From everyday dentistry to advanced photoacoustic endodontic applications (PIPS): Er:YAG & Nd:YAG dual wavelength laser

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Lasers provide an exciting new technology that allows the dentist the ability to give patients optimal care without many of the “four factors” found in conventional den-
tal techniques. Used with proper understanding of laser physics, lasers are extremely safe and ef-
fective.

Using lasers for caries removal, perioperative treatment, endodontic treat-
ment, bone management, cutting and shaping, and soft-tissue pro-
cedures can reduce postoperative discomfort and infection, and pro-
vide safe, simple in-office treat-
ment. As a result, we can improve 
efficiency, expand what we can do, achieve better results and increase production.

Lasers represent a real quantum leap forward in the treatment of our patients, including the pedi-
atric patient. The U.S. Food and Drug Administration (FDA) gave approval for the use of the Er:
YAG laser in 1997 for both hard-
and soft-tissue procedures. The erbium:yttrium-aluminum-
garnet (Er:YAG) development
and success have made the treatment of children safer and quicker.

Plainly stated, a laser is a piece of equipment that creates a concen-
trated monochromatic beam of visible or infrared light that can be absorbed by a specific target.
Since then, laser-assisted dental care has changed forever the way dentists can prepare diseased teeth, ablate bone and treat soft-
tissue abnormalities and disease.

An entire new standard of care is being introduced with lasers.
Lasers and pediatric dentistry are a perfect fit. There are a wide range of hard and soft dental pro-
cedures that may be completed using lasers as an alternative to conventional dental care on adults and, especially, children.
Many of these procedures may be treatments dentists histori-

cally refer out to other specialists; however, if you understand and 
understand your laser, it will easily pay premiums on your investment, and the cost factor becomes a non-issue.

The purchasing of lasers is an in-
vestment, not an expense, for any dental practice.

Lasers represent a fundamental change in the entire way den-
tistry has been taught. We can now rethink and often modify G.V.
Black’s principle of prevention for the concept of minimally invasive den-
tistry. We need to understand that laser dentistry is one portion of an entire new way of practicing conservative, pain-free dentistry.

The laser that we call the “all-

purpose” laser is the Lightwalker Er:YAG &Nd:YAG laser, manufac-
tured by Fotona and distributed in the United States by Technology-
Medicine. The Er:YAG produces its effect at 2940 nm and has as its primary target water and hydroxyapatite. It is very safe, relatively quiet, eliminates the smells and vibrations associated with the dental handpiece and, most importantly, is much more comfortable for the patient, signi-
ificantly reducing the need for local anesthesia.

The use of the new generation erbium lasers for repair of in-
cipient hard tissue disease allows the dentist to provide a stress-
free means of restoring teeth in a minimally invasive manner, most often with no shot and no numb-
ling, without the need for any local anesthetics.

The erbium laser can be used for restoring primary and permanent teeth, eliminating or reducing the amount of local anesthetics. In most cases, the patient will not require numbing for Class 1, 2 (sometimes), 3, 4, 5, 6 restorative procedures using bonded restor-
ative materials. Using the concept of minimally invasive restorative procedures, the Er:YAG laser allows the operator to remove only diseased tissue and thus pre-
serves much more of the healthy, unaffected tooth.

In cases where alloy is preferred, the laser’s analysis effect may also allow the dentist to create a restorative preparation using a conventional handpiece that is not meant for bonding. The er-
bium laser is effective because of its effect on its target, water within the tooth structure. This effect occurs when the laser heats up water within the target tissue, causing it to create small micro-
scopic explosions (photothermal followed by photoacoustic ef-
fected). When applied to soft tissue, bone or teeth and cavities, the explosions then cause the areas to be vaporized.

Er:YAG Laser 2940 nm: Soft-
tissue procedures

There is a wide array of soft-tissue procedures that may be completed using the all-purpose laser: max-
ilary and mandibular frenum re-
visions, lingual frenum revisions, treatment of pericoronary or pericoronal pain or infection, removal of hyperplastic tissue because of drugs or poor oral care in orthodontic patients, biopsies, treatment of aphthous ulcers and herpes labialis, pulpotomies, removal of impacted teeth and, in adults, apicectomies and bone contouring.

Pulpotomies

Parents often express concern about the need to take radi-
ographs because of the nature of X-

rays and their possible side effects on a child’s overall health. They question the use of alloys because of the chemical makeup of the alloy. Whether these should be a real concern in today’s dental care is open to debate, depending on your individual beliefs. There are also concerns by many, although not as loudly, about the effect of various pulpotomy procedure medications used in pulpotomy procedures, such as formocresol.

