Endodontic Applications of a Short Pulsed FR Nd: YAG Dental Laser: Photo-Vaporization of Extruded Pulpal Tissue Following Traumatic Fractures of Two Maxillary Central Incisors; A Clinical Trial Report

Robert H. Gregg, II[1]

The Institute for Laser Dentistry, Section of Clinical Training Seminars
3221 W. Big Beaver • Suite 308-B • Troy, Michigan 48084

ABSTRACT

Historically, many techniques have been attempted in the search for a satisfactory and consistent treatment of inflamed, painful, hyperemic pulpal tissue. Present techniques attempting to achieve profound local anesthesia in such tissue, have not been satisfactory. Local anesthesia techniques acceptable to the patient with painful hyperemic pulpal tissue, has eluded previous technology. The subsequent treatment of hyperemic tissue without sufficient anesthesia primarily involves undesirable invasive mechanical/surgical procedures. Described in this clinical trial is a technique using free running (FR) pulsed, Nd: YAG laser energy to ablate soft tooth pulpal tissue -- a technique employed after conventional endodontic methods failed. A free running pulsed, FR Nd: YAG dental laser was successfully used at 20 pulses per second and 1.25 watts to photovaporize endodontic pulpal tissue (pulpectomy) to allow a conventional endodontic file to extirpate the remaining soft tissue remnants and access the root apex. Also described in this paper is the "hot-tip" effect of contact fiber laser surgery. This clinical trial achieved the immediate, short term objective of endodontic soft tissue removal via photovaporization, without pain reported by the patient. The pulsed FR Nd: YAG dental laser used as described in this clinical report appears to be a very safe and very effective technique; offers a treatment alternative to traditional therapy that suggests high patient acceptance; and is significantly less stressful for the doctor and staff than traditional treatment options. Long-term, controlled scientific and clinical studies are necessary to establish the safety and efficacy of both the helium-neon energy for visualization and the low-watt pulsed FR Nd: YAG energy for photovaporization of soft endodontic pulpal tissue within the root canal. Research is especially needed to understand the effects of a low-watt, pulsed FR, Nd: YAG laser on the activity of osteoclasts and odontoclasts and identify risks for developing external and/or internal resorption after intracanal application of pulsed FR Nd: YAG laser energy.

KEY WORDS: FR Nd: YAG Laser, Endodontics, Carbonization, Pulp Tissue, Hyperemia, Tooth Fracture, Root Canal, Photoablation, Photovaporization, Laser Pulpectomy.

1. INTRODUCTION

Research papers of lasers for use on dental tissue were first published in 1964[2,3]. Studies investigating the effects of lasers and pulp tissue first appeared in 1971[4], and with the neodymium: yttrium-aluminum-garnet (Nd: YAG) in 1977[5]. The earliest reported study that focused on the use of lasers in root canals *per se*, appeared in 1982[6]. Extensive laser endodontic research began in 1984[7,8] and has been intensive ever since. Most laser endodontic studies by dental researchers have centered on the carbon dioxide (CO_2)[10-11] and the Nd: YAG[12-20], with investigational research involving the ultraviolet (UV) eximer laser just recently in 1989[21,22]. Research specific to pulsed FR Nd:YAG laser usage in dentistry investigated hard tissue procedures without damage to tooth pulp, surrounding tooth enamel and dentin, and minimal associated discomfort[23-43].

The last three years has seen a tremendous number of scientific investigations, clinical trials, and clinical procedures using a pulsed FR Nd: YAG dental laser with variable repetition rates of 10,15, 20, 25, and 30 pulses per second (pps) or hertz (Hz) which are controlled by the operator. This variable pulsed FR, Nd: YAG dental laser has been, and is being used by over 650 clinical practitioners in the United States, and 1000 worldwide, for numerous dental surgical procedures involving the hard tooth structure. No pulsed FR Nd: YAG dental laser commercially available has yet received hard tooth and bone tissue marketing clearance from the U.S. Food and Drug Administration (FDA) for use in endodontics, even though vital pulp is comprised chiefly of soft vascular, lymphatic, and neural tissue. However, most countries outside of the U.S. have authorized the clinical use of FR Nd: YAG laser energy for such dental laser surgery procedures.

