Apical Extrusion of Root Canal Irrigants When Using Er:YAG and Er,Cr:YSGG Lasers with Optical Fibers: An *In Vitro* Dye Study

Roy George, BDS, MDS, and Laurence J. Walsh, DDSc, PhD

Abstract

Because of the potential for irritant reactions in the periapical region, irrigant solutions must be constrained within the root canal. We examined fluid extrusion beyond the apical constriction by pressure waves generated by pulsed middle infrared lasers using needles and Max-I-Probes (Dentsply) as controls. Both free-running pulsed Erbium: Yttrium Aluminum Garnet (Er:YAG) and Erbium, Chromium: Yttrium Scandium Gallium Garnet (Er,Cr:YSGG) lasers with bare or conical fiber tips at distances of 5 or 10 mm from the apex displaced fluid past the apex. Larger apical openings showed greater extrusion of fluid. The volume of extruded fluid was similar to conventional 25-G needles, but fluid was distributed further from the apex. Because pulsed lasers create pressure waves in irrigant fluids within the root canal, the potential for extrusion of fluid from the apex should be considered when assessing intracanal laser treatments in endodontics. *(J Endod 2008;34:706–708)*

Key Words

Apical extrusion, Er,Cr:YSGG laser, Er:YAG laser, optical fibers, root canal

From the School of Dentistry, The University of Queensland Brisbane, Brisbane, Australia.

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Address requests for reprints to Dr Laurence J. Walsh, School of Dentistry, The University of Queensland, 200 Turbot Street, Brisbane, QLD 4000, Australia. E-mail address: l.walsh@uq.edu.au.

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In recent years, there has been increased interest in using pulsed middle infrared lasers (Er:YAG and Er,Cr:YSGG) within the root canal for disinfection (1–4), removing smear layer (5, 6), or for biomechanical preparation (7, 8). Water or other irrigants are used during lasing to reduce thermal stress to the radicular dentine and periodontium.

These pulsed lasers absorb in water and create pressure waves from explosions followed by implosions. A recent study reported that an Er,Cr;YSGG laser used within the canal with a plain endodontic tip (Biolase Z4; Biolase Technology, Irvine, CA) could generate fluid movement at speeds up to 100 km/h (9). With pressure waves causing such fluid movement, the possibility of accidental extrusion of fluid beyond the apical constriction must be considered. This laboratory study examined fluid extrusion caused by laser pulses using a matrix design to explore relevant variables (including laser type, fiber tip design, distance of the fiber tip from the apex, and size of the apical constriction). Considering the natural variation that occurs between teeth, a repeated-measures design was used so that the same root canal system could undergo multiple treatments.

Materials and Methods

Sample Preparation

A total of 16 recently extracted single-rooted human maxillary anterior teeth that had been collected from older adult periodontal patients undergoing clearances were stored in water saturated with thymol. The teeth comprised 6 maxillary incisors and 10 maxillary canines. All teeth had straight root canals of similar size to reduce effects of canal size and curvature on the extrusion of irrigant. Patency of the apical opening was confirmed with an International Organization for Standardization (ISO) #08 K-file passed in a retrograde manner. After coronal access to the pulp chamber was established using diamond burs, the working length was established by passing a ISO #08 K file to the apex in an anterograde direction and then backing off the measurement by 1 mm. The teeth were divided into two groups: those with a prepared apical foramen size of either ISO #15 or ISO #20. All canals were then prepared to the working length to size F5 (0.50 mm) using Protaper (Dentsply, Tulsa, OK) instruments by the one operator (an experienced endodontist).

The study used a matrix design with two different types of middle infrared lasers (Er:YAG and Er,Cr:YSGG), two different types of laser endodontic tips (convention bare optical fibers and modified conical-shaped fibers), and two sizes of the apical constriction.

Two irrigating needle types, a 25-G conventional nonbeveled needle and a 25-G side-vented needle (Maxi-I-probe; Dentsply, Tulsa, OK), served as controls for the extrusion that occurs with conventional endodontic irrigation. Both were attached to 10-mL syringes using a Luer-Lock connection. A constant fluid flow rate of 0.2 mL/s was achieved by using a regulated compressed air supply (0.35 bar) delivered to the piston of the syringe. Between experimental runs, the syringe was reloaded with 1 mL of the test dye solution.