Lasers provide a safe, non-chemi-
cal, effective and alternative treat-
ment for pulpotomies. During the span of eight years, post-treat-
ment results on more than 4,000 pulpotomies using the erbium (2940 nm) laser provide ample evidence that this method is both effective and safe for children without the need for introducing chemicals or using electrosur-
gery methods.

When the final result of orthodon-
tic positioning of the front teeth results in gingival hypertrophy, the laser can be a useful tool to in-
crease crown length and give the patient a more esthetic smile. This may be accomplished with-
out the need for local anesthesia. Patients who have medically in-
duced hyperplastic tissue, such as patients requiring dilantin, can also have their tissue reduced and reshaped with the erbium.

In addition to the many examples described in this article, lasers can be used for additional procedures not usually required in pediatric dentistry, such as revisions of the abnormal mandibular frenum, often avoiding the need for soft-
tissue grafts, crown-lengthening procedures where bone requires recontracting, apicectomies, removal of laryn exostoses, re-
moval of third molar impactions, removal of root remnants, incis-
ing and draining soft-tissue in-
factions, advanced periodontal treatments and the latest in ad-
vanced endodontic treatment via photoinduced photoacoustic streaming.

Photoacoustic endodontics us-
ing PIPS

The goal of endodontic treat-
ment is to obtain effective clean-
ing and decontamination of the smear layer, bacteria and their byproducts in the root canal sys-
tem. Clinically, traditional end-
odontic techniques use mechani-
cal instruments, as well as ultra-
sonic and chemical irrigation, in an attempt to shape, clean and completely decontaminate the endodontic system but still fall short of successfully removing all of the infective microorganisms and debris. This is because of the complex root canal anatomy and the inability for common irrigants to penetrate into the lateral canals and the apical ramifications. It seems, therefore, appropriate to search for new materials, tech-
niques and technologies that can improve the cleaning and the de-
contamination of these anatomical areas.

Among the new technologies, the laser has been studied in endo-
dodontics since the early 1970s13 and has become more widely used since the ‘90s.14

Different wavelengths have been shown to be effective in signifi-
cantly reducing the bacteria in the infected canals, and impor-
tant studies have confirmed these results in vitro.12 Studies reported that near infrared laser are highly efficient in disinfecting the root canal surfaces and the dentinal walls (up to 75 micron for the di-
ode 810 nm and up 4 mm for the Nd:YAG 1064 nm). On the other hand, these wavelengths did not show effective results in debrid-
ing and cleaning the root canal surfaces and caused characteris-
tic morphological alterations of the dentinal wall. The smearslayer was only partially removed and the dentinal tubules primarily closed as a result of melting of the inorganic dentinal structures.15

Other studies reported the ability of the medium infrared laser in debriding and cleaning root canal walls.15,16 The bacterial load reduction after erbium laser ira-
diation demonstrated high on the dentin surfaces but low in depth of penetration because of the high absorption of laser energy on the dentin surface.11 Also the laser activation of commonly used ir-
frared (Nd:YAG) resulted in significant and generally more effective removal of debris and smear layer in root canals compared with traditional techniques (U) and ultrasonic (PU).17,18,19 Additionally, the laser activation method resulted in a strong modulation in reaction rate.
of NaOCl significantly increasing production and consumption of available chlorine in comparison to ultrasonic activation.\(^{13}\)

A recent study has reported how the use of an Er:YAG laser, equipped with a newly designed radial and stripped tip, in combination with 17 percent EDTA solution, results in very low pulpal temperature (50 microseconds) and low energy (20 mJ) resulted in effective debris and smear layer removal with minimal or no thermal damage to the organic dental structure through a photoacoustic technique called photon-induced photoacoustic streaming or “PIPS.”\(^{14,15}\) Also the same photoacoustic protocol in combination with 5.25 percent sodium hypochlorite (NaOCl) has been investigated and shown to reduce the bacterial load and its associated biofilm in the root canal system three dimensionally.\(^{9}\)

Other similar studies are in progress for publication and the results are promising and suggest a three-dimensional positive effect of this laseractivated decontamination (LAD) method. The purpose of this article is to present briefly the experimental background of this laser technique and to introduce the clinical protocol.

**Scientific background**

The microphotographic recording of the laser tip and the root canal surfaces irrigated with the irrigant solutions of the instrument, suggested that the erbium lasers used in irrigant-filled root canals generate a streaming of fluids at high speed through a cavitation effect.\(^{3}\) The laser thermal effect generates the expansion implosion of the water molecules of the irrigant solution, generating a secondary cavitation effect on the intracanal fluids. To accomplish this streaming, it is suggested the fiber be placed in the middle-third of the canal, 5 mm from the apex and stationery.\(^{16}\) This concept greatly simplifies the laser technique, without the need to reach the apex to negotiate radicular curves.