The laser handpiece is used in the same manner as an electrocautery probe and can be used within the tooth where access is difficult with the dental air rotor handpiece. The contact fiber is extended beyond the tip of the cannula to the laser working distance (LWD). The LWD is 2 mm less than the radiographic length of clinical crown-to-root measurement. The interaction of laser wavelength and energy density with tissue at the tip of the fiberoptic contact delivery system allows photoablation via thermal vaporization of dental soft tissue. This is a report on a clinical trial that achieved the immediate short-term objective of pain control during pulp extirpation via photo-thermal vaporization.

2. MATERIALS AND METHODS

A pulsed FR Nd:YAG laser (*dLase 300®* manufactured for American Dental Laser of Troy, Michigan by Sunrise Technologies, Inc., Fremont, CA) was used to ablate and disrupt intraoral/intracanal hard tissue. The laser energy was directed to the treatment site through a flexible quartz optical fiber with a focal spot diameter of 320 µm. The instrument has a variable average power range of 0.30-3.00 W, and the number of pulses per second is 10-30 hertz (Hz), resulting in an energy range of 30-150 mJ per pulse. Each pulse width is 150 µsec. Because the FR Nd:YAG laser beam is invisible at its operating wavelength of 1.06 µm, a red helium neon laser at 0.63 µm provides a visible aiming beam coaxial with the YAG laser. The tip of the 320 µm optical fiber was extended from the end of an adjustable handpiece approximately 6 mm.

Total energy exposure of the fiber tip and at the target tissue was measured using a hand held pulsed energy meter designed specifically for pulsed FR Nd:YAG dental laser systems (a JD-500 Digital Meter™ and a J25LP Laser Probe™ Joule manufactured by Molectron Detector, Inc. of Portland, Oregon). The pulsed energy meter includes a fiber optic adaptor, laser attenuator, and calibration at 1.06 µm. Actual pulse energy output of the fiber optic is measured in millijoules at any desired repetition rate between one and 600 pps. The pulsed energy meter can measure peak pulse energy output, average pulsed energy, and total energy exposure over time. This allows the operator to determine the exact energy delivered to the target tissue during a particular dental procedure.

All laser procedures were performed with protective eyewear on the patient, dentist, and assistant. Gowns, gloves, and masks were worn by the dental personnel. High-volume evacuation was employed to remove ablated and disrupted tissue. After the laser surgery the handpiece was sprayed with an iodophor disinfectant. The tip of the used fiber was cleaved and discarded in a sharps container. The handpiece, cannula, and fiber were then cleaned and sterilized using an autoclave.

The teeth were continuously cooled during lasing with the teeth kept between high volume air stream and high speed vacuum. The teeth were intermittently cooled with water rinses in 5 second intervals.

3. CLINICAL PROBLEM

Complete removal of pulpal tissue from the apical area, and a complete root canal preparation, are often not possible using conventional endodontic methods[44-47]. No published studies have been found reporting successful clinical outcomes of *in vivo* Nd: YAG laser energy to ablate or vaporize soft vital tissue within a root canal.

The primary goal of this clinical trial was to determine if the laser could be used to perform intraoral and intracanal soft tissue surgery of pulpal tissue while reducing or even eliminating severe pain associated with conventional methods. The challenge was to extirpate the highly inflamed, extruded pulpal tissue in two traumatically fractured teeth; and to do so without the patient experiencing the severe pain usually associated with such a procedure.

3.1 Presentation and Diagnosis

The patient was a 21 year old male who presented on January 21, 1991 for a dental emergency on with complete, horizontal, mid-line, fractures of his two maxillary central incisors [Fig. #1]. A periapical (PA) radiograph of the area, taken during the patient's first office visit on November 30, 1988 was used for comparison [Fig. #2]. He had a chief complaint of acute, spontaneous and throbbing pain in the maxillary central incisors, teeth #8 and #9. Bright red hyperemic pulp tissue was extruding about 2 mm from each tooth remnant [Fig. #3]. An incisal view photograph of the teeth was taken [Fig. #4].

3.2 Initial Treatment

One carpule (1.8 ml) of Lidocaine® with epinephrine 1:100,000 was infiltrated in the vestibule near each tooth apex. The patient continued to report significant pain after 15 minutes. One additional carpule (1.8 ml) of Duranest® (Etidocaine) with epinephrine 1:200,000 was infiltrated in the same manner. The patient reported a large reduction in pain after another 15 minutes. Cetacaine® (10% Xylocaine) was applied to the extruded pulp tissues.