Dye Extrusion

To assess dye extrusion, teeth were mounted horizontally on a glass slide (Fig. 1), with the height of the apical foramen 2 to 3 mm above plain paper sheets 10 cm long and 5 cm wide, which were used to permanently record extruded dye. A custom jig held the

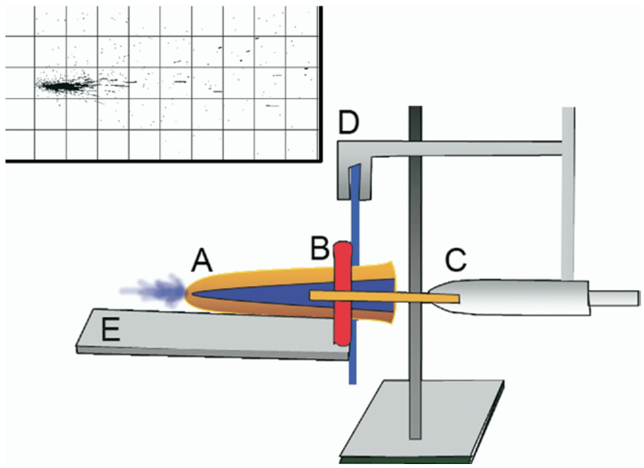

Figure 1. Experimental setup. (*A*) Apical foramen with dye exiting from it. (*B*) Tooth root held in place in a plastic block. (*C*) Fiber exiting from the laser handpiece. (*D*) Positioning devices for the tooth mount and laser handpiece. (*E*) A glass slide to hold the tooth in a fixed position and to support paper sheets used to record dye exiting from the apical foramen. (*Inset*) A binary image of extruded dye, with the solution being extruded from the left side of the image.

teeth at a fixed apical downward inclination of 10° and in a fixed position relative to the laser handpiece and laser fiber (or needle). This gave a consistent parallel orientation of the direction of the apical foramen relative to the recording paper.

Laser Systems

A Biolase Waterlase MD Er,Cr:YSGG laser system (2780 nm wavelength; Biolase Technology, Irvine, CA) was used at a panel setting of 1.25 W (62.5 mJ/pulse) at 20 pulses/s with no air or water. A total of 32 laser fibers (400 μm diameter Zirconia Z4 tips; Biolase, Irvine, CA) were used, of which 16 were unmodified (bare) and 16 had conical tips. The conical modification was undertaken using the tube etching technique at room temperature with 50% hydrofluoric acid (10) for 2.5 hours to give a terminal diameter of 33 μm, with the process controlled by continuous examination using a stereo microscope at a magnification of 30×.

A KaVo KEY3 laser system (2,940-nm wavelength; KaVo, Biberach, Germany) was used at a panel setting of 200 mJ/pulse (4 W) and 20 pulses/s with no air or water. A total of 32 tips of the "3-ring" 400-μm configuration were used, of which 16 were bare and 16 were modified conical tips. Tube etching for these germanium-doped glass fibers was undertaken for 90 minutes to give a terminal diameter of 33 μm. All conical fiber tips were assessed by using ray tracing (with the inbuilt coaxial diode laser–aiming beam) to ensure that their forward and lateral light-emission characteristics were identical.

The chosen laser parameters (panel settings) for both systems gave an average output power of 1 W from the terminal end of the bare (unmodified) optical fiber tip and an average of 0.75 W for the modified tip when measured using an external laser power meter (Nova II; Ophir Optics, Wilmington, MA) with the fiber tips placed at a distance of 10 mm from the sensor head. There is a shorter pulse duration with the Er,Cr:YSGG laser system than with the Er:YAG system (140 microseconds vs 200 microseconds, respectively). The exposure time used with both lasers was 5 seconds.

The intracanal dye solution used to show apical displacement of fluid was prepared by dissolving 0.1 g of ttoluidine blue dye (Gurr; Searle, Essex, England) into 50 mL of distilled water. By using a tuberculin syringe and 25-G needle, this solution was injected slowly into each canal until a droplet was expressed from the apical foramen, indicating complete filling of the root canal space. The various laser fibers and control needles were then each placed into the canal at a distance of either 5 or 10 mm from the apex. The laser handpiece and syringe were held in place with laboratory clamps to give a consistent position. Each experiment used 8 replicates, each with a fresh fiber tip or new needle but in the same teeth.

