Critical Appraisal

LASERS FOR USE IN DENTISTRY

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Lasers were first developed in the 1960s, and research into their applications in dentistry began soon thereafter. Early lasers were continuous wave devices with noncontact delivery that were found to be too hot for practical dental use. Of these early devices, CO_2 lasers were developed further and had limited use for soft tissue excision, primarily by oral surgeons. In the early 1980s, short-pulsed, fiber-optic contact delivery laser technology was developed. Neodymium:yttrium-aluminum-garnet (Nd:YAG), erbium:YAG (Er:YAG), and erbium-chromium:yttrium-scandium-gallium-garnet (ErCr:YSGG) laser systems use high peak powers with short interaction times delivered by contact fibers and tips to dental tissue. Further technologic advances have led to smaller laser units such as Nd:YAG and diode lasers. In the past 15 years, dental lasers have had a huge growth in practical dental applications.

Currently, there are 20 specific indications for use of a variety of dental lasers. These applications have been reviewed for safety and effectiveness following the US Food and Drug Administration (FDA) 510 (k) clearance for market mechanism. Specific laser devices are cleared for a number of soft tissue applications, including intraoral soft tissue surgery (ablating, incising, excising, coagulating), sulcular débridement, treatment of aphthous ulcers and herpetic lesions, removal of coronal pulp and pulpotomy (adjuncts to root canal procedures), and coagulation of extraction sites. Hard tissue applications include caries removal, cavity preparation, selective caries removal in enamel, enamel roughening, tooth preparation to obtain access to the root canal, root canal cleaning, and root canal preparation, including enlargement, apicoectomy, bone cutting, shaving, contouring, and resection. Miscellaneous uses of lasers include curing of composite materials, removal of composite filling materials (not amalgam), and softening gutta percha. Lasers also are used as an aid in diagnosis of dental caries, illumination of caries detection and endodontic orifice location, and blood flow measurements. Clearly, no one device can accomplish all of these practical dental uses. Generally, a specific laser device is maximized for diagnosis or for use in soft or hard tissues. It is common to find lasers that are good for use in soft tissues with some hard tissue applications, and other lasers that are good for hard tissue with some soft tissue applications.

Research is ongoing in the areas of caries prevention using lasers to change the structure of enamel. Research also is progressing in the area of optical coherence tomography for the

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nondestructive imaging of enamel and dentin to determine lesion progression over time. Exciting developments are occurring in the area of laser use in periodontal therapy for the removal and coagulation of the sulcular soft tissues and in the future for the selective removal of calculus on the tooth surface.

There has been continued growth in this new and maturing field in dentistry. The profession can review the substantial scientific evidence available in the field, including at least two texts, and a large amount of information is available through organized dentistry. The standard for practitioners who use lasers is successful completion of a recognized standard proficiency course according to a defined and accepted curriculum.

This Critical Appraisal focuses on the most used dental laser applications and the clinical trials conducted to support their safe and effective use.

USE OF THE PULSED ND:YAG LASER FOR INTRAORAL SOFT TISSUE SURGERY

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ABSTRACT

Objective: This randomized prospective clinical trial compared an Nd:YAG dental laser to conventional use of a scalpel in dental soft tissue procedures.

Materials and Methods: Seventy subjects participated in the study. Two surgery sites in 29 subjects were randomly selected and treated. An additional 41 subjects were treated exclusively with the pulsed fiber-optic-delivered Nd:YAG laser. Patients were at least 21 years of age, with a periodontal pocket depth of > 3 mm in two areas with inflammation, intact crestal lamina dura, and no radiographic evidence of bony defects. A pulsed Nd:YAG laser was used to cut, coagulate, ablate, and contour intraoral soft tissues at the marginal and interdental gingivae. Laser parameters available for the Nd:YAG were 1,064 nm emission wavelength, 0.3 to 3 W, 10 to 30 Hz with energy range from 30 to 150 mJ per pulse, 150 μs pulse width, and 320 μm diameter quartz optical fiber. The procedures were performed by five dentists who had training in laser tissue interactions and the use of this laser for dental soft tissue surgery.

