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# Versatility of an 810 nm Diode Laser in Dentistry: An Overview

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## Abstract:

The breakthrough for dental laser systems came in the mid 1990's. Among the various laser types with corresponding wavelengths, diode laser systems quickly began establishing themselves as compact, competitively priced and versatile additions to the dentist's repertoire, predominantly for performing soft tissue applications. Research has shown that near infrared (NIR) wavelengths are ideally suited for numerous soft tissue procedures due to their high absorption in hemoglobin. This fact gives NIR laser the ability to precisely and efficiently cut, coagulate, ablate or vaporize the target tissue. The added advantage of laser performed surgical procedures is the sealing of small blood and lymphatic vessels, resulting in hemostasis and reduced post-operative edema, disinfection of target tissue due to local heating and production of eschar layer and decreased amount of scarring due to decreased post-operative tissue shrinkage. Among the available NIR wavelengths, research has shown the wavelengths around 810 nm to be one of the most versatile with regard to the number of possible treatment options, as this wavelength range can be effectively used in the field of soft tissue surgery, periodontics, endodontics, implantology and tooth whitening. The versatility of the instrument, combined with the latest achievements in diode laser technology, compact design and affordability, should appeal to dental professionals seeking to optimize the procedures they currently perform and expand the number of services they offer.

**Key words:** laser; diode; diode lasers; dentistry; soft tissue; 810 nm

## INTRODUCTION

Even though Theodore Maiman had exposed an extracted tooth to his ruby laser in 1960, the breakthrough for lasers in the field of the dentistry came in the mid 1990s, with various laser types (Nd:YAG, Er,Cr:YSGG, Er:YAG, $CO_2$) with corresponding wavelengths (1064 nm, 2780 nm, 2940 nm, 10600 nm) becoming available to the dentists to address their needs for hard and soft tissue procedures. Soft tissue NIR lasers are characterized by a high absorption in chromophores found in soft tissue, e.g. hemoglobin, resulting in excellent soft tissue incision, ablation and coagulation performance as well as antimicrobial effectiveness, due to relatively deep highly localized tissue heating. Hard tissue lasers are highly absorbed in (carbonated) hydroxyapatite and water chromophores and are thus able to finely ablate hard tissues without heating of the surrounding tissue. Soft tissue NIR lasers include solid crystal Nd:YAG lasers (1064 nm) and diode lasers (810 nm and 980 nm).

Among the various lasers appearing in the mid 1990s, semiconductor diode lasers also made their debut. With several advantages, including their small size, price range and versatility regarding the possible treatment applications, the diode lasers represent a valuable addition to the dentist's repertoire.

Diode lasers can be used for a multitude of dental procedures which are predominantly soft tissue procedures and include soft tissue surgery [1, 2, 3], periodontal pocket therapy [4, 5], peri-implantitis [6], but can also be used for certain applications involving hard tissue (teeth), i.e. endodontics - root canal disinfection [7, 8, 9] and laser-assisted tooth whitening [10]. The ability to perform the aforementioned procedures depends on the appropriate technical characteristics, which the diode must posses. The most important characteristic is the wavelength of the diode laser used as the wavelength determines how the laser light will interact with the target tissue (absorption in the appropriate tissue chromophores, penetration depth into the tissue etc.). To date, research has shown that NIR (near infrared) laser light around 810 nm to be one of the most versatile wavelength ranges in diode lasers available to the dentist with regard to the number of different treatments it can be used for. Other characteristics which also need to be considered include maximum power available to the user (available power determines the number of procedures which can be done and the speed with which they can be done), the way the laser beam can be modulated (CW – continuous wave, pulsed mode) and the mode of delivery of the laser beam.

## OVERVIEW OF TECHNICAL CHARACTERISTICS OF A DIODE LASER

### Basic Design of a Diode Laser

One of the advantages of diode lasers in comparison to other laser systems, which is immediately apparent to the naked eye, is their size. The development of micro-structure diode cells which are capable of emitting laser light has drastically reduced the bulk of laser systems. The latest dental diode lasers have been designed to have dimensions similar to a standard phone [Fig. 1].

Fig. 1 Dental diode laser system (Fotona XD-2)

Only solid material active media (e.g. GaAlAs – Gallium Aluminum Arsenide) is used in diode lasers. Because of the crystalline nature of the active medium, the ends of the crystal can be selectively polished relative to internal refractive indices to produce totally and partially reflective surfaces thus serving the same function as the optical resonators of larger laser systems. The discharge of current across the active medium releases photons from the active medium, finally resulting in the generation of laser light of a specific wavelength, which is determined by the active medium used [Fig. 2].

