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

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Introduction
Lasers provide an exciting new technology that allows the dentist the ability to give patients optimal care without many of the ‘fear factors’ found in conventional dental techniques. Used with proper understanding of laser physics, lasers are extremely safe and effective. Using lasers for caries removal, periodontal treatment, endodontic treatment, bone management, cutting and shaping, and soft-tissue procedures can reduce postoperative discomfort and infection, and provide safe, simple in-office procedures. As a result, we can improve our efficiency, expand what we can do, achieve better results and increase productivity.

Lasers represent a real quantum leap forward in the treatment of our patients, including the pediatric 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 doped (erbium particles placed within the YAG crystal) Yttrium-Aluminum-Garnet’s (Er:YAG) development and success has made the treatment of children safer and quicker.

Plainly stated, a laser is a piece of equipment that creates a concentrated 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 diseases and disease. An entire new standard of care is becoming a reality.

Lasers and pediatric dentistry are a perfect fit. There are a wide range of hard and soft dental procedures that may be suitable for children. Lasers can serve as an alternative to conventional dental care on adults and, especially, children. Many of these procedures may be treatments dentists historically refer out to other specialists; however, if you understand and use your laser efficiently, you will discover that many of these are procedures that every dentist can easily complete.

The question that is often the major concern and barrier to beginning lasers in dentistry is how this investment will pay for itself, more recently described as return on investment (ROI). You pay for it itself. We prefer to speak of this as the secondary effect. If you can produce or earn within your investment, and the cost factor becomes a non-issue.

The purchasing of lasers is an investment, not an expense, for any dental practice.

Lasers represent a fundamental change in the entire way dentistry has been taught. We can now rethink and often restyle G.V. Black’s principle of extension for prevention with the concept of minimally invasive microns-dentistry. 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; manufactured by Fotona and distributed in the United States by Technology4Medicine. The Er:YAG produces its effect at 2940 nm and has as its primary tissue target water and hydargyration. It is very safe, relatively, eliminates the smells and vibrations associated with the dental handpiece and, most importantly, is much more comfortable for the patient, significantly reducing the need for local anesthesia.

The use of the new generation erbium lasers for repair of incipient 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 lip, 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 I, 2 (sometimes), 5, 4, 5, 6 restorative procedures using bonded restorative materials.

Using the concept of minimally invasive restorative procedures, the Er:YAG laser allows the operator to remove only diseased tissue and thus preserves much more of the healthy, unaffected tooth.

In cases where alloy is preferred, the laser’s amalgasia effect may also allow the dentist to create a restorative preparation in any area. The laser beam piece that is not meant for bonding. The erbium laser is effective because of its effect on its target, water within the tooth structure.

This effect occurs when the laser beam, directed within the target tissue, causes it to create small microscopic explosions (photothermal followed by photoacoustic effects). 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 can be completed using the all-purpose laser: maxillary and mandibular frenum removal, lingual frenum revisions, treatment of periodontal pain or infection, removal of hyperplastic tissue because of drugs or oral care in orthodontic patients, biopsies, treatment of aphthous ulcers and herpetic kahlipsis, pulpotomies, removal of impacted teeth and, in adults, apicectomies and bone recontouring.

Pulpotomies
Parents often express concern about the need to take radio- graphs because of the nature of X-rays and their possible side ef- fects on a child’s overall health. They question the use of al- loys 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 in- dividual beliefs. There are also concerns by many, although not as loudly, about the effect of various pulpotomy procedure me- dicaments used in pulpotomy procedures, such as formocresol.

Lasers provide a safe, non-chemical, effective and alterna- tive treatment for pulpotomies. During the span of eight years, post-treatment results on more than 4,000 pulpotomies using the erbium laser have pro- vide ample evidence that this method is both effective and safe for children who are needed for introducing chemicals or using electrolysis methods.

When the final result of ortho- dontic positioning of the front teeth results in gingival hyper- trophy, the laser can be a useful tool to increase crown length and give the patient a more esthetic smile. This may often be accomplished without the need for local anesthesia. Patients who have medically induced hyperplastic tissue, such as pa- tients requiring dilantin, can also have their tissue reduced and reshaped with the erbium.

