The clinical use of the Er,Cr:YSGG laser in endodontic therapy

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_**Total elimination of bacteria** from infected root canal systems remains the most important objective of endodontic therapy. However, in spite of a plethora of new products and techniques, achieving this objective continues to elude our profession. Historically, endodontic treatment has focused on root canal disinfection with "entombment" of remaining bacteria within dentinal tubules and inaccessible areas of the root canal system. Although many factors have been implicated in the etiology of endodontic failures, it has become evident that these "entombed" bacteria play a pivotal role in the persistence of endodontic disease (Siqueira & Rocas 2008).

Although impressive results have been obtained *in vitro*, laser energy alone has not been able to achieve total bacterial kill in extracted teeth. From a clinical perspective it is apparent that a combination of different treatment modalities is needed to sterilize root canal systems. In addition, many clinical obstacles exist that further complicates the clinician's ability to achieve this goal. These include, but are not limited to: restricted endodontic access, complex root canal anatomy, limitations of irrigation and instrumentation techniques, inability to entomb bacteria and the inability to reach and eliminate bacteria deep within the tooth structure. While the purpose of this article is to focus on the clinical use of the Er,Cr:YSGG laser with radial-firing tips, a definitive treatment protocol needs to be in place to reduce the intracanal bacterial load prior to laser usage and also to facilitate delivery of the laser energy to the most critical part of the root canal, the apical third.

The erbium,chromium:yttrium-scandium-gallium-garnet (Er,Cr:YSGG) laser emits at a wavelength of 2,780 nm and is highly absorbed by water. The lower the penetration depth in water

Fig. 4

Fig. 5

Fig. 1_Comparison of different wavelengths used by lasers and their penetration depth in water/tissue. The higher the absorption, the greater is the ability of the laser to cut or ablate tissue.

Fig. 2_Laser energy is emitted as a broad cone providing better coverage of root canal walls.

Fig. 3_RFT2 (yellow) and RFT3 (blue) laser tips compared to hand files.

Fig. 4_Master delivery tip delivers irrigant to the pulp chamber and evacuates any overflow.

Fig. 5_True negative pressure apical irrigation and evacuation provided by macro- and microcannulas.

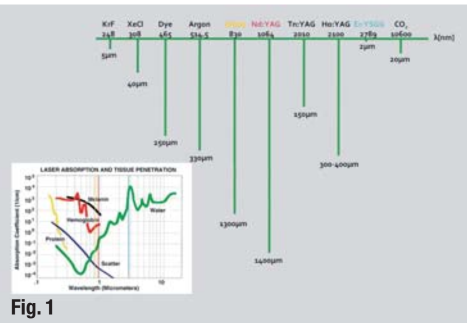

Fig. 1

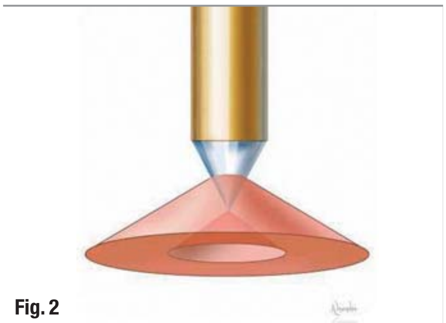

Fig. 2

Fig. 3

or tissue (or the higher the absorption), the greater is the ability of the laser to cut or ablate tissue (Fig. 1). Since this wavelength is very similar to the absorption maximum of water in hydroxyapatite, photo-ablation occurs where water evaporates instantaneously, thereby ablating the surrounding tissue. Gordon et al (2007) found that it was possible to achieve expansion and collapse of intratubular water as deep as 1,000 µm or more. This micropulse-induced absorption was capable of producing acoustic waves strong enough to disrupt and kill intratubular bacteria. These findings are significant as bacteria have been identified at depths of 1,000 µm (Kouchi et al. 1980), with *E. faecalis* at depths of 800 µm (Haapasalo and Orstavik 1987). Irrigants such as sodium hypochlorite have a limited effect on these bacteria with penetration depths of only 100 µm (Berrutti et al. 1997). Increasing concentration, exposure time and temperature was recently found to improve NaOCl penetration (Zou et al. 2010). Promising bacterial kill rates using the Er,Cr:YSGG laser with radial-firing tips have been reported in extracted teeth. A disinfection reduction of 99.7% was obtained for *E. faecalis* at depths of 200 µm into dentin (Gordon et al. 2007) and 94.1% (1 log) at depths of 1,000 µm (Schoop et al. 2007).

The development of the radial-firing laser tip (Biolase Technology, Inc.) with a tip shape that emits the laser energy as a broad cone, allows better coverage of the root canal walls than end-firing tips (Fig. 2). This facilitates entry of the emitted laser energy into the dentinal tubules reaching bacteria that have penetrated deep into the dentin.