At the present, each diode "chip" produces relatively low-energy output. Some low power diode lasers, operating in milliwatt range, are usually being advertised for low level laser therapy (LLLT). In order to achieve the power necessary for various dental procedures (e.g. soft tissue surgery), today's dental diode lasers employ banks of individual diode chips in parallel to achieve the appropriate power levels (several watts). Some dental diode lasers can also be set to lower power (milliwatt range) and can also perform LLLT procedures.

The design of diode laser systems also brings several advantages with it. Already mentioned was the small size of the laser system, which can be of great benefit as it means the device will take up very little office space and assures great portability of the laser system due to its low weight. Also mentioned was the attractive price range of diode lasers, which makes them accessible to a wide range of dental professionals, who want to perform current procedures faster and more efficiently and wish to expand the services currently offered in their practice. Other benefits include a very short time (usually a couple of seconds) in which the laser treatment beam is available to the user after switching the system on. Other laser systems generally need a couple of minutes to reach the ready status. Also, diode lasers consume very little power when compared to other laser systems, thus saving the user money and contributing to the protection the environment. Another important aspect to consider is the widespread use and the reliability of diode laser technology, with more than 40 million pieces produced annually which are being used in devices ranging from DVD-players and laser pointers to state of the art dental diode lasers.

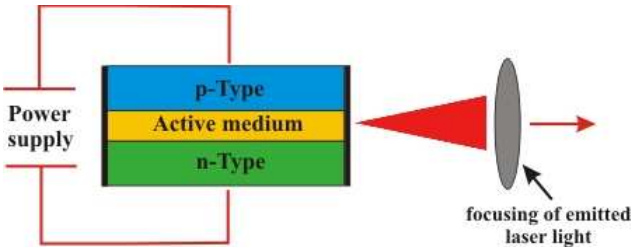

Fig. 2 Simplified schematic outline of a typical diode laser

### Laser light emission modes

Lasers are said to be running in either continuous wave (CW) or pulsed mode. This relates to the rate of emission of laser light with time and the prime benefit of a pulsed mode will be the capacity of the target tissue to cool between successive pulses. The CW mode is generally the fastest way to ablate tissues but heat can build up and cause collateral damage to the target and adjacent tissues. Modern dental diode lasers can operate in both CW and pulsed mode. The factors that determine the average power when the diode laser is operating in pulsed mode are the current power setting and the duty cycle setting. Duty cycle is a periodic phenomenon defined as the ratio of the duration of the phenomenon (pulsewidth) in a given period to the period (reciprocal value of the current frequency setting - number of pulses per second). To clarify the previous statement, consider a following example – when the diode is set to CW mode and the power is set to 2 W, the system will emit an average power of 2 W per second. When operating in pulsed mode, a power setting of 2 W and the duty cycle set to ½ will result in an average power emission of 1 W per second.

It is important to familiarize oneself with the various average and peak powers that can be achieved when using different emission mode settings of the laser system in order to achieve an optimal transfer of the energy from the laser beam to the target tissue, resulting in a desired therapeutic effect.

## Laser light Delivery to the Target Tissue

Most dental diode lasers employ a flexible optic fiber (usually inserted into an appropriate handpiece for comfortable handling) to deliver the treatment beam to the desired area. There are a number of things to consider when using an optic fiber. When using parameters mentioned in application notes or in research papers, always note the diameter of the fiber described in those papers. Using a smaller diameter fiber will increase the power density at the fiber tip. As a result, you may need to decrease the power setting. Increasing the power may be required when using a larger diameter fiber. As a rule of thumb, in order to achieve the same rate of work after changing fiber diameters, a smaller diameter fiber will require less power and conversely, a larger diameter will require more power. Another thing to keep in mind is the speed of movement of the fiber tip during treatment. Tissue charring is an undesirable side effect of too much power and/or the tip moving too slowly. Always use the least amount of power necessary to complete your procedure and move the fiber tip using short 1-2 mm "paint brush" type strokes and move quickly when working on soft tissue. Finally, regularly check the condition of the optical fiber. Always cleave the fiber tip after it becomes blackened (2-4 mm from the tip), because tissue debris accumulate on the tip during surgery and this causes the fiber tip to retain extreme heat and begins to act as a "branding iron". This can lead to unwanted tissue heating and can lead to rapid tip deterioration and subsequent breakage. It is also important to properly cleave the fiber so that no shard is present on the fiber tip, as it may act as a miniature scalpel and damage the small blood vessels, thus interfering with hemostasis and coagulation.