In addition to the many exam- ples described in this article, lasers can be used for additional procedures not usually required in pediatric dentistry, such as revisions of the abnormal man- dibular frenum, often avoiding the need for soft-tissue grafts, crown-lengthening procedures where bone needs recontouring, apicectomies, removal of foreign exostoses, removal of third molar impactions, removal of root remnants, incising and draining soft-tissue infections, advanced periodontal treat- ments and the latest in advanced endodontic treatment via photo- inducible photoacoustic stream.

Photoacoustic endodontics using PIPS
The goal of endodontic treat- ment is to obtain effective clean- ing and decontamination of the smear layer, bacteria and their biofilms in the root canal system. Clinically, traditional endodontic techniques use me- chanical instruments, as well as ultrasonic and chemical ir- rigation, in an attempt to shape, clean and completely deco- ntain the endodontic system but still fail short of successfully removing all of the infective mi- croorganisms and debris. This is because of the complex root ca- nals anatomy and the inability for common irrigants to penetrate into the lateral canals and the apical ramifications. It seems necessary, appropriate search for new materials, techniques and technologies that can im- prove the cleaning and the de- contamination of these anatomical areas.

Among the new technologies, the laser has been studied in en- dodontics since the early 1970s1 and has become more widely used since the 1990s.2,3 Different wavelengths have been shown to be effective in significantly reducing the bac- teria in the infected canals, and important studies have con- firmed these results in vitro.4 Studies reported that near ir- fared lasers are highly efficient in disinfecting the root canal surfaces and the dentinal walls (up to 750 microns for the diode 810 nm and up to 1 nm 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 character- istic morphological alterations of the dentinal wall. The smear layer was only partially removed and the dentinal tubules primar- ily closed as a result of melting of the inorganic dentinal struc- tures.5,6 Other studies reported the ability of the mid-infrared laser in debridging and cleaning root canal walls.7,8 The bacterial load reduction after erbium laser ir- radiation demonstrated high on the dentin surfaces but low in depth of penetration because of the high absorption of laser ener- gy on the dentin surface.9 Also the laser activation of commonly

Figs. 1, 2. Representative sample images of root canal dentinal walls irritated with 17 percent EDTA and PIPs for 20 seconds. (Photos/Processed by Technology4Medicine)
used irrigants (LAI) resulted in statistically more effective removal of debris and smear layer in root canals compared with traditional techniques (CI) and ultrasonic (US). Additionally, the laser activation method resulted in a strong modulation in reaction rate of NaOCl, significantly increasing production and consumption of available chloride in comparison to ultrasonic activation.11

A recent study has reported how the use of an Er:YAG laser, equipped with a newly designed nanosecond pulse tipped in combination with 17 percent EDTA solution, using very low pulse duration (30 or 60 ms) and low energy (20 mJ) resulted in effective debris and smear layer removal with minimal or no thermal damage to the organic dentinal structure through a photomechanical technique called photon induced photoacoustic streaming or “PIPS.”1,12,13 Also the laser-irrigation protocol in combination with 5.25 percent sodium hypochlorite solution has been investigated and shown to reduce the bacterial load and its associated biofilm in root canal system three dimensionally.14

Other similar studies are in progress for publication and the results are promising and suggest a potential therapeutic effect of this laser activated decon- tamination (LAD) method.

The purpose of this article is to present briefly the experimental background of this laser technique and introduce the clinical protocol.

Scientific background

The microphotographic recording of the LAI studies suggested that the erbium lasers used in irrigant-filled root canals generate a streaming of fluids at high speeds with a minimal thermal effect.15 The laser thermal effect generates the expansion implosive wave which contains the molecules of the irrigant solution, generating a secondary cavitation effect on the root surface. To accomplish this streaming, it is suggested the fiber be placed in the middle third of the canal 5 mm from the apex and stationary.16 This concept greatly simplifies the use of the laser since it is not needed to reach the apex and to negotiate radicular curves.