Periodontal pocket depth measurements were taken before and immediately after surgery, at 1 week, and at 1 month. Bleeding was rated as none, minimal, moderate, or severe. Bleeding on provocation was measured at 1 week and 1 month. A visual analog scale for pain was used to assess patient perceptions during the procedure, at 24 hours, 1 week, and 1 month. Surgical prognosis was made immediately after the procedure, and treatment outcome was evaluated at 1 month as poor, fair, good, or excellent. All procedures were performed with proper laser safety eyewear, high-volume evacuation, and infection control. Statistical analysis of the data was performed using repeated-measures analysis of variance (ANOVA) with the independent variable being treatment and the dependent variables being pocket depth, pain, bleeding, inflammation, procedure time, prognosis, and healing assessment.

Results: Laser parameters ranged from 1.25 to 3 W and 15 to 20 Hz. An estimate of time for the procedure was recorded in the total number of pulses used for the procedure, which ranged from 980 to 15,000. This corresponded to 1 to 12 minutes of laser time with an average of less than 4 minutes. In all cases the periodontal soft tissues were removed successfully. Specific procedures accomplished were gingivectomy (n = 19), gingivoplasty (n = 11), gingival curettage (n = 10), frenectomy (n = 2), tissue excision

(n = 13), distal wedge (n = 2), and pocket elimination with restoration (n = 13).

There was a significant reduction in pocket depth as a result of both surgical techniques with an average reduction of 2 mm. Anesthesia was not required in 73% of the laser procedures. Gingival tissue was obtained from 11 subjects and submitted for histologic evaluation. The tissue exhibited normal tissue architecture close to the area of laser application and a thin layer of thermal coagulation at the site of surgery. The areas treated with the laser had less regrowth of tissue than did areas treated with the conventional scalpel surgery at 1 month. Operative and postoperative bleeding was significantly reduced with the Nd:YAG laser treatment as compared with the scalpel. Pain assessments ranged from 0 to 6 on the visual analog scale, with an average of 2.2 for the laser treatments. There was a trend for less bleeding on provocation at 1 week and 1 month for the laser treatment group, although it was not significantly different than for the scalpel group. No adverse events occurred.

Conclusions: This study demonstrated the use of the pulsed fiber-optic delivered Nd:YAG laser for soft tissue dental applications with less bleeding and lower anesthetic requirements compared with conventional scalpel techniques.

COMMENTARY

This study is a classic in the dental laser field as it was the first randomized prospective clinical trail demonstrating the use of the newer laser technology for soft tissue dental applications. These data were critical for the FDA clearance to market the Nd:YAG laser for soft tissue dental use. The advantages of this laser over conventional techniques are its precision in removing extremely small amounts of soft tissue around the teeth with its short pulse duration and small fiber-optic delivery.

Since this landmark study was published, there have been a number of corroborating studies focused on specific periodontal treatments. Experience has shown that the majority of uses are for incision, excision, and coagulating marginal and attached gingivae especially associated with soft tissue management in conjunction with restorative and prosthetic procedures. Another extensive use is in the sulcular débridement of the soft tissue side of the periodontal pocket in conjunction with scaling and root planing. There is encouraging evidence regarding the healing events that occur with the use of lasers on the soft tissue side of the periodontal pocket. Critics of laser use point to the potential for damage to adjacent tissues, which does not occur with experienced clinicians using these devices. The least invasive laser that cuts and coagulates is the Nd:YAG, which can remove the least amount of tissue, followed by the diode lasers and CO_2. Er:YAG and ErCr:YSGG lasers excise soft tissues but have minimal coagulation and reduction in bleeding.

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DENTISTRY FOR THE 21ST CENTURY? ERBIUM:YAG LASER FOR TEETH

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ABSTRACT

Objective: This randomized, prospective, multicenter clinical trial was conducted in two phases. Phase I evaluated laser cavity preparation on teeth planned for extraction to determine pulpal safety. Phase II evaluated the efficacy and safety of the Er:YAG laser for caries removal

and cavity preparation in enamel and dentin compared with the high-speed dental handpiece.

Materials and Methods: Five clinical investigations sites were included in this study. Sixty subjects, aged 12 to 60 years, participated in phase I, and 107 participated in phase II. For the safety study, investigators treated teeth scheduled for extractions either immediately or 2 days or 1 month after the completion of the restorative procedure. The treated teeth were vital and had caries and at least 1 mm of remaining dentin thickness. It was reported that 350 procedures were performed on 62 teeth in the laser group and 63 teeth in the control group. The procedures were Class I to V preparations with amalgam or composite restorations. Teeth were then extracted, bio-prepared, and evaluated histologically by blinded independent investigators. The degree of pulpal changes was assessed according to standard methods.

