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 dental techniques. Used with proper understanding of laser physics, lasers are extremely safe and effective.

Using lasers for caries removal, perioperative treatment, endodontic treatment, bone management, cutting and shaping, and soft tissue procedures can reduce postoperative discomfort and infection, and provide safe, simple in-office treatment. As a result, we can improve our 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 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 element is found in natural particles (placed within the YAG crystal) of Yttrium-Aluminum-Garnet’s (Er:YAG) development and success and 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 abnormalities and diseases. An entire new standard of care has been established.

Lasers and pediatric dentistry are a perfect fit. There are a wide range of hard and soft dental procedures that may be completed using lasers as an alternative to conventional dental care on adults and, especially, children.

Many root canal procedures may be treatments dentists historically refer to other specialists; however, if you understand and use your laser efficiently, you will discover that many of these procedures that every dentist can easily complete.

The question that is often the major concern and barrier to including lasers in the how this information is presented for you recently described as return on investment (ROI). Will it pay for itself? We prefer to speak of this as the secondary effect. If you 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 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 modify G.V. Black’s principle of extension for prevention with the concept of minimally invasive 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 Technology 4Medicine. The Er:YAG produces its effect at 2940 nm and has as its primary tissue target water and hydroxyapatite. It is very safe, relatively quiet, eliminates the smell and irritation present 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 inoperable 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 contaminated and decayed teeth, eliminating or reducing the amount of local anesthetics. In most cases, the patient will not require numbing for Class I, 2 (sometimes), 4, 5, 4, 5 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 analysis effect may also allow the dentist to create a restorative preparation using a conventional handpiece 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 heats up water within the target tissue, creating it to cause 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 & Nd:YAG 2900 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 revisions, lingual frenectomy procedures with the dental handpiece and, most importantly, is much more comfortable for the patient, significantly reducing the need for local anesthesia.

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, apicoectomies, removal of bony exostoses, removal of third molar impactions, removal of remnant roots, incising and draining soft-tissue infections, advanced periodontal treatments and the latest in advanced endodontic treatment via photoinduced photoacoustic streaming.

Photoacoustic endodontics using PIPS

The goal of endodontic treatment is to obtain effective cleaning and decontamination of the smear layer, bacteria and their byproducts in the root canal system. Clinically, traditional endodontic techniques use mechanical instruments, as well as ultrasonic 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, technologies and techniques that can improve the cleaning and the decontamination of these anatomical areas.

Among the new technologies, the laser has been studied in endodontics since the early 1970s and has become more widely used since the 1990s.

Different wavelengths have been shown to be effective in significantly reducing the bacteria in the infected canals, and important studies have confirmed these results in vitro. Other studies reported that near infrared laser are highly efficient in disinfecting the root canal surfaces and the dental walls (up to 75% for the diode 980nm and up to 4% for the Nd:YAG 1064 nm). On the other hand, these wavelengths did not show effective results in debridging and cleaning the root canal walls and caused characteristic morphologic alterations of the dentinal wall. The smearlayer was only partially removed and the dentinal tubules primarily closed as a result of melting of the inorganic dentinal structures.

Other studies reported the ability of the medium infrared laser in debriding and cleaning root canal walls. The bacterial load reduction after erbium laser irradiation demonstrated high on the dentin surfaces but low in depth of penetration because of the high absorption of laser energy on the dentin surface. Also the laser activation of commonly used tr (Er:YAG) resulted in statistically more effective removal of debris and smear layer in root canals compared with traditional techniques (U) and ultrasound (PU). Additionally, the laser activation method resulted in a strong modulation of the reaction rate.
of NaOCl significantly increasing production and consumption of available chlorine in comparison to ultrasound activation.\(^9\)

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, using very low pulse duration (50 microseconds) 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 photonic-activated cavitation effect called photon induced acoustic streaming or “PIPS.”\(^{10,11}\) Also the same photonic-acoustic 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 the root canal system three dimensionally.\(^8\)

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 LAD technique suggested that the erbium lasers used in irrigant-filled root canals generate a streaming of fluids at high speed through a cavitation effect.\(^1\) 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 stationary.\(^2\) This concept greatly simplifies the laser technique, without the need to reach the apex and the need to coordinate radiiucal 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 LAD technique by activating the irrigant solutions in a totally different way. A profound photonic and acoustic streaming and photomechanical phenomena. The use of low energy (50 microsecond pulse, 20 mJ at 15 Hz, 0.5 W average power, or 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 after 20 seconds and 1.5 degrees C after 40 seconds of continuous radiation.\(^3\)

When the erbium laser energy is delivered at only 50 microsecond pulse durations through a special designed tapered and stripped 400 microns tip (Fotona Light Walker, Technology4Medicine), it produces a large peak power of 400 watts when compared to a longer pulse duration. Each impulse, absorbed by the water molecules, creates cavitations giving rise to an acoustic effect to spread into the tissue.\(^4\) 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.\(^5\)

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 ranging with 5.25 percent sodium hypochlorite and laser irradiation for 20 seconds produced a strong activation of the solution, as reported by Macedo,\(^6\) improving the disinfection action of the sodium hypochlorite.\(^6\) The disinfecting action of PIPS is very 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 seed 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 LAD\(^7\), the PIPS tip is placed directly in the coronal portion of the pulpal channel only and left stationary, allowing the photonic-acoustic effect to spread into the endodontic system. 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 expansion of energy compared to the frontal tip. This mode of energy expansion allows for improved lateral diffusion with low energy and enhanced photonic-acoustic 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 wave-length. Also a combination of the near and medium infrared lasers has been proposed. A technique, called twinline endodontic treatment (TET), uses the erbium-lasers first to cleanse 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 position 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 demonstrate 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 meaningful treatments 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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