Also, the recorded video of the new technique, PIPS, showed a spreading and a covering effect inside the canals. It differs from the already cited LAI technique by activating the irrigant solutions in the endodontic system through a profound photoacoustic and photomechanical phenomena. The use of low energy (50 microsecond pulse, 20 mJ at 15 Hz, 0.5 mm, 30 ms duration, however, less) generates only a minimal thermal effect. The study with thermocouples applied to the radicular apical third revealed only 1.2 degrees C of thermal rise in intracanal fluids and 1.5 degrees C after 40 seconds of continuous radiation.17

When the erbium laser energy is delivered at only 50 microsecond pulse duration through a specially designed tapered and stripped 400 microns tip (Futura LightWasher, Technology Medicine), it produces a large peak power of 400 watts when compared to a longer pulse du- ration. Each impulse, absorbed by the water molecules, creates a strong “shock wave” that leads to the formation of an effective streaming of fluids inside the canal while also inducing micrometric or nanometric thermal effects seen with other methodologies. The placement of the tip in the coronal portion of the treated tooth allows for a more minimally en- larged canal preparation with less thermal damage as seen with those techniques placed into the canal system. The root canal systems irritated with 17 percent EDTA and PIPS for 20 seconds showed exposed collagen matrix, stripped tubules and the absence of smear layer and debris (Figs. 1-3). The rinsing with 5.25 percent sodium hypochlorite and laser irradiation for 20 seconds produced a strong activation of the solution, as reported by Mac- crow, improving the disinfecting action of the sodium hypochlorite.8 The disinfecting action of PIPS is very effective both on the root surface, the lateral canals and the dentinal tubules, as con- firmed 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 canal apex, or even 5 mm to 1 cm from the apex as proposed for LAI,18 the PIPS tip is placed in the coronal portion of the pulp chamber only and left stationary, allowing the photoacoustic effect to spread into the openings of each canal. A new tip design consists of a 400-µmair-micron, 12 mm long, tapered end is used for this technique (Fig. 5). The final 5 mm of coating is stripped off to allow for greater lateral energy of emission com- pared to the frontal tip. This mode of energy emission allows for improved lateral diffu- sion with low energy and en- hanced photoacoustic effect.

Discussion

Laser irradiation is a common technique used in endodontics to improve the cleaning, the de- bridging and disinfection of the root canal system. Many wave- lengths and protocols are used. Near infrared lasers are used for the three-dimensional decon- formity of the endodonic sys- tem, Nd:YAG and carbon dioxide thermal energy to destroy bacte- ria. Often, to clean reveal a certain grade of thermal injury in the canal surface and create a typical histological profile of damage. More- over, they are not able to thor- oughly remove the smear layer.

On the contrary, erbium la- sers are used for effective smear layer removal while their bactericidal activity is limited to the root surface. The placement 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 the near and me- dium infrared lasers has been proposed to improve the treatment.19-21 A strong “shock wave” that leads to the formation of an effective streaming of fluids inside the canal while also inducing micrometric or nanometric thermal effects seen with other methodologies. The placement of the tip in the coronal portion of the treated tooth allows for a more minimally en- larged canal preparation with less thermal damage as seen with those techniques placed into the canal system. The root canal systems irritated with 17 percent EDTA and PIPS for 20 seconds showed exposed collagen matrix, stripped tubules and the absence of smear layer and debris (Figs. 1-3). The rinsing with 5.25 percent sodium hypochlorite and laser irradiation for 20 seconds produced a strong activation of the solution, as reported by Mac- crow, improving the disinfecting action of the sodium hypochlorite.8 The disinfecting action of PIPS is very effective both on the root surface, the lateral canals and the dentinal tubules, as con- 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 canal apex, or even 5 mm to 1 cm from the apex as proposed for LAI,18 the PIPS tip is placed in the coronal portion of the pulp chamber only and left stationary, allowing the photoacoustic effect to spread into the openings of each canal. A new tip design consists of a 400-µmair-micron, 12 mm long, tapered end is used for this technique (Fig. 5). The final 5 mm of coating is stripped off to allow for greater lateral energy of emission com- pared to the frontal tip. This mode of energy emission allows for improved lateral diffu- sion with low energy and en- hanced photoacoustic effect.

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