In phase II of the study, teeth were not extracted. Subjects were randomized to Er:YAG laser or high-speed caries removal and cavity preparation. Tooth-vitality measurements were obtained in repeated measures design. The clinical procedure used a fiber-optic-delivered Er:YAG laser (2,940 nm emission wavelength) with air and water spray coolant. Low laser parameters were used for caries removal (50 mJ at 5–10 Hz) and etching of tooth structure (25 mJ at 5–10 Hz). Higher laser parameters were used for cavity preparation in dentin and enamel (80–120 mJ at 5–10 Hz). Investigators were asked to rate caries removal, cavity preparation, and laser etching as compared with those aspects when a dental handpiece was used, with a rating of 1 being much more effective than the handpiece, 2 being more effective than the handpiece, 3 being equally effective as the handpiece, 4 being less effective than the handpiece, and 5 being unable to perform the procedure with the laser. Statistical ANOVA was performed.

Results: In phase I there were no statistically significant differences in pulpal assessments of hemorrhage, hyperemia, inflammation, necrosis, changes in vascularity, odontoblasts, predentin, and dentin between the Er:YAG laser treatment and the high-speed handpiece at extraction immediately, at 2 days, and 1 month. In phase II the laser procedure was more effective than the handpiece, the mean efficacy score for caries removal was 2.32 ± 0.89, for cavity preparation was 2.64 ± 0.95, and for laser etching was 1.44 ± 0.73. Less than 2% of the subjects required anesthetic during the operative procedure.

Conclusions: The Er:YAG laser was safe and effective for caries removal, cavity preparation, and enamel etching. The investigators rated the laser procedure as more effective than the dental handpiece with the same pulpal response.

COMMENTARY

This was a landmark study demonstrating hard dental tissue removal of enamel and dentin using short-pulsed fiber-optic-delivered lasers. It led to the first FDA clearance for marketing of lasers for use in caries removal and cavity preparation. The research methods employed were a compilation of standard pulpal response, restorative, and laser scientific methods. Inclusion of pulpal symptoms assessment and diagnosis would have strengthened the study.

Similar work has been completed for the ErCr:YSGG laser with a randomized prospective study of 68 subjects and 75 teeth with up to 6-month assessments. There also has been a randomized prospective clinical trial using an Er:YAG laser for children with 124 subjects. These three studies, combined with research that has occurred in Japan and elsewhere, establish a sound foundation for laser use in caries removal and cavity preparation. Similar to soft tissue applications, these laser hard tissue applications are less invasive and remove less tooth structure than do conventional methods. It is not clear whether there is an advantage for etching tooth structure. The macro-etch accomplished by these lasers still requires a conventional acid-etch to achieve micromechanical retention and strong bonds to enamel and dentin.

The mechanisms of action of both the Er:YAG and ErCr:YSGG lasers are the same. Both lasers use air and water coolant. The air-water spray cools the adjacent tissue and increases the ablation of the mineralized tissue. Absorbance of the laser is a function of the water on the surface and within the mineralized tissue and by the mineral itself. Because these devices are high peak power, the ablation occurs within very short times, generally < 200 μs for each pulse. These lasers are not intended for amalgam removal owing to the risk of mercury release caused by heat. Preparations typically are restored with composite. The laser procedures are slower to accomplish. The laser procedures are more precise than those done with a conventional handpiece. The Er:YAG and ErCr:YSGG lasers are safe and effective for caries removal and minimally invasive cavity preparations.

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SELECTIVE ABLATION OF SURFACE ENAMEL CARIES WITH A PULSED Nd:YAG DENTAL LASER

D.M. Harris, J.M. White, H.E. Goodis, et al

Lasers in Surgery and Medicine 2002 (30:342–350)

ABSTRACT

Objective: The purpose of this study was to demonstrate, in a multicenter, randomized, prospective clinical trial, selective ablation of enamel caries using an Nd:YAG laser. This study also used applied science techniques to identify surface changes using Fourier transform infrared (FTIR) spectroscopy.