## LASER – TISSUE INTERACTIONS

## The basics

In clinical dentistry, laser light is used to effect controlled and precise changes in target tissue, through the transfer of electromagnetic energy [11]. Light energy interacts with a target medium (e.g. oral tissue) in one of four ways [12] [Fig. 3]:

### *Transmission*

Laser beam enters the medium and emerges distally without interacting with the medium. The beam exits either unchanged or partially refracted.

### *Reflection*

When either the density of the medium or angle of incidence are less than the refractive angle, total reflection of the beam will occur. The incident and emergence angles of the laser beam will be the same for true reflection or some scatter may occur if the medium interface is non-homogenous or rough.

### *Scatter*

There is interaction between the laser beam and the medium. This interaction is not intensive enough to cause complete attenuation of the beam. Result of light scattering is a decrease of laser energy with distance, together with a distortion in the beam (rays travel in an uncontrolled direction through the medium).

### *Absorption*

The incident energy of the laser beam is attenuated by the medium and converted into another form. With the use of dental diode lasers, the most common form of conversion of laser energy is into heat or, in the case of very low energy values, biomodulation of receptor tissue sites seems to occur [13, 14]. Heat transfer mediated physical change in target tissue is termed photothermolysis.

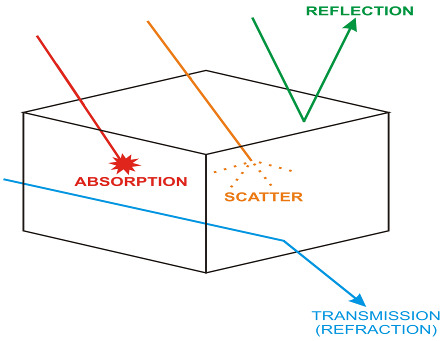

Fig. 3 Possible laser light - tissue interactions

## Absorption

In any desired laser-tissue interaction, the goal is to achieve the maximum absorption of laser light by the target tissue, as this will allow maximal control of the resultant effects.

Absorption is determined by matching incident laser beam energy (wavelength) to the electron shell energy in target atoms. Absorption of laser energy in the target tissue leads to generation of heat and rising heat levels lead to dissociation of covalent bonds (in tissue proteins), phase transfer from liquid to vapour (in intra- and inter-cellular water), onto phase transfer to hydrocarbon gases and production of residual carbon [15]. Secondary effects can occur because of heat generation (through conduction).

When predicting the conversion of electromagnetic energy to heat effects in target tissue, unwanted change through conductive thermal spread must be taken into account and reduced to lowest possible level. The ability to control a progressively increasing heat loading of target tissue is termed as thermal relaxation [16]. Thermal relaxation rates are proportional to the area of tissue exposed and inversely proportional to the absorption coefficient of the tissue, assuming fixed values of thermal and light diffusivity for the tissue in question.

## Factors Associated with Absorption and Thermal Relaxation

Some of the more important factors that affect the thermal relaxation of the target tissue and absorption of laser light by the target tissue (separately and/or collectively) [17] are:

### *Laser Wavelength and Tissue Composition*

Parts of the tissue that absorb laser light energy are termed chromophores. Oral tissues contain several chromophores: hemoglobin, melanin and other pigmented proteins, (carbonated) hydroxyapatite and water. The absorption coefficients for the listed chromophores with regard to the wavelengths used in dental lasers is shown in Fig. 4. Generally, pigmented tissues will better absorb visible or NIR wavelengths, whereas non-pigmented tissues absorb longer wavelengths. In addition, absorption peaks of water and hydroxyapatite coincide for example with Er:YAG.

Water as a constituent of every living cell will influence the penetration of longer wavelength laser light into the tissue, whilst non-pigmented surface components will enable greater penetration for visible or NIR wavelengths. For example, a $CO_2$ laser might penetrate the oral epithelium to a depth of 0.1-0.2 mm whilst NIR wavelengths can result in penetration of 4-6 mm [18] (when using equal power settings for the mentioned lasers).

