Photo-acoustic endodontics using PIPS

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_The goal of endodontic treatment is to obtain an effective cleaning and decontamination of the smear layer, including bacteria and all its products, in the root canal system. Clinically, traditional endodontic techniques use mechanical instruments as well as ultrasound and chemical irrigation in an attempt to shape, clean and completely decontaminate the endodontic system. The effectiveness of debriding, cleaning and decontaminating of all the intra-radicular space is, however, limited given the anatomical complexity and the inability of common irrigants to penetrate into the lateral canals and the apical ramifications. The complexity of the root canal system is well known. Numerous lateral canals of various dimensions and with multiple morphologies branch off from the principal canals. A recent study found the presence of these anatomical structures in 75 % of the teeth analyzed as well as the presence of residual infected pulp, after completion of chemo-mechanical preparation, both in the lateral canals and in the apical structures of vital and necrotic teeth associated with periradicular inflammation.[1]

Lasers were initially introduced in endodontics as an attempt to help improve the decontamination of the endodontic system.[2–7] Laser-assisted canal decontamination performed with the near-infrared laser, such as an Nd:YAG or a diode laser, requires the canals to be prepared in the traditional way, and the radiation is performed at the end of the traditional endodontic preparation as a final passage to decontaminate the endodontic system before obturation. An optical fiber of 200–300 micron diameter is placed 1 mm from the apex and retracted with a helical movement moving coronally (for 5–10 seconds according to the different procedures). Gutknecht *et al.* (1996) showed that the Nd:YAG (1,064 nm) laser demonstrated a superior bacterial reduction of 85 % at 1 mm depth[2], while the diode laser (810 nm) achieved only 63 % at 1 mm depth or less.[6] Schoop *et al.* (2004) demonstrated through an experimental model how lasers spread their energy and penetrate into the dentinal wall, showing them to be physically more efficient than traditional chemical irrigant systems in decontaminating the dentinal walls.[7] This marked difference in penetration is due to the low and varying affinity of these wavelengths for hard tissue.

In recent years, the use of laser technology in endodontics has undergone another important evolution. In addition to the now well-researched use of infrared lasers for thermally destroying bacterial cells deep within the dentinal walls, lasers are now also beginning to be used very effectively for debriding, cleaning and decontaminating the root canal system.[8–18] This area represents a new trend of research in laser-assisted endodontics. One of the techniques, known as Photon Initiated Photo-acoustic Streaming (PIPS), presupposes the use of an Erbium laser (Fidelis AT and LightWalker AT, Fotona d.d.) and its interaction with irrigant solutions (EDTA or distilled water).[18] The technique uses a differ-

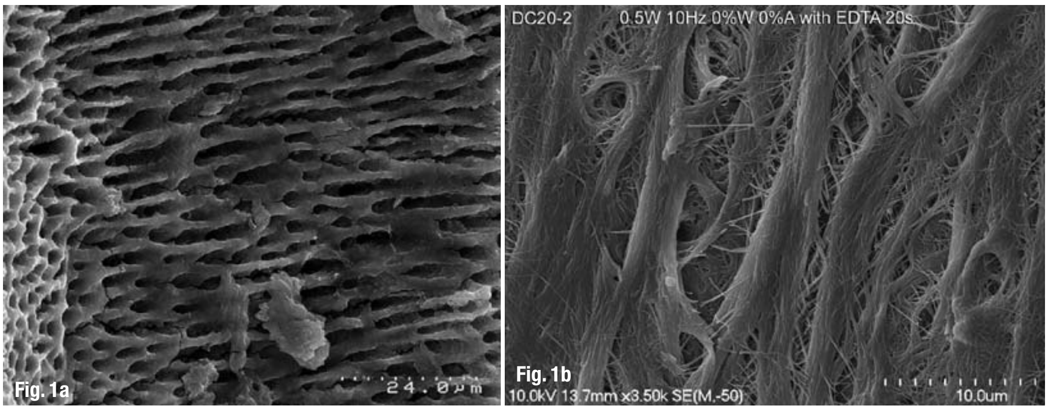

Fig. 1a & b_SEM images of radiated dentin with radial firing tip, at 50 mJ, 10 Hz for 20 and 40 seconds in a canal irrigated with EDTA. The images show a noticeable cleaning of debris and smear layer from the dentin.*

