et al.³⁾ used 15 ml of cold water (7°C) which was rinsed around the mouth for a few seconds. These investigators suggested that cold water at 7°C was ideal for the identification of sensitive teeth as well as minimizing the

incidence of false positive responses. Sensitivity for reasons other than cervical dentine sensitivity, however, cannot be ruled out. Cold water testing, therefore, has been criticized for its lack of objectivity.²⁷⁾ It is also difficult to determine how much water has been placed on the tooth and the timing of this placement.²⁸⁾ Ice stick was used in this study to determine qualitatively the degree of sensitivity to cold stimulus. The surface temperature of ice stick used in this study was in the range of 7°C and 8°C as recommended by several researchers.³⁾ An ice stick, which was not melted easily for 3 seconds, was relatively stable and it is thought that it didn't cause to stimulate gingiva or adjacent teeth during test in this study. It was believed, therefore, the use of an ice stick in a cold test should be very helpful for us to decrease false positive responses. Resultantly, the cold test used in this study showed the most significant difference after laser irradiation than other tests.

Electrical stimuli have been used by several investigators to quantify both prepain and pain thresholds in cervical dentine sensitivity.²⁹⁻³²⁾ Unlike the other stimuli used to quantify cervical dentine sensitivity, dentinal tubule fluid movement is not necessary for transmission of the electrical stimulus, but rather the presence of lower resistance organic material in cementum, enamel or dentine.³³⁾ Electrical stimuli, would, therefore, appear to be more suitable for measuring pulpal activity than for quantifying cervical dentine sensitivity,²²⁾ but the validity of such pulp testing has been called into question.^{34,35)} Current leakage via the periodontal ligament and subsequent stimulation of periodontal nerves may also yield false positive data. A conventional pulp tester, which was used in this study, is battery powered, producing pulses of direct current. The intensity of the output voltage (stimulus intensity) may be increased by pre-setting various numbered gradations (0-10) on a thumb wheel. Problems, however, arise in the interpretation of the information gathered in such a procedure, since it is incorrect to assume a direct relationship between stimulus intensity in volts and the number

on the thumb wheel.³⁶⁾ Results from initial studies by these latter investigators clearly demonstrated that conventional pulp testers were not suitable for quantifying cervical dentine sensitivity. Further, stimulation of the pulp on the basis of applied voltage may fail to represent exact pain threshold values, in as much as the stimulating current depends on varying resistance pathways to the pulp or to other adjacent tissues.³⁷⁾

The use of electrical stimuli to quantify cervical dentine sensitivity has been criticized on the basis of being non-physiology, since the response to such stimuli fails to correspond to the painful response normally experienced by cervical dentine sensitivity patients. Unlike thermal stimuli, electrical stimuli are not normally encountered in real life situations, and as such there is a question as to the relationship between the voltage values with the electrical stimulus procedure and the pain scale values obtained with normally experienced stimuli.²¹⁾ Fear of experiencing an unknown stimulus and possible discomfort, may, therefore, influence the patient's assessment of pain and in consequence a lower pain threshold value may be recorded. The result of EPT in this study showed that the values of EPT in both groups decreased considerably after 1st EPT, especially the EPT value of control group was significantly lower than that of experimental group after 1st EPT experience. This EPT result was different from those of other tests, cold and tactile tests in this study.

The order of application when more than one kind of stimulus is used is important. Care should be taken to ensure that the 1st should not distract from the 2nd, nor the 2nd from the 3rd and so on. The least disturbing stimulus should, therefore, be applied first, with the most disturbing used last.³⁷⁾ Several investigators have applied either tactile, electrical or heat stimuli prior to the application of cold air on the basis that the former do not appear to elicit a painful response which could affect the latter.^{20,30,31,38,39)} In this study, however, the order of test application was tactile, cold and electrical pulp tests. Because, unlike thermal stimuli, electrical

stimuli are not normally encountered in real life situations, EPT was performed last of all in this study. It is not assumed that cold test having performed in advance necessarily affect the result of EPT performed later in this study. However, because several reports suggested the order of application is important, further research for the effects of cold test on EPT results is required.

There are problems in evaluating patient subjective response to the various stimuli used in the assessment and treatment of cervical dentine sensitivity. Opinions vary as to the reliability of some of these methods of assessment^{27,39)} although more recently efforts have been made to develop controlled reproducible stimuli more suited to the evaluation of cervical dentine sensitivity.^{20,38-40)}

Although Tarbet et al.³⁰⁾ claimed that their methodology was objective, the examiner determined a threshold through the patient's response on perceiving discomfort in this study and methodology employed in this study, may therefore, not be as objective as claimed by them. Currently, no single method of eliciting and assessing cervical dentine sensitivity may be considered ideal. The absence of suitably objective methodology of assessing cervical dentine sensitivity and the lack of standardized measurement of the subjective response following application of stimuli still gives cause for concern. In this study, therefore, three tests such as tactile, cold and electrical pulp tests were used to obtain as much as a reliability of test results from a subjective test and the cold test using an ice stick, among three subjective tests used in this study, would be recommended for researchers to use in the assessment of dentine hypersensitivity based on the results of this study. Further research is, however, required to evaluate suitable methodology for the quantification of realistic test stimuli under controlled clinical conditions, whereby the subjective response may be objectively measured.