Image Analysis

Dye impacts were photographed by using a digital camera mounted at a fixed distance under constant lighting conditions. Images were processed using PhotoFiltre version 6.2.7 (Antonio Da Cruz 2001–2007) to enhance edges and overall image contrast and then converted into binary format (Fig. 1 *inset*) for analysis with Image J (version 1.38x; Wayne Rasband, National Institutes of Health). The amount of extruded dye (in pixels) was determined with the aid of a 10-mm grid. Data from the 8 replicates per group were then pooled and assessed for normality by using the Kolmogorov-Smirnov test. Because normality was established, differences between groups were analyzed by using multiway analysis of variance with Tukey-Kramer post-hoc multiple comparison tests.

Results

Dye extrusion was seen in all groups, except for the Max-I-Probe when used at a 10-mm distance from an ISO #15 apex. There were significant effects for needle type (conventional > Max-I-Probe), treatment type (laser = conventional needle > Max-I-Probe), and apex size (ISO #20 > #15). There were no significant effects for the variables of laser type (Er:YAG = Er,Cr:YSGG) or optical tip design (straight = conical ends). The variable of distance of the instrument tip from the apex was only significant for the two needle groups (5 mm > 10 mm) but not for any of the laser groups (Fig. 2).

In all laser groups, considerable apical extrusion occurred, with the maximum distance of extrusion from the apex being some 90 mm (Fig. 3). The maximum concentration of dye (measured by pixels per grid square) was observed at a distance of 20 mm from the apex in all laser experimental groups. There was a three-fold increase in dye extrusion in the ISO #20 apex group versus the ISO #15 group when matched for the same laser system, fiber design, and distance from the apex.

Overall, for the same apical foramen size, there was no statistically significant difference between the various laser groups and the conven-

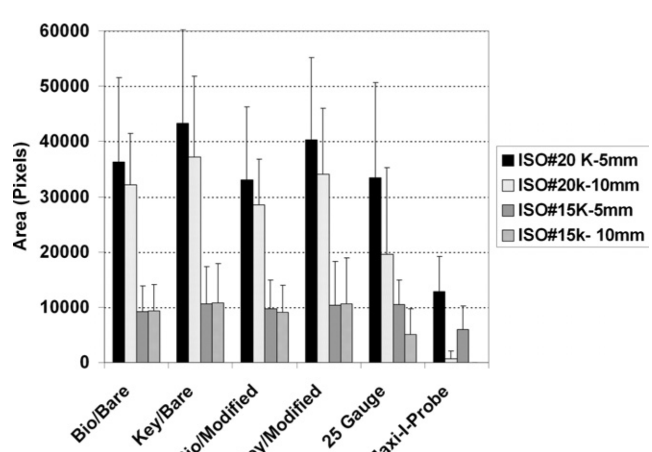

Figure 2. The amount of dye extrusion measured in a grid square 20 mm from the apex. The data show mean pixels (and standard deviation) in a 10-mm grid square from 8 experiments.

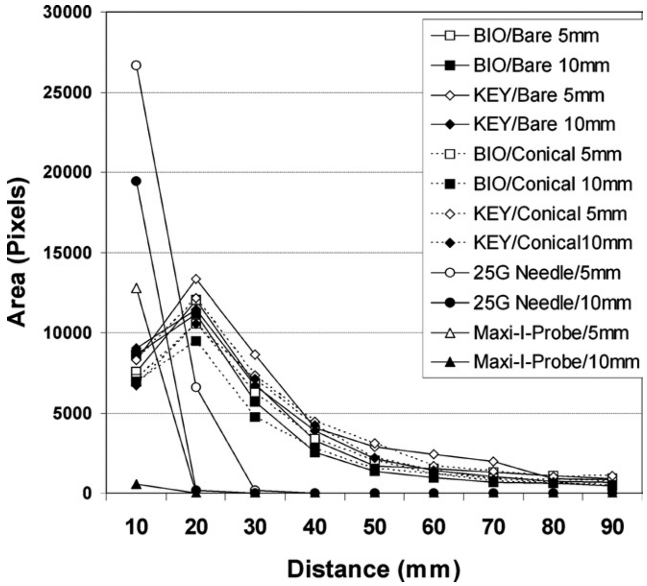

Figure 3. Dye extrusion at different distances from the apex expressed as mean pixels per 10-mm grid square. The maximum extrusion occurred at a distance of 20 mm. Note the similarity between the eight laser groups.

tional needle control in terms of the number of pixels. However, with the laser treatments, these pixels were distributed much further forward from the apex by a factor of approximately four times. For the same apical size, there was much lower dye extrusion with the Max-I-Probe than with the conventional needle or any of the laser treatments.

