In Vivo Evaluation of Human Pulp Sensitivity After Nd:YAG Laser Irradiation

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Purpose: The aim of this study was to evaluate Nd:YAG laser irradiation for its potential usefulness to achieve in vivo human pulp anesthesia.

Materials and Methods: Thirteen faculty members from the Tsurumi University School of Dental Medicine participated in this study, following review of the Nd:YAG laser irradiation test protocol by the University Human Subject Committee. Thirteen canines served as controls and 13 served for experimental tests. For heat application and measurement of pulpal response, an electrothermal stimulator was used (Unique Medical: UDH-104), which consisted of a heat probe and a pain thermometer. The buccal surface of each of control tooth was heated to 65°C with the tip of the heat probe, and each patient reported extreme sensitivity at that temperature. The gingivobuccal epithelium adjacent to each of the 13 experimental mandibular canines was coated with India ink and irradiated with an Nd:YAG laser for 30 s at 120 mJ, 10 pps. The degree of pulp sensitivity response was measured by the pain thermometer immediately before and after each Nd:YAG laser irradiation treatment.

Results: Temperature sensitivity threshold increased significantly after each laser irradiation treatment (Wilcoxon signed-rank test).

Conclusion: The thermal pain perception threshold level for each pulp was significantly increased immediately following Nd:YAG laser irradiation. After one week, the increased pain thresholds for each tooth returned to the pretreatment values. It is suggested that Nd:YAG laser irradiation has anesthetic effects on human pulp.

Key words: Nd:YAG laser, pulp, anesthetic effect, thermal pain threshold, temperature sensitivity, pain thermometer.

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Research has recently expanded the clinical applications of certain lasers to treat different kinds of tissue alteration.[1-3] Previous data from the Tsurumi University dental research group have specified the effects and the biological principles of high power Nd:YAG laser irradiation.[1,4,5,7] In addition, we have also examined the effects of Nd:YAG laser irradiation in terms of hypersensitivity,[1] anesthesia of the gingival surface,[6] pain relief during tooth movement, and irradiation of the dental pulp.[7]

However, the possible mechanisms regarding its anesthetic effect are still unclear. The aim of this study was to evaluate Nd:YAG laser irradiation for its ability to achieve human pulp anesthesia.

MATERIALS AND METHODS

The Nd:YAG laser irradiation protocol was evaluated and approved by the Tsurumi University Human Study

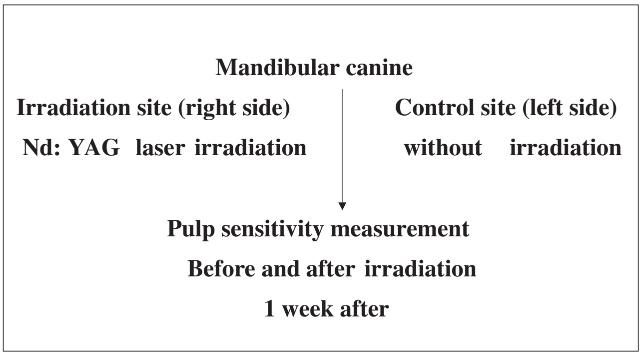

Fig 1 Measurement of temperature sensitivity.

Review Committee before beginning treatment of patients. Before giving their signed consent, each human subject was fully informed of any potential complications which may arise from the use of Nd:YAG laser irradiation. Thirteen adult male volunteers participated in this study, presenting with a mean age of 32.1 years. The experimental site in each patient was an area of keratinized and nonkeratinized gingiva, 2 mm below the mucogingival line, adjacent to the mandibular right canine.[6,7] All teeth and periodontal and alveolar tissues adjacent to the test areas were verified as normal by radiographic and clinical evaluation, without any restorations or pathology, such as caries. In addition, clinical and radiographic examination showed all of the adjacent periodontal and alveolar tissues to be normal.

In previous studies employing the methods mentioned above, we confirmed the safety of treatment, pain relief in dentin hypersensitivity, and topical anesthetic effects on the gingival surface.[1,6,7] The gingival areas were coated with India ink and immediately irradiated with Nd:YAG laser irradiation (American Dental Technology, Pulse Master, Corpus Christi, TX, USA) at an energy density of 50 J/cm^2 (30 s of 120-mJ pulses at 10 pps). The laser energy was applied to the gingival site in noncontact mode through a flexible quartz optical fiber with a focal spot diameter of 320 µm in a sweeping motion. The left side (control) was not irradiated.

For heat application and measurement of pulpal response, an electrothermal stimulator was used (Unique Medical: UDH-104), which consisted of a heat probe and a pain thermometer (Figs 1 and 2). Pulp vitality and sensitivity were measured with the electrothermal stimulator in each tooth prior to the initial Nd:YAG laser irradiation procedure to serve as untreated controls (mandibular left canines), and again one week after each Nd:YAG laser treatment. The vitality and sensitivity of each canine was measured at temperatures from 39°C to 65°C, heat being applied to the buccal enamel with the tip of the heat probe; all test persons reported extreme sensitivity at the latter temperature (Figs 1 and 2).

The data from this study were statistically evaluated using the Wilcoxon test. Statistical significance was set at $p < 0.05$.