3.3 Treatment Complication

Sixty minutes after the first anesthetic administration, light contact on the extruded pulp of #9 with the tip of a #10 endodontic Hedstrom file was intolerable for the patient. Presented with a high probability for very uncomfortable intra-pulpal and intra-canal injections of local anesthetic, the patient asked if the laser could be used to vaporize the pulpal contents.

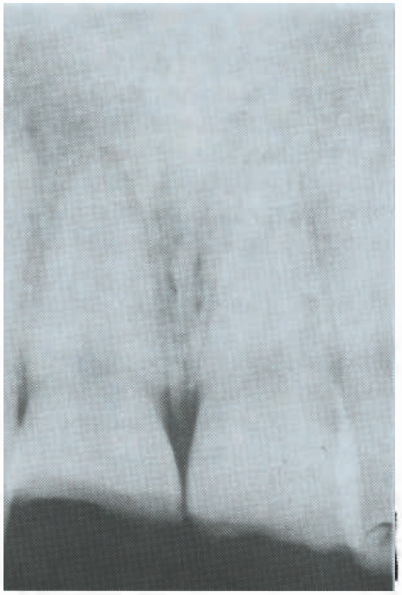

Fig 1. Diagnostic x-ray of January 21, 1991.

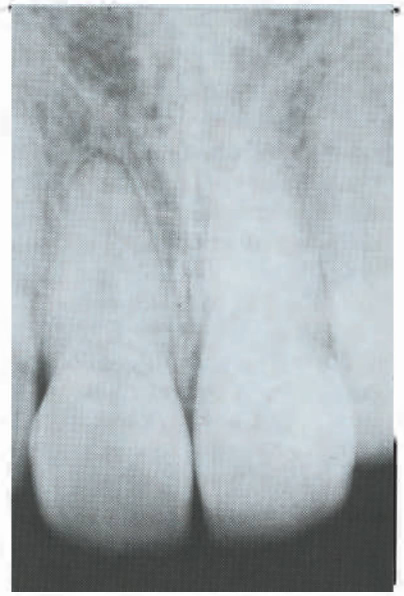

Fig 2. Diagnostic x-ray of November 30, 1988.

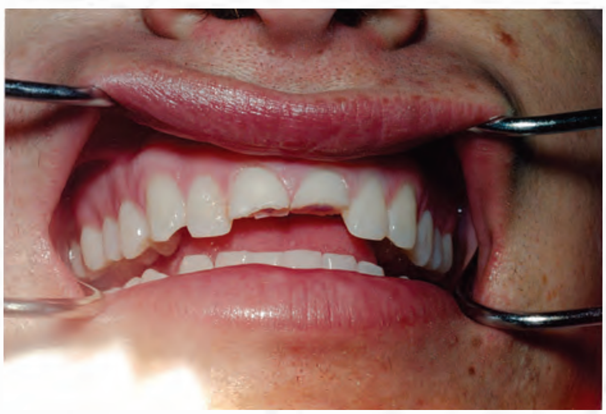

Fig 3. Patient Presentation on January 21, 1991.

Fig 4. Mirror Image Photograph of January 21, 1991.

3.4 Laser Pulpectomy: Photo Ablation, Photo Vaporization--Photo Thermal Effects

The photo-coagulation, photo-thermal vaporization capabilities of Nd:YAG lasers with a 1.06 micron wavelength have been well established. When photons of laser light are absorbed by the target tissue at the focal point of the beam, the atoms and molecules of increase the vibrations of their organized structures, which results in the conversion of photon energy into heat or thermal energy. This photo thermal effect causes the tissue to boil and vaporize. Molecular vibration is then converted to heat, which destroys selected tissue. Increased absorption of laser energy, or additional time on the target tissue, will cause molecules in the tissue to similarly increase their rate of vibrations, conversion to heat, and tissue destruction.

