

Minimally invasive biomimetic endodontics: the future is here

Mark Malterud, DDS, MAGD

As mentioned in an earlier column, minimally invasive biomimetic dentistry (MIBD) can reach all aspects of dentistry from preventive care all the way to complex implant restoratives.¹ Most dentists never think of endodontics as fitting solidly into the area of MIBD, but with straight-line access being taught with rotary endodontics, crown down techniques, and conventional hand instrumentation of canals, their eyes have been opened to the amount of tooth structure that is necessary to remove in order to achieve the best straight-line access. Considering the complexity of root canal morphology, none of the above-mentioned techniques seemed to resolve how to best clean, disinfect, and, hopefully, sterilize the canals; therefore, many adjunctive techniques were added, along with chemical intervention and solution activation. Reciprocating handpieces and sonic devices were introduced with the idea of saving precious tooth structure, but these methods didn't seem to satisfy the problem with extra canals, anastomoses, multiple apical foramina, and lateral canals. Recent articles have been written in peer-reviewed literature describing a new way to effectively remove canal debris from all of these areas with minimal additional instrumentation, utilizing a stripped radial firing Er:YAG laser tip (Fotona D.D.).²⁻⁵

This new technology, *photon-induced photoacoustic streaming* (PIPS), was presented by its developers, DiVito and Colonna, at the World Congress of Minimally Invasive Dentistry meeting in San Francisco, in August, 2009. PIPS technology creates a turbulent 3-dimensional flow of irrigants in the canals. These extremely short bursts of laser energy are directed down into the canals, and the action pumps the tissue debris out of the canals and cleans, disinfects, and sterilizes each main canal to the apex and out into the lateral canals, dentin tubules, and anastomoses. This movement is achieved without the need to place the stripped radial firing laser tip (PIPS tip) into the canal, as with conventional hand and ultrasonic systems; rather, the PIPS tip stays in the coronal aspect of the access preparation only. This allows the clinician to better debride and decontaminate the root canal system without the need to overshape and enlarge the preparation needed for adequate access to the apical one-third. A canal system prepared this way will allow the use of a hydrophilic resin filler system to obturate all the prepared canals, accessory canals, apical foramina, and anastomoses.

In endodontic therapy, dentists who work on root canals have been working nearly blind in a deep, dark hole that has all kinds of nooks and crannies, using only tactile senses to be effective. Studies on root canal success rates range all over the board, depending on if they are multicentered, single site, or single operator, and the parameters describing success vary greatly with all of these studies.⁶⁻⁹ These success rates might only relate to patient comfort or how the tissues have appeared to heal with

2-dimensional X-rays, and not indicative of the full removal of debris. Three-dimensional viewing, using cone-beam computerized tomography (CBCT), of the endodontically treated teeth, shows more pathology than has been previously believed. Often, accessory canals, lateral canals, and apices have been missed, and, consequently, organisms capable of reinfection are left behind. Hopefully these organisms have been entombed in the treated teeth and will eventually die, but in many cases all that is needed is an opportunity, such as a "dip" in the patient's immune system, or loss of a coronal seal, for reinfection to occur. Recent articles in peer-reviewed journals presented protocols using the PIPS technology that demonstrated how this technology virtually sterilizes the root canal system.^{2-5,10} This new process, along with careful obturation, may cause the success rates exhibited in these studies to climb to even higher levels in future studies.

Since the root forms and canal systems are so varied in size, shape, and patterns, the ability to effectively instrument with conventional systems is nearly impossible. Fig. 1 shows the variation of these canal forms, and the inherent difficulty of trying to reach a file into any one of these lateral canals, the multiple apical openings, and the cross-bridging between the canals. The only way around these canal patterns with conventional root canal treatments (RCTs) is to remove more tooth structure, which thereby weakens the tooth. However, with PIPS technology protocols, the canal systems are cleaned out with the turbulence created by the Er:YAG laser PIPS tip (Fig. 2). Consequently, the canals are left with very bondable surfaces, as shown by scanning electron microscopical (SEM) analysis (Fig. 3 and 4). Fig. 4 not only shows how clean the tooth canal surface is after the PIPS protocols but also offers a view into a lateral canal.