The maximum extrusion recorded by using the 25-G conventional nonbeveled needle was 20 mm when the needle tip was placed 5 mm from the apex. A maximum distance of 20 mm was seen with the Maxi-I-Probe when placed at 5 mm from an ISO #20 apex, which reduced to 10 mm when the apex was ISO #15 or when the tip was retracted to 10 mm from the apex.

Discussion

This study shows that apical extrusion occurred with both lasers when used with different fiber types and at different working distances. Because the laser fibers were placed passively in the canals and did not occupy the majority of the canal space, no dye extrusion occurred merely from the action of placing the fiber.

In contrast to laser treatment and conventional irrigating needles, the Maxi-I-probe gave very little extrusion. The conventional 25-G needle showed the same extent of apical extrusion of dye when compared with the laser groups. With laser treatment, the dye was ejected in bursts following each pulse, whereas with the conventional 35-G needle, the movement of solution through the apical constriction was more constant over the time period of 5 seconds used in the study.

Despite the results reported herein, in the clinical situation in the presence of an intact periodontium, there may not be sufficient force to propel irrigants past the apex in any great quantity. This particularly seems so when side-vented needles such as the Max-I-Probe are used. The present study deliberately used air pressures similar to those of past investigations of irrigating needles (11) for the conventional needle control. In our preliminary studies, we attempted to create an environment external to the tooth apex using air pressures to simulate the resistance of an intact periodontium and its associated tissue fluids (~50 kPa); however, anterograde movement of the dye occurred, rendering accurate measurement of dye extrusion impossible.

The use of coolant sprays and irrigants during root canal lasing procedures warrants the need to evaluate the effect of laser pulses in the fluid-filled confines of the root canal space. Pulsed erbium lasers can create pressure waves of sufficient force to propel microdroplets of aqueous irrigant beyond the apical constriction, with greater ease when the apical foramen is larger. Thus, caution should be used when using such lasers in combination with irrigants such as sodium hypochlorite and hydrogen peroxide.

References

1. Gutknecht N, Moritz A, Conrads G, Sievert T, Lampert F. Bactericidal effect of the Nd:YAG laser in in vitro root canals. J Clin Laser Med Surg 1996;14:77–80.
2. Moritz A, Gutknecht N, Goharkhay K, Schoop U, Wernisch J, Sperr W. In vitro irradiation of infected root canals with a diode laser: results of microbiologic, infrared spectrometric, and stain penetration examinations. Quintessence Int 1997;28:205–9.
3. Lee MT, Bird PS, Walsh LJ. Photo-activated disinfection of the root canal: a new role for lasers in endodontics. Aust Endod J 2004;30:93–8.
4. Wang QQ, Zhang CF, Yin XZ. Evaluation of the bactericidal effect of Er,Cr:YSGG, and Nd:YAG lasers in experimentally infected root canals. J Endod 2007;33:830–2.
5. Khabbaz MG, Makropoulou MI, Serafetinides AA, Papadopoulos D, Papagiakoumou E. Q-switched versus free-running Er:YAG laser efficacy on the root canal walls of human teeth: a SEM study. J Endod 2004;30:585–8.
6. Altundasar E, Ozcelik B, Cehreli ZC, Matsumoto K. Ultramorphological and histochemical changes after ER,CR:YSGG laser irradiation and two different irrigation regimes. J Endod 2006;32:465–8.
7. Varella CH, Pileggi R. Obturation of root canal system treated by Cr, Er:YSGG laser irradiation. J Endod 2007;33:1091–3.
8. Karlovic Z, Pezelj-Ribaric S, Miletic I, Jukic S, Grgurevic J, Anic I. Erbium:YAG laser versus ultrasonic in preparation of root-end cavities. J Endod 2005;31:821–3.
9. Blanken JW, Verdaasdonk RM. Cavitation as a working mechanism of the Er,Cr:YSGG laser in endodontics: a visualization study. J Oral Laser Appl 2007;7:97–106.
10. Stockle R, Fokas C, Deckert V, et al. High-quality near-field optical probes by tube etching. Appl Phys Lett 1999;75:160–2.
11. Bradford CE, Eleazer PD, Downs KE, Scheetz JP. Apical pressures developed by needles for canal irrigation. J Endod 2002;28:333–5.