The FR Nd: YAG laser was initially set at 20 pps @ 1.75 w. The laser fiber was brought slowly towards the pulp tissue of #9 until there was an out-of-focus distance of twelve inches (30 cm). The patient felt no pain. Continuing, the fiber was brought slowly to a distance of six inches (15.2 cm) before the pain was intolerable for the patient. The laser energy was decreased to 20 pps @ 1.25 w.

Cetacaine® (10% Xylocaine) was again applied to the extruded pulp tissue. At 30 centimeters and at 15.2 centimeters the patient felt no pain. Out-of-contact, at three inches (7.6 cm), the patient felt no pain or sensation, however, the pulpal tissue began to vaporize [Fig. #5].

3.5 Laser Hot-Tip Soft-Tissue Thermal Effects

Once the exposed surface of the pulp was coagulated, the patient was able to tolerate the laser ablation with the quartz glass fiber "in-contact". Delivery of short pulsed laser energy through a silica glass fiber in a contact mode, allowed for a "hot tip" effect to occur. This "hot-tip" effect is due to the accumulation of proteins at the fiber tip, which absorbs most of the laser thermal energy and cause the tip and accumulated tissue to get hot enough in temperature to remove tissue. The reason is because laser energy is absorbed by the carbonized proteins adhering to the tooth. Tissue ablation then occurs by the photo thermal effects of heat conduction. The tissue does not have the opportunity to convert laser light into heat directly. The hot tip effect of a contact laser fiber does not allow laser energy to be transmitted or penetrated into the tissue to any appreciable amount.

The fiber was introduced into the canal to the laser working distance (LWD) to vaporize as much hyperemic pulp tissue as possible [Fig. 6 & 7].

The patient reported no pain, discomfort, or unpleasant sensation of any kind. The appearance of tooth #9 has a more shiny appearance than a minute or two previously. The reason for this is due to the low wattage and therefore low energy of the laser. The low wattage will not allow the tissue to rapidly reach the temperature necessary to cause coagulation or carbonization. This would seem to suggest that the low watt pulsed Fr Nd: YAG dental laser is unlikely to cause rapid temperature increases necessary to cause thermal damage to the pulp and contiguous hard and soft tissues [Fig. #8 & 9].

Conventional modalities were subsequently used to enlarge and fill the single canals of each tooth [Fig. #10 & 11].

Fig 5. Out-of-Contact Initial Photothermal Vaporization.

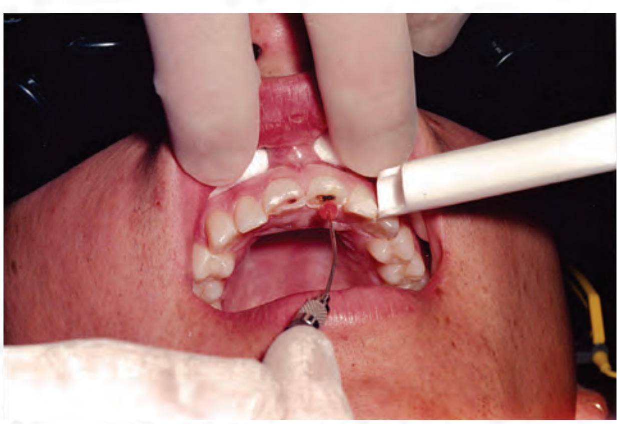

Fig 6. Fiber Shown Approaching the LWD.

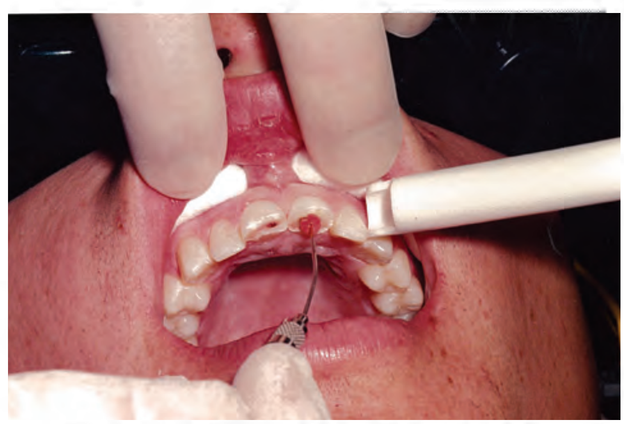

Fig 7. Fiber Shown at the LWD of Tooth #9.