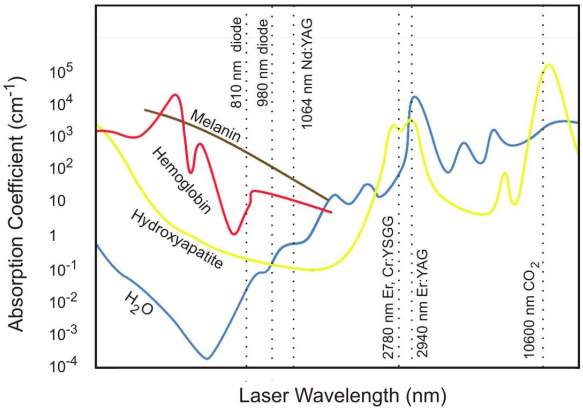

Fig. 4 Absorption coefficients of various tissue chromophores relative to laser wavelength

### *Incident Angle of Laser Beam*

Maximum control of laser-tissue interaction can be achieved if the incident laser beam is perpendicular to the tissue surface. Reducing the incident angle towards the refractive angle of the tissue surface will increase the potential for true light reflection with an associated reduction in tissue change [19].

### *Exposure time and Laser Emission Mode*

Pulsing of laser light delivery will allow some cooling to occur in-between pulses.

### *Beam diameter and beam movement*

As laser light exits the optic fiber, divergence of the beam will occur. Consequently, the spot size of the beam (relative to the target tissue) will determine the amount of laser energy (fluence – J/cm$^2$) being delivered over an area [20]. The spotsize will increase with increasing distance (optic fiber – target tissue). Therefore, thermal changes at the target site can be effectively controlled by modifying the amount of energy delivered to the target site via moving the handpiece closer or farther from the target site. To summarize, for any chosen power setting, the smaller the beam diameter, the greater the concentration of heat effects.

Faster laser beam movement will also reduce heat build-up in the target tissue and aid thermal relaxation.

### *Coolants*

Coolants can control or limit the temperature rise of target and associated tissues. Coolants can be either endogenous (e.g. blood flow) or exogenous (e.g. air, water, pre-cooling of tissue).

### NIR Laser light and Soft Tissue Cutting

When correct parameters are used, a central zone of tissue ablation is surrounded by an area of irreversible protein denaturation (coagulation, char). Around this central zone, a reversible, reactionary zone of edema will develop along a thermal gradient. Ideally, the incision line will equal the beam diameter. Heat build-up will also disinfect the targeted and surrounding area and the production of a surface coagulum discourages bacterial contamination of the wound. When using NIR lasers on soft tissue there is minimal or no bleeding due to a combination of sealing of small vessels through tissue protein denaturation and stimulation of Factor VII production in clotting. The heat buildup also allows for the sealing of small lymphatic vessels which results in a reduced post-operative edema. Suturing is usually not necessary also due to the surface coagulum. The formation of scar tissue should be minimal due to reduced post-operative tissue shrinkage [1, 3, 21].

When comparing NIR lasers - the Nd:YAG (1064 nm) and diode lasers (805 nm, 810 nm), the mentioned wavelengths have a similarly high absorption in soft tissue which translates into excellent incision performance and coagulation of tissue [22, 23].

### NIR Laser light and Hard Tissue

NIR wavelengths have little absorption in dental hard tissue and have the potential to cause thermal cracking and amorphous change in the hydroxyapatite crystal structure. Additionally, they can also have a deleterious effect on pulp tissue due to the intra-pulpal temperature rise because of relatively high transmission of NIR wavelengths through enamel and dentin [24].