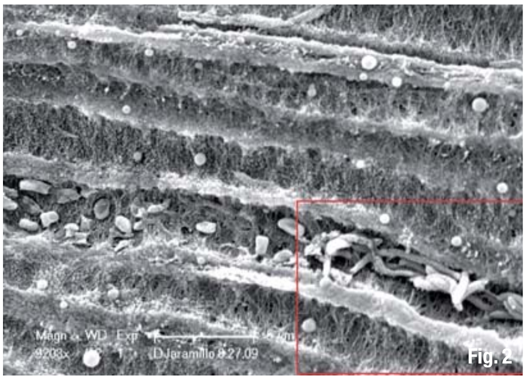
Fig. 2

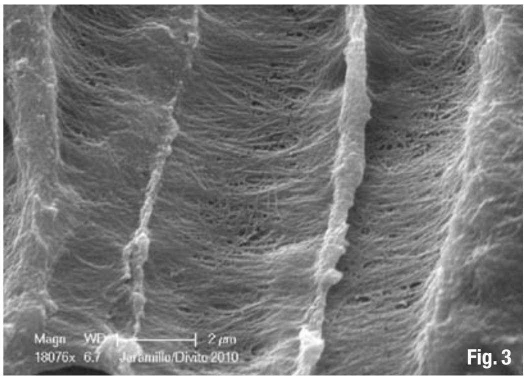

Fig. 3

Fig. 2_SEM image of radicular dentin covered with bacterial biofilm of e.faecalis, before laser radiation.*

Fig. 3_SEM image of radicular dentin covered with bacterial biofilm of e.faecalis, after radiation with Er:YAG laser at 25 mJ,15 Hz, using a PIPS tip with irrigation (EDTA). The procedure results in the destruction and detachment of the bacterial biofilm and its complete vaporization from the principal root canal and from lateral tubules.*

ent mechanism from the preceding laser-assisted irrigation (LAI) methods[10], and is based on the latest special endodontic "radial firing and stripped" fibers tips and laser impulses of a reduced pulse energy and frequency.

Using lower laser energies in the presence of chemical irrigants, the PIPS technique minimizes undesirable thermal effects on the dentinal walls. It exploits the photo-acoustic and photomechanical phenomena which result from the use of subablative energy of 20 mJ at 15 Hz with impulses of only 50 microseconds. With an average power of only 0.3 W, each impulse interacts with the water molecules with a peak power of 400 W, creating expansion and successive "shock waves" leading to the formation of a powerful streaming of fluids inside the canal, without generating the undesirable thermal effects seen with other methodologies. A study with thermocouples applied to the radicular apical third revealed only 1.2 degrees C of thermal rise after 20 seconds and 1.5 degrees C after 40 seconds of continuous radiation.[18] Another considerable advantage is derived from the insertion of the tip in the coronal pulp chamber only, eliminating the problematic insertion of the tip into the canal or at 1 mm from the apex required by the other techniques (LAI and traditional). Tips of a new design consisting of 12 mm in length, of 300–400 microns in diameter, with "radial and stripped" terminals are used. The final 3 mm are without coating to allow a greater lateral emission of energy compared to the frontal tip. This mode of energy emission makes better use of the laser energy when, at subablative levels, delivery with very high peak power for each single pulse of 50 microseconds (400 W) produces powerful "shock waves" in the irrigants leading to a demonstrable and significant mechanical effect on the dentinal wall (Figs. 1a & b).

The studies show the removal of the smear layer to be superior in comparison to the control groups with only EDTA or distilled water. The samples treated with laser and EDTA for 20 and 40 seconds show a complete removal of the smear layer with open dentinal tubules (score 1 according to Hulsmann) and the absence of undesirable thermal phenomena, which is characteristic in dentinal walls treated with traditional laser techniques.

With high magnification, the collagen structure is maintained intact suggesting the hypothesis of a minimally invasive endodontic treatment. The research group of Medical Dental Advanced Technologies Group (MDATG, Scottsdale, Arizona), in affiliation with the Arizona School of Dentistry and Oral Health (Mesa, Arizona), with the University of the Pacific Arthur A. Dugoni School of Dentistry San Francisco, California), with the University of Genoa, and with the University of Loma Linda, School of Dentistry, California, is currently investigating the effects of this technique for root canal decontamination and the removal of bacterial biofilm in the radicular canal. The results, which are soon to be published, are very promising (Figs. 2–3).

In conclusion, current instrumentation techniques using rotary instruments and chemical irrigations still fall short of successfully removing the smear layer from inside the root canal system. The use of the Erbium laser at subablative energy using a radial and stripped tip, in combination with EDTA irrigation, results in significantly more debridement and smear layer removal. From the energy levels used at sub-ablative operating parameters, the SEM investigation of the dentin walls and apical structures revealed no thermal effect or damage. The PIPS photo-acoustic endodontic treatment thus demonstrates a great potential for an improved alternative method for debriding and cleansing the root canal system in a minimally invasive mode.[18]_

Editorial note: A list of references is available from the publisher.

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