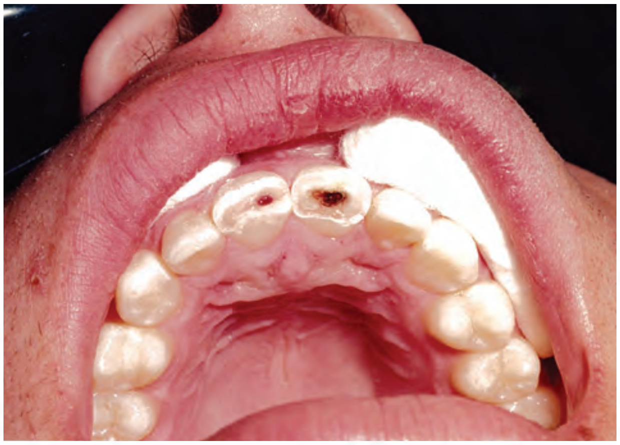

Fig 8. Appearance of Hard and Soft Tissue After Laser Pulpectomy of tooth #9.

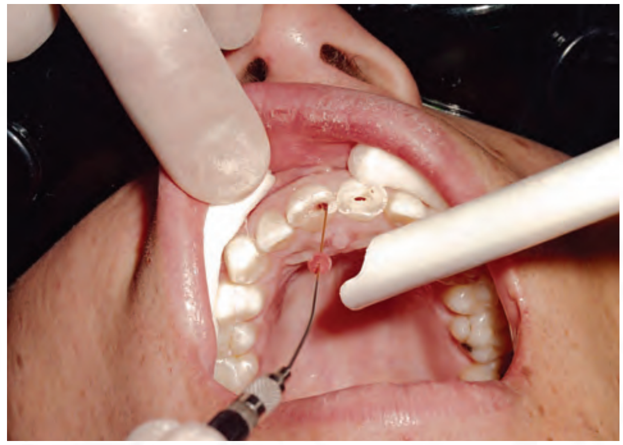

Fig 9. Appearance of Hard and Soft Tissue After Irrigation of the Area.

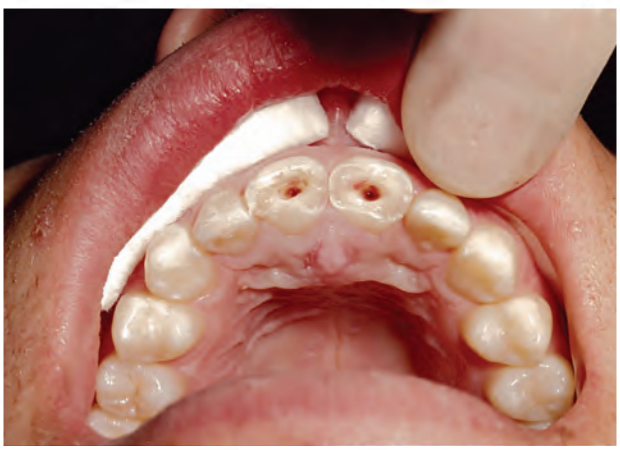

Fig 10. Canal Entrance Diameters After Use of Carbide Bur.

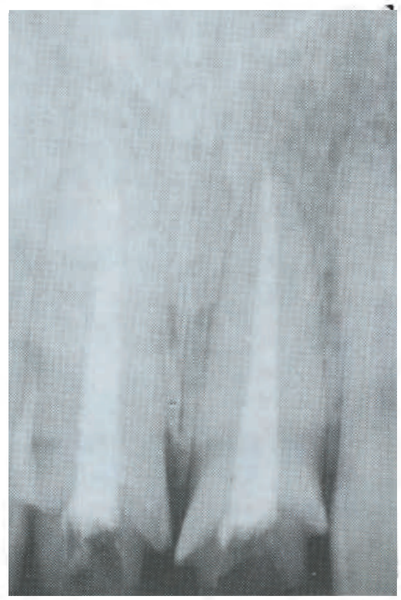

Fig 11. X-ray of #8 & #9 After RCT Fill With Gutta Percha and Sealer.