Fig. 1. Intricacies of the canal system on a maxillary molar using a differential stain technique.



Fig. 2. PIPS tip in laser handpiece showing the stripped and radial firing tip.

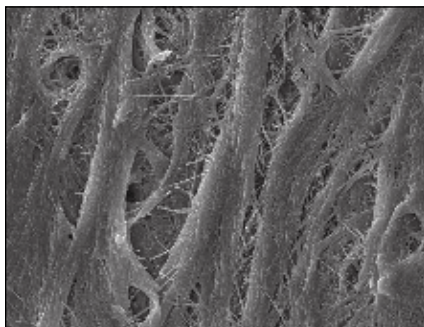


Fig. 3. After laser-activated irrigation using PIPS, an SEM analysis reveals extremely clean collagen fibril networks of bondable surfaces.

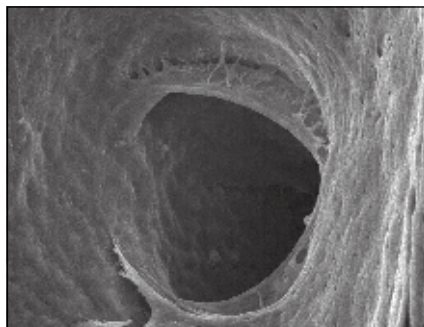


Fig. 4. Well-cleaned lateral canal after laser-activated irrigation using PIPS.

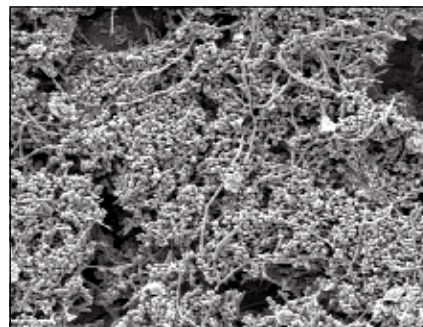


Fig. 5. SEM of surface biofilm infected with *Enterococcus faecalis*.

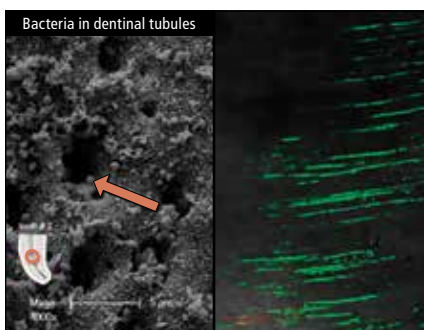


Fig. 6. *Left*: SEM photo showing *E. faecalis* infecting dentinal tubules. *Right*: Confocal image of same sample shown on the left, demonstrating penetration of live (green) *E. faecalis* deep into the dentinal tubules.

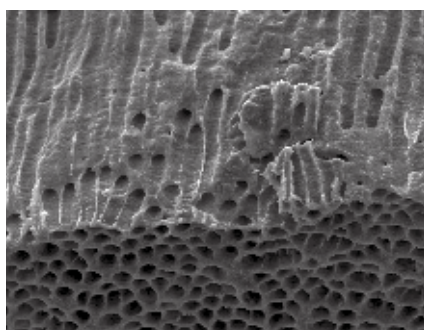


Fig. 7. SEM surface photo of an *E. faecalis*-infected tooth, after laser-activated irrigation using PIPS protocol, showing extremely clean dentinal tubules.



Fig. 8. Clarified root after PIPS and placement of flowable sealer demonstrating the minimally invasive 3-dimensional obturation of the intricate apical morphology.