RESULTS

We evaluated thermal pain thresholds in test participants with increasing temperature. In all 13 subjects, thermal pain perception thresholds increased after laser irradiation (pain threshold reached at 58.8 ± 7.30°C). In comparing thermal pain perception before and after laser irradiation, thresholds were significantly increased after laser treatment. The increased pain thresholds for each tooth returned to their previously recorded pretreatment values by one week post-treatment (Table1). Laser microscopy showed no damage to mucogingival surfaces after laser irradiation.[1]

DISCUSSION

Many procedures performed by dentists – such as cavity preparation, drying human dentin with air blasts, or thermal tests – are capable of inducing pain. The common feature of stimuli such as heat, cold, hyper-osmotic solutions, and air blasts applied to dentin is that they are capable of including fluid flow in dentinal tubules in vitro.[8,9]

Heating the tooth may induce tissue damage in the dental pulp,[10] with the severity of the injury varying according to intensity of the irritation. When heat is applied to human teeth, the sensory response seems to have two phases. A sharp, rather localized pain is induced within a few seconds.[11,12] Hensel and Mann[11] showed that when sharp pain was perceived, temperature at the amelo-dentinal junction had been elevated 11.7°C, but the change in pulp temperature was only 0.6°C. When the dull pain was experienced, pulp temperature had changed by several degrees.

Most of the studies concerning pulp nerve function have been based on recording the activity of A-fibers. When intradental A-fibers are heat stimulated, the temperature change is rapid.[10] With slow heating, no response can be found.[10,13] Nahri[14] reported in experi-

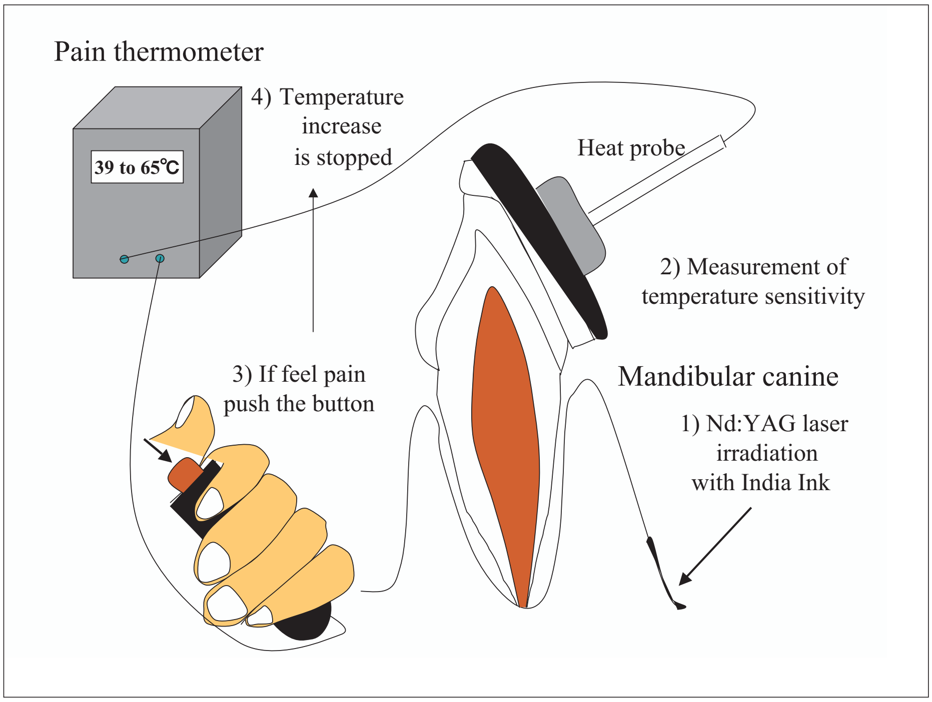

Fig 2 Experimental procedures.

Table 1 Temperature sensitivity thresholds (°C) (mean ± SD)

Laser-irradiated site		Nonirradiated site (control)	
Immediately post-irradiation	1 week post-irradiation	Baseline	1 week later
58.8 ± 7.30 *, **, ***	48.66 ± 4.51 **	48.45 ± 3.81*	47.65 ± 4.12***

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.005$, Wilcoxon signed-rank test. No significant difference existed between the irradiated and the control site 1 week after baseline.

ments on cats that the mean threshold temperature of 30 C-fiber nerve units was 43.8 ± 3.4°C.

In this study, the pain thermometer provided thermal stimuli up to a temperature of 65°C. This temperature improves the insertion of hot gutta-percha, but imparts quantities of heat to the already compromised dental pulp which may exceed the safety level.[15] The heat probe used in this study could transfer thermal pain to the patient's pulp. As a result, we could evaluate laser anesthetic effects precisely.

We have reported reversible suppression of action potentials of Xenopus (frog) tactile nerve fibers using Nd:YAG laser irradiation; the conduction of nerve action potentials was reversibly suppressed in the bundle. Staining with India ink has a considerable effect on reversible suppression.[16] Therefore, the results of that study suggest the pulp nerves were immediately affected during Nd:YAG laser irradiation.

In this study, the anestheic effects of Nd:YAG laser irradiation on human pulp disappeared within 1 week. This is supported by Goodies[17] and Yamaguchi,[7] who measured pulp response by electric pulp testing 1 month after Nd:YAG laser irradiation and found that the pulp response of all the treated teeth had returned to baseline values.[7]

The duration of the anesthetic effect of Nd:YAG laser was 1 week in every case, and the patients' condition was stable post-anesthetically. We will continue to examine the mechanism of anesthetic effects of laser irradiation on human pulp.

CONCLUSION

Thermal pain perception thresholds for each pulp were significantly increased immediately following Nd:YAG laser irradiation. The increased threshold values for each tooth returned to their pretreatment values after one week.

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