From the clinician's viewpoint, two wavelengths have the ability to effectively interact with dental hard tissue, Er:YAG (2940 nm) and Er,Cr:YSGG (2780 nm). Another wavelength which was tested on dental hard tissues was the $CO_2$ laser, but the laser's CW and gated CW emission modes render its power output low and have a significantly negative impact on the thermal relaxation potential, which can lead to disastrous effects on dental hard tissue [25, 26]. In contrast, both erbium lasers can reach high peak powers due to their pulsed emission modes and have relatively high absorption in water. High peak powers combined with high absorption in water effectively results in an instant vaporization of the water content in enamel and dentin, leading to explosive dissociation of the tissue and ejection of micro-fragments, resulting in precise tissue ablation. Both lasers also employ co-axial water sprays, which help to disperse the ablated tissue and cool the target [27]. The result is the ability to selectively ablate carious dental tissue due to higher water content when compared to healthy enamel and dentin. Additionally, pulpal temperature rise is minimal when using erbium laser wavelengths and therefore has less potential to cause thermal damage to the pulp when compared to rotary instrumentation [28]. Of the two erbium laser, the Er:YAG appears to be better suited for hard dental tissues. Er:YAG wavelength has a higher absorption coefficient for water (13,000/cm for Er:YAG vs. 4,000/cm for Er,Cr:YSGG), resulting in a more efficient ablation of dental hard tissue. For example, the ablation threshold for enamel is 9-11 $J/cm^2$ for Er:YAG and 10-14 $J/cm^2$ for Er,Cr:YSGG [29]. The precise mode of action of Er,Cr:YSGG laser on dental hard tissue is another contested issue - claims have been made as to the involvement of the atomized water spray, used with the Er,Cr:YSGG ("hydrokinetic effect") [30]. The hypothesis is that water droplets axial to the laser beam absorb kinetic energy. The droplets are then accelerated and help with hard tissue ablation. Research into this effect has questioned the validity of such claims and as previously mentioned, with comparable incident energies, the ablation rate of the Er, Cr:YSGG for enamel is slightly slower than that of Er:YAG [31]. The Er:YAG is also superior to Er, Cr:YSGG with regard to heat produced with laser ablation of bone [32]. Higher water content and lower density of bone compared to enamel allows faster cutting, through dislocation of hydroxyapatite and cleavage of the collagen matrix. The relative ease of bone cutting establishes the Er:YAG wavelength as the preferred choice when compared to other laser wavelengths.

## CLINICAL APPLICATIONS

### "Loose" Soft-Tissue Surgery with the 810 nm Diode Laser

Applications include the removal of fibromata, labial and lingual frenectomies, small hemangiomata, mucocele, denture granulomata, treatment of non-erosive lichen planus, aphthae and herpes lesions [3, 33, 34]. The etiology of the lesion should be assessed and as with a scalpel, the abnormal tissue should be placed under tension to enable accurate cleavage (whenever possible). With regard to diode laser surgery, the laser handpiece tip is generally held very close to the tissue surface. This allows the laser energy to effect the incision and minimizes the build-up of debris on the tip, which can lead to unwanted thermal damage to the tissue. For most minor intra-oral surgical procedures, the recommended average power setting is in the range of 2-4 W [33].

As was already mentioned, the 810 nm wavelength diode laser transverses the epithelium and penetrates 2 – 6 mm into the tissue. When laser cutting is in progress, small blood and lymphatic vessels are sealed due to the generated heat, thereby reducing or eliminating bleeding and edema. Denatured proteins within tissue and plasma are the source of the layer termed "coagulum" or "char", which is formed because of laser action and serves to protect the wound from bacterial or frictional action. Clinically, during 48-72 hours post-surgery, this layer becomes hydrated from saliva, swells and eventually disintegrates to later reveal an early healing bed of new tissue [33].

Care must be taken when working near anatomical sites that might be damaged through excessive power values [35]. For example, excessive power settings might cause thermal damage to the underlying periosteum and bone. Damage to these anatomical sites can be avoided by using appropriate (lower) power levels, keeping the laser beam parallel to and away from the underlying bone and employing proper irradiation time intervals to allow sufficient tissue cooling [33].

## "Fixed" Soft-Tissue Surgery with the Diode Laser

The 810 nm diode laser can be used for numerous "fixed" soft tissue procedures including gingival hyperplasia, tooth exposure and hyperpigmentation. Additionally, there is a range of gingival adaptation procedures, both to allow restorative procedures and to allow access to restorative margins during restorative procedures [36]. The laser energy will act primarily as a means of incision, excision or ablation, with the same advantages over the scalpel that were mentioned previously (no or minimal bleeding, no sutures, less chance for infection of the wound). When possible, any laser surgical procedure in and around the gingival cuff should seek to preserve a biological width (the zones of connective and epithelial tissues attached to the tooth), minimum 3 mm in depth, which will help to maintain gingival margin stability, alveolar bone height and health and prevent overgrowth [37, 38, 39]. Power settings of 1.5-3.0 watts with intervals should be optimal for most, if not all gingival procedures [36]. Again care must be taken to avoid thermal damage to the underlying periosteum and bone, together with root surface at gingival margin levels. Therefore assessment of the thickness, vascularity and position of any target gingival tissue, together with an assessment of adjacent bone and tooth tissue, is recommended. Also, to minimize the buildup of carbonized debris, post-ablation tissue should be discarded using a curette, damp cotton wool or gauze [36].