Confocal microscopical studies have validated the effectiveness of the PIPS technique in killing bacteria deep into the dentin tubules and canal systems.¹⁰ Extracted teeth, with their canals opened to the outside, were stored in a culture medium of *Enterococcus faecalis*, which resulted in severely infected surfaces (Fig. 5). A confocal micrograph of the dentinal tubules shows the deep penetration of bacteria (Fig. 6). After the tooth has been put through the entire PIPS protocol, there is nothing notable left on the canal surfaces (Fig. 7). With virtually no biofilm and bioburden left in the intricate canal systems, the tooth can be filled thoroughly with hydrophilic root canal resin filling materials. The canal surface prepared in this way allows for these free-flowing materials to reach deep into the open dentinal tubules and out into lateral canals and apices, sealing the canal system thoroughly. When a tooth has been treated using the PIPS protocol and subsequently filled with hydrophilic resin filling material, a close-up view through the clarified tooth of the fill of the canal systems shows the ability of these procedures to reach deep into areas that cannot be reached by a file. Fig. 8 shows the apex of one of these teeth and illustrates the ability of the PIPS process to open up and fill canals, apices, and lateral canals that used to be either extremely difficult or very time consuming to fill.

Looking at the overall procedures involved in the use of conventional or rotary endodontics, one of the tenets of success has been the ability to get straight-line access of the canals to keep the flex of the rotary instruments to a minimum. These processes remove a significant amount of coronal structure that leaves the tooth weaker and more prone to fracture.¹¹⁻¹³

Many new irrigation systems and chemical lavage techniques have been brought to market to help remove the materials from these areas that are not addressed with many of the systems. All of these new processes can be incorporated into the simple process of utilizing a modified Er:YAG laser and the PIPS technique.

The actual process of utilizing the PIPS procedure is as follows. First, an anesthetic is delivered to create profound anesthesia to the tooth requiring root canal treatment. The area is carefully isolated with a rubber dam to prevent not only leakage of intraoral fluids into the canal, but also to keep fluids from entering the mouth once they are being activated with the PIPS laser energy. The patient is fitted with laser radiation safety glasses for the prevention of any inadvertent use of the laser and, more importantly, to protect the patient from any splatter of the PIPS-activated solutions.

The tooth is opened to the pulp chamber wide enough to allow access to all the canals with the PIPS tip and also to allow files to be placed to the apex to determine the working length and to locate constrictions. Once the working length is established for all of the canals, the canals can be opened with filing to accommodate a size 20 file at the working length. The PIPS protocol is then initiated to remove debris and sterilize the canals. This procedure is done with low energy levels so that it is virtually subablative. Consequently, the PIPS energy cleans out the canal systems using the acoustic shock and the turbulence created within the canals with these fluids. The first solution to be utilized in the PIPS protocol is sodium hypochlorite (NaOCl). This solution is placed in the pulp chamber and the PIPS tip is activated in the chamber aiming at the canals. High volume suction is utilized to keep the NaOCl and canal debris spatter from reaching areas outside the rubber dam owing to the turbulence of the acoustic shock. Extra NaOCl is syringed into the pulp chamber to replenish the solution that is pulsed out of the access by the PIPS technique. The pulsed energy is utilized for a very specific number of cycles and times using the recommended PIPS protocol.

The NaOCl is evacuated from the canals, the chamber is rinsed with water, and the PIPS tip is activated to remove the leftover NaOCl and canal debris. Once the canal is cleaned out, a chelating agent, EDTA in a fluid form, is placed into the canals and pulp chamber and the PIPS tip is activated again to open up the dentinal tubules to give access to more of the canal anatomy. Once the EDTA has been pulsed, the canal system is rinsed with water and the PIPS tip is activated to remove any remaining EDTA materials so that the tooth can be bonded effectively.

The canal is dried, but not desiccated, with extra-fine paper points, a good quality hydrophilic resin cement root canal filler is placed into the canals, and a gutta-percha point is placed so that the resin can be displaced apically and laterally to help in obturation of the lateral and apical canals as well as the anastomoses within the canal systems.