Recently, a low level laser was introduced in treating dentin hypersensitivity comparing desensitizing efficacy of GaAlAs laser and dentin

bonding agent.⁴¹⁾ They observed two treatment groups using GaAlAs laser and dentin bonding agent promoted a considerable decrease in sensitivity after 15 days of the first application and continued desensitizing effects were observed 30 days later. In a study on the desensitizing effects of an Er:YAG laser for hypersensitive dentine,¹¹⁾ it was concluded that Er:YAG laser is effective and the maintenance of the positive result was more than with a desensitizing aqueous solution containing polyurethane-isocyanate and methylenechloride.

It is possible that the two kinds of lasers may reduce DH by different mechanisms. If DH results from the movements of fluid in the tubules, fusing the tubules should result in a predictable elimination of DH. Thus, it could be suggested that dentin fused by a high power laser such as Er:YAG, Nd:YAG⁴²⁻⁴⁴⁾ and CO₂^{45,46)} lasers are responsible for an obturation of the dentinal tubules. The clinical effect of high power laser on DH, therefore, occurs immediately as reported by Schwarz et al. and can be remained for long time. Whereas, a diode laser irradiation also provided reductions in dentinal pain elicited by thermal, tactile, and air blast stimulation. The clinical effect of low-level lasers on DH relies upon an immediate analgesic effect as a consequence of the interruption of the nerve impulse path in the affected nerve fiber, concluding that laser acts as a reversible suppressor directly on the neuronal activity⁴⁷⁾ and an increase in the nerve ending threshold for pain, attributed to the maintenance of the receptor membrane potential and the suppression of the nerve ending fiber pulp potential.⁴⁸⁾ This study, however, showed a long lasting effects of GaAs diode laser irradiation on DH during 4 weeks like previous studies such as Sicilia et al. (2 months)⁴⁹⁾ and Vieira et al. (3 months).⁵⁰⁾

Gerschman et al. investigated the effectiveness of four applications of the GaAlAs laser using the wavelength of 830 nm to both the apex and the cervical areas of hypersensitive teeth at 1 wk, 2 wk, and 8 wk intervals. It was observed that the decrease in pain severity became more evident over time and that at 8 wk, the percent reduction in

sensitivity to probe and air stimuli based on a VAS was 65% and 67%, respectively. These results have some similarity from the findings obtained in the present study. The present study, although the duration of examination, the method of cold test (ice stick instead of air blast) and the laser diode used were different those of that study, showed that the sensitivity of dentin decreased more and more over time and that at 4 wk, the percent reduction in sensitivity to probe and cold (ice stick) test based on a VAS was larger than their results: 75.7% and 77.5% respectively.

It can be assumed that this long clinical effects of LLLT on DH should be a delayed obliteration of dentinal tubules by tertiary dentin, caused by increased metabolic activity of odontoblasts.⁵¹⁾ Many authors have questioned if the laser light actually reached the dental pulp. Sommer et al. have clarified this point.⁵²⁾ These authors also observed that the light reaches the pulp without losing practically any energy, thereby clearly showing that laser light is conducted through the inter-tubular dentine and the highly orderly structure of the dentine. It is important to note that light travels parallel to the tubuli, but not through the tubuli.^{52,53)} It is, therefore, suggested that LLLT, when used with the appropriate treatment parameters and method such as irradiating perpendicularly on a cervical dentine, is effective in treating DH as it quickly reduces pain and maintains a prolonged pain-free status. Further clinical investigations are needed in order to evaluate the long-term stability of the positive results obtained with various diode lasers.

V. CONCLUSION

Treatment modality used in this study (1week interval irradiation of 904 nm GaAs laser) provided statistically significant gradual reductions in dentinal hypersensitivity for 4 weeks. Conclusively, it can be suggested that the 904 nm GaAs laser irradiation could be positively used as an effective, reversible method in treating cervical dentine hypersensitivity.

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국문초록

과민치아에 대한 904nm GaAs 반도체레이저의 효과

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본 연구의 목적은 과민치아에 904 nm GaAs 다이오드 레이저를 조사하여 치료효과를 연구하여 과민 치아의 치료에 이러한 저수준 레이저 요법을 임상적으로 사용할 수 있는지 가능성을 파악하는 데 있다. 단국대학교 치과대학 부속치과병원 안면동통 구강내과에 내원한 환자를 대상으로 하였으며, 각 환자는 치경부에 사아질이 노출된 치아가 적어도 좌우로 2개 이상의 짝이 되는 치아를 소유하였다. 본 연구에 사용된 치아는 모두 50 개로써 실험군 25개, 대조군 25 이었다. Tactile test, cold(ice stick) test, electrical pulp test 를 실험전, 실험 1주후, 2주후, 3주후, 4주후 모두 5회 시행하였다. 레이저조사는 첫방문시, 1주후, 2주후, 3주후 등 4회하되 모두 세가지 검사를 마친 후 시행하였다. 전기치수 검사 외 Tactile test와 cold test는 주관적 평가인 visual analogue scale을 사용하였다.

실험 결과, Tactile test에서 VAS 수치는 시간 경과에 따라 유의하게 감소하였으나 실험군과 대조군간에는 유의한 차이가 없었다. 전기치수 검사에서는 실험군의 과민도가 대조군에 비해 유의하게 높았으나 (높은 역치를 의미) 시간 경과시 유의한 변화는 볼 수 없었다. 온도 (cold) 검사에서는 레이저 조사후 실험군과 대조군 간의 차이뿐만 아니라 시간 경과 시에도 유의하게 감소하였다. 이러한 결과를 보아 904 nm GaAs 레이저는 과민치아의 치료에 비가역적인 방법으로 효과적으로 사용할 수 있으리라 사료된다.

주제어: 상아질 지각과민, GaAs, 저수준 레이저 요법