Materials and Methods: In the laboratory study, FTIR spectroscopy was used to identify caries on enamel surfaces before laser treatment. The pulsed fiber-optic-delivered Nd:YAG laser (emission wavelength 1,064 nm) was then used to remove pit and fissure caries at 1 W and 10 Hz, 100 mJ/pulse with a fiber-optic diameter of 320 μm. FTIR spectroscopy was used again to measure the surface changes. In the clinical portion of the study, safety and efficacy of the Nd:YAG procedure were evaluated in two sets of clinical trials at three dental schools. Subjects meeting inclusion criteria were randomized to Nd:YAG laser treatment or conventional caries removal using a handpiece. Pulpal vitality was determined before treatment as was a symptom assessment of subjects to give a baseline pulpal diagnosis. Pit and fissure caries was removed from 104 third molars scheduled for extraction, and the preparations were restored with composite resin restorations. Pulpal vitality and symptom assessments were made at 1 week, and the teeth were extracted and evaluated histologically. In the second set of clinical trials, 462 carious lesions in 374 teeth in 90 subjects were randomized to a laser or handpiece group. The teeth were treated and restored, with a 6-month follow-up. As in the first set of trials, pulpal vitality and symptom assessment were determined, and caries removal, preparations, and restorations were assessed.

Results: Caries was successfully removed using both the Nd:YAG and conventional treatments. A significantly greater number of preparations in the handpiece group entered dentin as compared with the Nd:YAG laser group. There were no adverse events during the clinical trials. Pulpal diagnosis was pulpal health with no evidence of reversible or irreversible pulpitis. Histologic evaluations of pulp showed normal pulp. Preparation and restoration evaluations were clinically acceptable, and restorations remained intact and serviceable through the 6-month follow-up

interval. The pulsed Nd:YAG dental laser was found to be more conservative than the handpiece and was safe and effective for selective caries removal in enamel.

COMMENTARY

Selective caries removal in enamel by Nd:YAG laser is the most extensively investigated use of laser in dentistry. Since it was first proposed as an indication for use, it required two FDA panel meetings and over 12 years of study before being cleared by the 510 (k) mechanism. The series of studies conducted during this period set the standard for dental laser clinical trials and became the template for the other studies described above. The unique feature of the Nd:YAG laser is its ability to selectively ablate the highly organic caries in enamel. The Nd:YAG laser is not able to ablate sound enamel and is limited to removal of caries. The ability to selectively remove diseased tissue is unique to certain lasers. Because the Nd:YAG laser does not remove healthy enamel, caries that penetrates enamel and spreads out along the dentinoenamel junction presents a challenge for the Nd:YAG laser. In these cases a handpiece must be used to remove the healthy enamel to gain access to the underlying caries. Selective removal of diseased tissues by lasers is an exciting area for future applications in dentistry.

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Editor's Note: We welcome readers' suggestions for topics and contributors to Critical Appraisal. Please address your suggestions to the section editor:

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THE BOTTOM LINE: LASERS FOR USE IN DENTISTRY

The evidence for safe and effective use of lasers for both soft and hard tissue applications is strong and includes a number of excellent clinical trials. No one laser can perform every one of the over 20 laser applications in dentistry. Laser use in dentistry continues to grow. Survey data from clinicians who have lasers demonstrate that most practitioners use their lasers between one and five times a day. Overall, 75% of practitioners are satisfied, and patients are enthusiastic and accepting 79% of the time. The most frequent soft tissue procedures are gingivectomy and gingivoplasty (performed by 90% of practitioners who own lasers), followed by excisional surgery (87%) and sulcular débridement (76%). The fiber-optic-delivered Nd:YAG and diode lasers are the most widely used soft tissue lasers, followed by the noncontact CO_2 laser, because of their ability to cut and coagulate.

The most common hard tissue procedures are caries removal and tooth preparation for minimally invasive restorations (54%) and selective caries removal (37%). The most frequently used lasers in hard tissue are the Er:YAG and ErCr:YSGG lasers. In the area of diagnosis, laser fluorescence is an accepted technique and is beneficial in finding hidden caries missed in clinical examinations of pits and fissures. Future applications for lasers include selective calculus removal, optical coherence tomography for diagnosis, and enamel modification for prevention.

SUMMARY

There are a number of laser applications for dentistry that are proven to be safe and effective. These laser applications offer a number of advantages over conventional methods, primarily in the area of minimally invasive dentistry. Future uses for lasers in dentistry include a number of new applications. The current and future outlook for lasers in dentistry is bright.