Also, the recorded video of the new technique, PIPS, showed a strong agitation of the liquids inside the canals. It differs from the already cited LAI technique by activating the irrigant solutions in a single shot with a very low energy (20 mJ at 15 Hz, 0.5 W average power, or less) generating only a minimal thermal effect. The study with thermocouples applied to the apical canal third revealed only 1.2 degrees C of thermal rise after 20 seconds and 1.5 degrees C after 40 seconds of continuous radiation.\(^{17}\)

When the erbium laser energy is delivered at only 50 micosecond pulse duration through a special designed tapered and stripped 400 microns tip (Fotonla Light Walker, Technology 4Medicine), it produces a large peak power of 400 watts when compared to a longer pulse duration. Each impulse, absorbed by the water molecules, creates a streaming wave\(^{18}\) that leads to the formation of an effective streaming of fluids inside the canal while also limiting the undesirable thermal effects seen with other methodologies.

The placement of the tip in the coronal portion only of the treated tooth allows for a more minimally enlarged canal preparation with less thermal damage as seen with those techniques placed into the canal system.

The root canal surfaces irrigated with 17 percent EDTA and laser activated for 20 seconds showed exposed collagen matrix, opened tubules and the absence of smear layer and debris (Figs. 1-3). The results are in line with that previously published by Macedo,\(^{19}\) improving the disinfecting action of the sodium hypochlorite.\(^{20}\) The disinfecting action of PIPS is effective both on the root surface, the lateral canals and the dentinal tubules, as confirmed with SEM and confocal studies (Fig. 4).

The profound and distant effect of PIPS eliminates the need to introduce the tip into the root canal system. Unlike traditional laser techniques requiring placement of the tip 1 mm from the apex, or even 5 mm from the apex as proposed for LAI,\(^{14}\) the PIPS tip is placed in the coronal portion of the pulpal chamber only and left stationary, allowing the photoacoustic effect to spread into the opening of each canal. A new tip design consisting of a 400-micron diameter, 12 mm long, tapered end is used for this technique (Fig. 5). The final 5 mm of coating is stripped from the end to allow for greater lateral emission of energy compared to the frontal tip. This mode of energy emission allows for improved lateral diffusion with low energy and enhanced photoacoustic effect.

**Discussion**

Laser irradiation is a common technique used in endodontics to improve the cleaning, the debridging and disinfection of the root canal system. Many wave-lengths and protocols are used. Near infrared lasers are used for the three-dimensional decontamination of the endodontic system. Nd:YAG and diode lasers use thermal energy to destroy bacteria. Observations reveal a certain grade of thermal injury to the root canal surface and create a typical morphological damage. Moreover, they are not able to thoroughly remove the smear layer.

On the contrary, erbium lasers are used for their effective smear layer removal while their bactericidal activity is limited to the root surface. The placing of the tip close to the apex and its back movement during the activation process is related to the risk of apical perforation, leading and surface thermal damage, because of the ablation ability of this wavelength. Also a combination of near and medium infrared lasers has been proposed. A technique, called twinned endodontic treatm (TET), uses the erbium laser energy first, to clean the root canal surface and remove the smear layer, and the Neodimium:YAG laser second, used in dry mode as the final disinfecting step. All these techniques utilize traditional tips and fibers placed into the canal, close to the apex (1 mm) with all the corresponding thermal disadvantages observed in long, narrow and curve canals. The erbium lasers are also used as a medium of activation of commonly used irrigants (LAI), avoiding the risk of thermal damage, while increasing the cleaning and disinfecting activity of the fluids. PIPS, in particular, reduces all these risks and disadvantages, thanks to the positioning of the tip in the coronal orifice only and to the use of minimally ablative energy levels of 20 mJ or less.

The findings of our studies demonstrated that PIPS technique resulted in a safe and effective debridging and decontaminating of the root canal system. Our clinical trials showed that PIPS technique greatly simplifies root canal therapy while facilitating the search for the apical terminus, debridging and maintaining patency.

As a result of the efficacy of PIPS, the final size required for canal shaping can be significantly reduced, offered to a size 25/04, allowing for a more minimally invasive and biologically more favorable treatment that can then be obturated three dimensionally.

**Conclusion**

Lasers are an extremely versatile addition to the dental practice and can be used in many instances instead of the conventional methods employed by the vast majority of dentists. Incorporating a laser in the dental practice should be viewed as an investment rather than a cost. When used with a good knowledge of laser physics, training and safety, lasers provide our patients a new standard of dental care.

**References**


**Full list of references is available from the publisher.**

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**About the Author**

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