_Treatment protocol

Current techniques incorporating hand and/or rotary instrumentation, positive pressure irrigation, with or without sonic and ultrasonic agitation, fall short of total canal disinfection. The treatment protocol presented in this article incorporates three main components: management of the working width of the root canal, negative pressure apical irrigation and intracanal laser therapy.

Working width management

The working width (WW) of a root canal is the diameter of the canal immediately before reaching its apical constriction. Allen (2007) found that 97% of canals not cleaned to their WW had residual debris in the critical apical region, while 100 % of those cleaned to their WW were free of debris 1 mm from the apical constriction. Studies have shown that we need to clean to larger sizes to remove bacteria and debris (Kerekes 1977, Wu 2000). Conventional tapered files cannot accomplish this without transporting the canal, creating strip perforations, weakening the tooth or separating instruments. The LightSpeed LSX (Discus Dental) file is a unique, extremely flexible, taperless, nickel titanium instrument capable of cleaning to the WW. The final apical size (FAS) is the instrument size that completes WW preparation and is determined when the LSX file binds 4 mm (or more) from the working length and requires a firm push to reach WL. The customized apical preparations created are critical for predictably successful endodontics and provide significant advantages:

_Effective removal of infected material, debris, inflamed and necrotic tissue from the apical region.
_Allows placement of irrigating needle to WL for negative pressure apical irrigation.
_Facilitates placement of intracanal medication deeper within the canal.
_Facilitates placement of radial-firing laser tip within 1mm of WL.

Negative pressure apical irrigation

There are two main reasons why irrigants fail to reach the critical last 3 mm of a root canal. Firstly, using positive pressure irrigation with a side-vented needle there is little flushing beyond the depth of the needle (Chow 1983). Most of the irrigant follows the path of least resistance and backs out of the canal with apical flushing penetrating only 1–2 mm apical to the end of the needle. To achieve effective apical flushing, the needle tip needs to be placed 1mm from working length which dramatically increases the risk of a sodium hypochlorite accident.

Secondly, the presence of apical vapor lock from air trapped in the canal as well as ammonia and carbon dioxide released from the dissolving action of sodium hypochlorite on pulp tissue prevents penetration of irrigants into the apical third. This vapor lock cannot be removed with hand or rotary files, sonic or ultrasonic activation. In a recent study, vapor lock resulted in "gross retention of debris and smear layer remnants" in the apical 0.5–1.0 mm of closed root canal systems (Tay et al. 2010).

The EndoVac (Discus Dental) is a true apical negative pressure irrigating system that provides continuous, high volume irrigation of fresh fluids to the canal terminus with simultaneous evacuation. It is comprised of a master delivery tip (Fig. 4) that delivers fluid to the pulp chamber and a macro- and microcannula (Fig. 5) that draw the fluid from the chamber to the canal terminus by way of evacua-

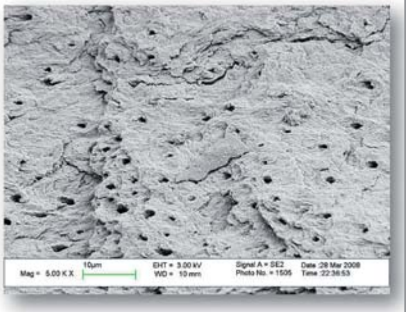

Fig. 6

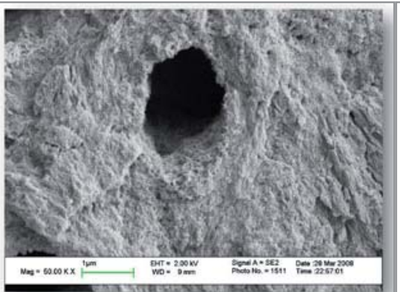

Fig. 7

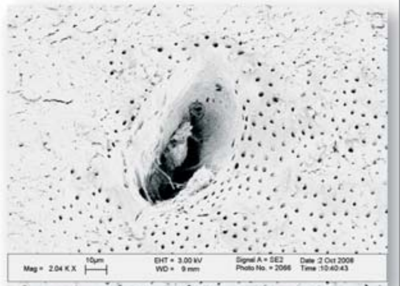

Fig. 8

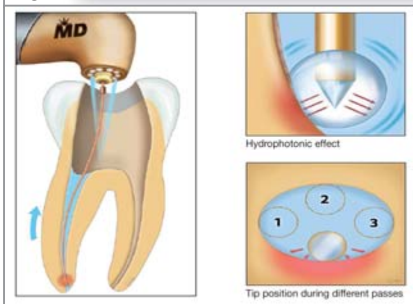

Fig. 9

Fig. 10

Fig. 11

Fig. 12

Fig. 13

Fig. 6_Laser removal of smear layer in apical third of canal (Biolase Technology. Unpublished data).

Fig. 7_Single dentinal tubule after laser ablation (Biolase Technology. Unpublished data).

Fig. 8_Accessory canal after laser ablation (Biolase Technology. Unpublished data).