## Periodontal Therapy with the 810 nm Dental Diode Laser

The main use for the 810 dental diode laser in the periodontal therapy is the removal of diseased pocket lining epithelium and disinfection of periodontal pockets. Optic fiber delivery systems, with 200-320 µm fiber diameters, enable extremely easy access into the periodontal pocket. After hard and soft deposits have been removed through scaling and/or root-planing, the pocket architecture is re-assessed, with emphasis on the depth. The fiber is then measured to a distance of one to two millimeters short of the pocket depth and is inserted at an angle to maintain contact with the soft tissue wall at all times. The fiber is then used in light contact, sweeping mode to cover the entire soft tissue lining. Power setting of 0.8-1 W should suffice to ablate the epithelial lining. Start with the ablation near the base of the pocket and slowly proceed upwards. Often some bleeding of the pocket site will occur, possibly due to damage to the inflamed pocket epithelium, but in terms of laser hemostasis, the power levels used are low and aimed at removing the epithelial surface and disinfecting the pocket [4, 5, 40]. The fiber tip should be regularly inspected and cleaned with a damp sterile gauze or cleaved in order to prevent the buildup of debris on the fiber tip. The treatment time per pocket should be around 20-30 s, amounting possibly to 1-2 minutes per tooth site. Re-treatments should follow at weekly intervals during the maximum four week period. Pocket probing and measurement to establish benefits of treatment is not advised during this period [40]. With regard to the disinfection of periodontal pockets, studies [4, 41] have shown the effectiveness of diode laser in eliminating bacteria commonly implicated in periodontal disease and bone loss (e.g. *Actinobacillus actinomycetemcomitans, Porphyromonas gingivalis*). When using the diode laser, care must be taken to avoid unwanted heating, both of the tooth and periodontal attachment apparatus. Without tactile feedback, coupled with the "blind" treatment of non-reflected periodontal flaps, caution is paramount and a thorough diagnosis of the diseased periodontium must be obtained prior to laser use [40].

## Using the 810 nm Dental Diode Laser in Implantology and Endodontics

In implantology, the 810 nm dental diode laser can be used for second stage implant recovery and the treatment of peri-implantitis.

In second stage implant recovery care must be exercised to avoid contact with the implant body. Soft tissue ablation leads to precise and predictable healing and the procedure can usually be performed with the use of a topical anesthetic. The appropriate power setting for the removal of gingival tissue overlying the implant cover screw is 1-2 W. The advantages of using a diode laser to perform this procedure are easier visual access to the cover screw due to hemostasis and the production of the protective coagulum to aid in healing and patient comfort [42].

Peri-implantitis is described as one of the most important causes of implant loss and is not restricted to any one type of implant design or construction [43, 44]. It can be recognized as a rapidly progressive failure of osseo-integration [45], in which the production of bacterial toxins leads to inflammatory change and bone loss [46]. Always, an assessment must be made to determine the causative factors associated with the condition (infection, implant overloading, occlusion and other local, systemic and life-style factors), to establish whether the implant can be saved [42]. Curettage of granulation tissue is especially important. Research has shown that a diode laser can be used to perform the procedure with the added bonus of disinfecting the treated area. Use of appropriate coolant (eg. water spray) is needed to avoid any detrimental heat effects to the surrounding tissues [42, 6]. Effective power range is from 1-1.5 W [6].

In endodontics, published papers [7, 8, 9] indicate the effectiveness of the diode laser root canal treatment (disinfection of the root canal), with slightly inferior bactericidal performance against *Enterococcus faecalis* when compared to a solid-state NIR Nd:YAG laser system [9]. The fine diameters of optic fibers (200-320 µm) enable effective delivery of laser light to the root canal to help with reduction of bacterial contamination. The antibacterial effect observed reaches over 1 mm deep into the dentin [9], surpassing the effective range of chemical disinfectants, such as NaOCl and displaying moderate effectiveness against *Enterococcus faecalis* even in the deeper layers of dentin. The procedure can be carried out by drying the root canal with sterile paper tips enlarging the root canal opening up to ISO 30. After measuring the canal depth, the optic fiber should be inserted in the prepared root canal down to the apex - in no case further. The optic fiber is then led in slow, circular, spiral-forming movements from the apical to the coronal part, while the laser is activated. The procedure should be repeated four times for five seconds. Be cautious to always keep the fiber-optic beam delivery tip moving when the laser is activated to avoid excessive temperature rise on the tooth surface, which can be detrimental to the tissues surrounding the tooth. If necessary, repeat the laser treatment after three to seven days, but not more than twice in total. The power should be set in the range of 1-1.5 W [9, 47].