The PIPS procedure described in this article minimally opens up the coronal aspect of the tooth, then cleans and allows the thorough obturation of the canal system to prevent future issues. This fits well into the MIBD philosophy. MIBD can be included in all areas of dentistry, including endodontics, as shown in this article. The PIPS procedure isn't the only way to endodontically subscribe to the MIBD philosophy, but this process creates a situation in which very little hard tooth structure is removed and the soft tooth structure is selectively removed along with any pathologic materials that are in the canal system. Lasers are becoming more involved daily in our lives and Er:YAG lasers have a wide range of uses beyond the endodontic procedures described within this article. Future MIBD articles will, over time, include information on the use of lasers as a minimally invasive technique in hard- and soft-tissue applications.

Author information

Dr. Malterud is in general practice in St. Paul, Minnesota. He has lectured and published about minimally invasive dentistry for more than 17 years.

Acknowledgments

The author wishes to thank Drs. DiVito and Colonna for their help in collating information and the pictures used in this article.

References

1. Malterud MI. Minimally invasive dentistry—a biomimetic approach. *Gen Dent*. 2012;60(3):186-187.
2. Peters OA, Bardsley S, Fong J, Pandher G, Divito E. Disinfection of root canals with photon-initiated photoacoustic streaming. *J Endo*. 2011;37(7):1008-1012.
3. DiVito E, Peters OA, Olivi G. Effectiveness of the erbium:YAG laser and new design radial and stripped tips in removing the smear layer after root canal instrumentation. *Lasers Med Sci*. 2012;27(2):273-280.
4. DiVito E, Crippa R, Iaria G, Kaitsas V, Benedicenti S, Olivi G. Lasers in endodontics. *Roots*. 2012;1:38-44.
5. DiVito E, Colonna MP, Olivi G. The photoacoustic efficacy of an Er:YAG laser with radial and stripped tips on root canal dentin walls: an SEM evaluation. *J Laser Dent*. 2001;19(1):156-161.
6. Ricucci D, Russo J, Rutberg M, Burleson JA, Spangberg LS. A prospective cohort study of endodontic treatments of 1,369 root canals: results after 5 years. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*. 2011;112(6):825-842.
7. Bernstein SD, Horowitz AJ, Man M, et al; Practitioners Engaged in Applied Research and Learning (PEARL) Network Group. Outcomes of endodontic therapy in general practice: a study by the Practitioners Engaged in Applied Research and Learning Network. *J Am Dent Assoc*. 2012;143(5):478-487.
8. Lazarski MP, Walker WA 3rd, Flores CM, Schindler WG, Hargreaves KM. Epidemiological evaluation of the outcomes of nonsurgical root canal treatment in a large cohort of insured dental patients. *J Endod*. 2001;27(12):791-796.
9. Ng YL, Mann V, Rahbaran S, Lewsey J, Gulabivala K. Outcome of primary root canal treatment: systematic review of the literature – part 1. Effects of study characteristics on probability of success. *Int Endod J*. 2007;40(12):921-939.
10. Jaramillo DE, Aprecio RM, Angelov N, DiVito E, McClammy TV. Efficacy of photon induced photoacoustic streaming (PIPS) on root canals infected with *Enterococcus faecalis*: a pilot study. *Endod Pract*. Available at: <http://www.endopracticeus.com/web/continuing-education/ce-articles/334-efficacy-of-photon-induced-photoacoustic-streaming-pips-on-root-canals-infected-with-enterococcus-faecalis-a-pilot-study.html>. Accessed Nov. 12, 2012.
11. Topcuoglu HS, Arslan H, Keles A, Koseoglu M. Fracture resistance of roots filled with three different obturation techniques. *Med Oral Patol Oral Cir Bucal*. 2012;17(3):e528-e532. Available at: <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3476110/>. Accessed November 12, 2012.
12. Wu MK, Shemesh H, Wesselink PR. Limitations of previously published systematic reviews evaluating the outcome of endodontic treatment. *Int Endod J*. 2009;42(8):656-666.
13. Taha NA, Palamara JE, Messer HH. Fracture strength and fracture patterns of root filled teeth restored with direct resin restorations. *J Dent*. 2011;39(8):527-535.

Manufacturer

Fotona D.D., Slovenia
386.1.500.91.00, www.fotona.com