Fig. 9_Technique for laser tip positioning in canal.

Fig. 10_Upper premolar treated with laser protocol.

Fig. 11_Lower molar treated with laser protocol.

Fig. 12_Lower premolar treated with laser protocol.

Fig. 13_Lower molar treated with laser protocol.

tion. This system eliminates vapor lock and provides superior cleaning, disinfecting and smear layer removal while virtually eliminating the threat of sodium hypochlorite accident (Schoeffel 2008). When compared to positive pressure irrigation with a ProRinse needle, EndoVac produced canals that were 366 % and 671 % cleaner 1 mm and 3 mm respectively from WL (Nielsen & Baumgartner 2007).

When EndoVac was used in combination with LightSpeed LSX instrumentation, canals were 99 % and 99.5 % free of debris 1 mm and 3 mm respectively from WL (Prashanth & Shivanna 2008).

Intracanal laser therapy

The final stage of root canal preparation and disinfection is completed with the Waterlase MD laser (Er,Cr:YSGG) using radial-firing tips (Biolase Technology Inc.).

The laser tips are available in two sizes: RFT2 and RFT3 with diameters of 275 µm and 415 µm respectively (Fig. 3). The RFT2 tip is inserted 1 mm short of WL, requiring canal preparation sizes of ISO 30 or more while the RFT3 tip is inserted to the junction of middle and apical thirds, requiring canal sizes of ISO 45 or more. These sizes fall well within typical working width preparation sizes prepared with LSX files. Intracanal laser therapy is performed in two phases, the Cleaning Phase for smear layer and debris removal and the Disinfection Phase for tissue ablation and bacterial elimination.

Cleaning phase (1.25 W; 50 Hz; 24 % air; 30 % water):

This phase uses water and removes smear layer and debris without using chemical irrigants. It takes 2–3 minutes per canal and uses Hydrophotonics™ to create a powerful micro-agitation effect throughout the canal system.

It is generally accepted that smear layer removal facilitates the cleaning and disinfecting of the dentinal tubules and improves the sealing of the root canal. When merging results of two studies, the Er,Cr:YSGG with radial-firing tips produced significantly better smear layer removal in the apical, middle and coronal thirds than two rotary techniques (Sung et al. 2007, Peters & Barbakow 2000). This extremely efficient action opens the dentinal tubules, lateral canals and isthmuses in preparation for disinfection (Fig. 6, 7 & 8).

Technique for cleaning phase: after completion of access, working width preparation and negative-pressure irrigation:

_Use the RFT2 to perform apical and partial coronal 2/3 cleaning.
_Select the recommended laser settings in the wet mode.
_Fill canal with sterile solution.
_Insert RFT2 tip 1 mm short of working length (WL).
_Activate laser on withdrawal of tip coronally at approximately 1 mm/s. Maintain tip in contact with the side surface of the canal wall during the entire apical to coronal pass.
_Repeat steps 4 and 5 one or two more times to ensure that the entire inner canal has been cleaned (Fig. 9).
_Place the RFT3 tip in handpiece to perform final

cleaning of the coronal 2/3.
_Fill canal with sterile solution.
_Insert the tip to the junction of apical and middle third of the root canal.
_Repeat steps 5 and 6.

Disinfection phase (.75 W; 20 Hz; 10% air; 0% water)

As stated previously, the laser energy emitted from the Er,Cr:YSGG laser is highly absorbed by water in tissue and micro-organisms resulting in instantaneous photo-ablation. In addition, the resulting micro-pulse expansion and collapse of intratubular water produce acoustic waves strong enough to disrupt and kill intratubular bacteria.

This effect is most effective in a dry mode as the laser energy is not absorbed by the water spray and can exert its full effect on the bacteria. This was confirmed by Gordon et al (2007) who achieved a 99.7% kill rate for E. faecalis in the dry mode. Technique for the disinfection phase is the same as the cleaning phase but with different laser settings in the dry mode.

_Clinical applications

While this protocol is recommended for all endodontic treatments (Fig. 10, 11 12 & 13), it is most valuable in the following clinical situations:

_Infected cases with apical, lateral and/or furcal radiolucencies.
_Retreatments with periapical periodontitis.
_Acutely inflamed cases, especially those diagnosed with Cracked Tooth Syndrome.
_Internal and external resorption.
_Persistent infections not responding to conventional endodontic treatment.
_Unexplained, prolonged post-operative discomfort.

_Summary

A root canal cleaning, shaping and disinfection protocol has been described that maximizes the removal of tissue, debris, smear layer and bacteria from root canal systems. Utilizing a combination of working width management with LightSpeed LSX instruments, high volume apical negative pressure irrigation and evacuation with the EndoVac system and intracanal laser therapy with radial-firing tips using the WaterlaseMD laser, the ability to totally eliminate bacteria from infected root canal systems may soon be within our grasp._

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