## Teeth Whitening using the 810 nm Dental Diode Laser

Teeth whitening procedures continue to grow in popularity due to the increased desire for whiter teeth with increasing number of articles being published on the subject in the popular press and on television in regular intervals. This has resulted in renewed interest from the dental profession in the process of teeth whitening, as the procedure itself is relatively simple and non-invasive to carry out. Current bleaching systems are based primarily on hydrogen peroxide (HP) or carbamide peroxide (CP). These bleaching systems usually exist in a form of a gel which is applied on the tooth surface and activated via light, for example. Activation of HP causes formation of free radical ions, which immediately seek available targets to react with. Long-chained molecules that "stain" the tooth react with the free radicals, altering the optical structure of the molecule and creating a different optical structure. The stain on the tooth surface disappears, or the large molecules become virtually dissociated into smaller, shorter chained molecules, giving the tooth surface a brighter appearance. 810 nm laser light also generates heat on the tooth surface. In order to prevent excessive conduction of heat to the pulp and avoid pulpal necrosis, proper laser power must be used and according to the recently published research, an up to 2 W setting should be well within safety margins with regard to the pulp tissue as well as being high enough to accelerate the bleaching process by causing the breakdown of the HP gel to reactive free radicals that penetrate the tooth to cause the oxidation of stain molecules within the tooth structure [10]. One thing to keep in mind with regard to the parameters in the aforementioned study [10] is the fact that no spot size was mentioned, making energy density (fluence) impossible to calculate. Therefore manufacturer's instructions should be carefully examined with regard to the proper spot size and power settings when performing the procedure.

## CONCLUSION

In conclusion, research has proven that the 810 nm is the premier wavelength available in today's dental diode laser systems when considering the versatility of the system. It can be used for a variety of procedures which are routinely carried out in a modern dental practice, including a multitude of soft tissue procedures, such as soft tissue surgery, periodontal therapy as well as being an efficient tool for use in implantology, endodontics and tooth whitening. When compared to "classical" dental techniques, the 810 nm dental laser offers distinctive advantages, such as the ability to cut, coagulate, ablate or vaporize target tissue elements, enabling dry-field surgery through the sealing of small blood vessels (hemostasis), disinfection of the tissue, reduced post-operative edema (through the sealing of small lymphatic vessels) and decreased amount of scarring, contributing to faster and more effective treatment resulting in improved treatment outcome and increased patient comfort and satisfaction.

The main limitation of the 810 nm diode laser is its lack of ability to perform hard tissue procedures (e.g. cavity preparation, bone cutting). The currently optimal solution for such procedures appears to lie in the use of an 2940 nm Er:YAG laser. Additionally, the current technology limits the available peak powers when compared to solid-state lasers, such as the solid crystal Nd:YAG laser. The inherent CW emission mode of the diode lasers means that peak powers cannot be used as effectively as is the case with Nd:YAG lasers, which can have an inherent pulsed emission mode and have a wide variety of available pulse widths. The solid crystal Nd:YAG laser has a special position among soft tissue lasers. It is capable to deliver energy in short bursts with approximately 1000 times higher intensities compared to those of diode lasers. In addition, the Nd:YAG laser wavelength has the most homogeneous (2 to 3 mm) penetration into the oral tissue. For this reason, the combination of solid state lasers such as an 1064 nm Nd:YAG and an 2940 nm Er:YAG might represent a nearly optimal choice when considering the spectra of possible soft and hard tissue treatment options and the efficiency and safety with which the procedures can be performed. When the Nd:YAG laser is incorporated within a solid crystal Er:YAG laser system, the cost of this additional solid crystal Nd:YAG laser wavelength is not very high. However, when considering buying only a single soft tissue laser, then an 810 diode laser may be the second best choice due to its lower price and smaller size. If the clinician's main use for the laser system lies in soft tissue procedures then the 810 nm dental diode laser undoubtedly represents a worthwhile investment.

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