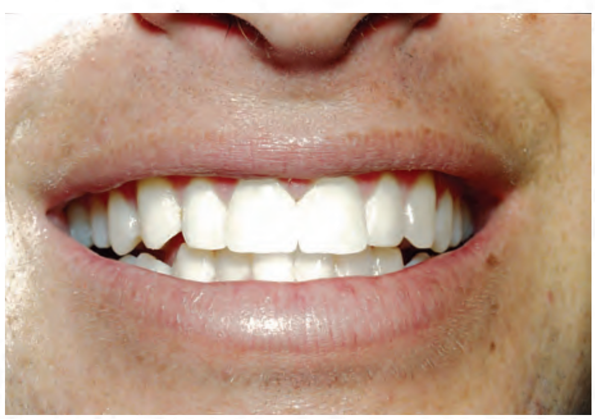

Fig 12. Completed RCT's and Ceramic Restorations.

4. RESULTS

There were no adverse reactions or complications from either surgical technique. The surrounding dentition, periodontal soft tissues, and bone were unaffected by the laser. There were no surgical or postsurgical complications or sequelae. The patients response was positive and the postoperative course was uneventful. There was no need for special home treatment instructions. Postoperative analgesia was prescribed, but was not needed.

The case remained a clinical success without side-effects after eleven month follow-up.

5. DISCUSSION

The laser contact probe was monitored using the helium neon indicator for a uniform round spot. The power setting of 1.25 watts @ 20 Hz, and total tissue energy exposure ≤ 2500 millijoules, caused no discernible adverse effects to adjacent soft or hard tissue, adjacent teeth, or bone. The FR Nd:YAG laser procedure was extremely well tolerated by the patient in both maxillary central incisors. This clinical trial demonstrates the use of the FR Nd: YAG laser for endodontic soft tissue removal within hard tooth structure. The exposed hyperemic pulp tissue is highly vascular and will contain most tissue components. However, painful hyperemic pulpal tissue also contains the chief tissue target for this procedure--the neural tissue of the pulp. The Nd:YAG has clinically demonstrated an ability to induce analgesia in neural tooth tissue.

The infection control procedures used in this study are essential to prevent contamination, cross contamination and to insure sterile instrumentation. The fibers were easily cleaned and autoclave sterilization did not effect the fibers performance in delivering the FR Nd:YAG laser to the tissue. It is assumed that the laser procedure reduced the endodontic pathogens but it is not known to what extent. It can be hypothesized that endodontic laser photothermal vaporization surgery, used in conjunction with conventional endodontic techniques will be an alternative to more invasive surgery. Continued investigation is needed to determine the role of this laser system in procedures and its efficiency used in conjunction with traditional endodontic methods.

The subject of laser sterilization and/or antisepsis of infected tissue incidental to a particular treatment objective is discussed frequently (of great interest), and needs to be investigated in further scientific studies.

6. SUMMARY

The free running (FR) pulsed, 3.00 watt (W), FR Nd: YAG; *dLase 300®* dental laser (American Dental Laser™) has been, and is being used by over 1200 clinical practitioners worldwide for numerous clinical procedures involving hard tooth structure. This clinical case report involves the use of the FR Nd: YAG laser to assist in the access of a root canal which contained a complication to conventional endodontic methods.

7. CONCLUSION

This paper reports the clinical trial of a soft tissue endodontic procedure using a free running (FR) pulsed, Nd: YAG dental laser, after conventional endodontic techniques failed. Described is a technique using FR, Nd: YAG laser energy to assist in accessing a root canal and the apex. This paper also discusses the "hot-tip" effect. The 3.00 watt (W), pulsed FR, Nd: YAG; *dLase 300®* dental laser (American Dental Laser™) was successfully used at 20 pulses-per-second (pps) @ 1.25 W to photo-vaporize sufficient hyperemic pulpal tissue to allow a conventional endodontic file the full length of the canal and access the root apex. Research is especially needed to understand the effects of a low-watt, pulsed FR, Nd: YAG laser on the activity of osteoclasts and odontoclasts, and identify any risks for developing external and/or internal resorption after the intra-canal application of pulsed FR, Nd: YAG laser energy. The pulsed FR, Nd: YAG *dLase 300®* dental laser (American Dental Laser™) used as described in this clinical report appears to be a very safe, and very effective technique, offers a very conservative treatment alternative to endodontic surgery or extraction, and is significantly more cost-effective than any existing treatment options.

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