Journal of
Pediatric Dentistry
DOI: 10.14744/JPD.2021.11_82
J Pediatr Dent 2021;7(3):146-155

Review Article

Er:YAG Laser for Cavity Preparation in Pediatric Dentistry: A Review of Literature

Raghdah Emad Abdrabuh[1] Ahmed Samir Bakry[2,3] Omar Abd El Sadek El Meligy[1,4] Najat Mohammed Farsi[1]

[1]Department of Pediatric Dentistry, Faculty of Dentistry, King Abdulaziz University, Jeddah, Saudi Arabia
[2]Department of Operative Dentistry, Faculty of Dentistry, King Abdulaziz University, Jeddah, Saudi Arabia
[3]Department of Conservative Dentistry, Faculty of Dentistry, Alexandria University, Alexandria, Egypt
[4]Department of Pediatric Dentistry and Dental Public Health, Faculty of Dentistry, Alexandria University, Alexandria, Egypt

Address for correspondence: Omar Abd El Sadek El Meligy, BDS, MSc, PhD, Department of Pediatric Dentistry, Faculty of Dentistry, King Abdulaziz University, P.O. Box: 80209, Jeddah 21589, Saudi Arabia
E-mail: omeligy@kau.edu.sa

Abstract

Laser technology offers minimally invasive, painless alternatives to the conventional ways of performing many hard and soft tissue procedures in dentistry. Pediatric dentists should learn the new, less invasive technologies, and adopt them in their routine practice. This article aimed to review the clinical applications of erbium-doped yttrium aluminum garnet (Er:YAG) lasers in pediatric dentistry. An electronic search of databases including Scopus, Science Direct, PubMed, ProQuest, Medline, and Google Scholar databases identified articles published from 1996 to 2020 that described the potential and clinical applications of Er:YAG laser in the pediatric dentist's practice. The literature shows that Er:YAG laser can accomplish a wide variety of dental procedures with minimal pain and while reducing the risk of infection and bleeding. In clinical studies, patients prefer lasers over conventional methods. Er:YAG laser is preferred among pediatric dentists because it is suitable for both hard tissue and soft tissue procedures.

Keywords: Erbium-doped yttrium aluminum garnet (Er:YAG), lasers application, laser caries removal, laser cavity preparation, lasers types, pediatric dentistry

Introduction

The history of the laser (the word is an acronym for "light amplification by stimulated emission of radiation) began in 1916 when Albert Einstein described stimulated emission theory.[1] For the next several decades, physicists studied possible ways to build a stimulated emission device that could achieve light amplification at various wavelengths, but the first functioning laser was the one built-in 1960 by Theodore Maiman; its active medium was synthetic ruby.[2] Since the older lasers were only capable of cutting soft tissue, the first medical uses of lasers were for dermatology, ophthalmology, and endoscopic surgery.[3] With the advent of a new generation of lasers with wavelengths absorbed by water, laser hard tissue ablation became possible, opening the door to advances in laser dentistry. Lasers have a wide variety of applications in dentistry, as well as in other fields. Laser treatments of the hard and soft tissues of the mouth can make visiting the den-

How to cite this article: Abdrabuh RE, Bakry AS, El Meligy OA, Farsi NM. Er:YAG Laser for Cavity Preparation in Pediatric Dentistry: A Review of Literature. J Pediatr Dent 2021;7(3):146-155

tist a much more pleasant experience. In general, laser treatments in the dental clinic are painless, often not requiring local anesthesia; they are also bloodless, minimally invasive, and effective at preventing infection.[4] While researchers have tested the feasibility of using many different types of lasers for almost every dental procedure imaginable, and some of these have gained acceptance in clinical practice, the erbium-doped yttrium aluminum garnet (Er:YAG) laser is the most versatile laser for use in dentistry. The Er:YAG laser is capable of ablation of both hard and soft tissue. It is theoretically suitable for a wide variety of applications in pediatric dentistry. In clinical practice, pediatric dentists have adopted the use of the Er: YAG laser for caries removal and cavity preparation in enamel and dentin, but researchers have also studied its appropriateness for other dental procedures. Although Er:YAG lasers have the potential for many applications in pediatric dentistry, the appropriate treatment parameters have yet to be established. This study aimed to review the clinical applications of the Er: YAG laser in pediatric dentistry.

Types of lasers and their applications in dental practice

A laser is a device that emits a beam of light from a light chamber when the active medium in the light chamber receives a stimulus, usually from an electrical current. The active medium will then give off light of an unchanging wavelength; the laser operator may set it to a continuous mode or pulse mode. Every laser emits a beam of unchanging wavelength; the active medium determines the wavelength in the laser's light chamber, and each laser takes its name from its active medium (such as carbon dioxide laser or diode laser). Some laser-activated media are crystals or glasses; these are called solid-state lasers. Others use gases, liquid dye solutions, or semiconductors as their active media, and most of them use optical fibers made of glass, plastic, or silica as their delivery systems.[5,6] The lasers used in dentistry have wavelengths ranging from 572 nm (blue-green) to 10,600 nm (infrared) and represent the gas, semiconductor, and solid-state groups (Table 1).

Lasers used for cavity preparation

The United States Food and Drug Administration approved the Er:YAG laser for cavity preparation in 1997.[7] It is one of two types of lasers currently approved for cavity preparation, the other type being the Er, Cr:YSGG (Erbium, chromium-doped yttrium, scandium, gallium, and garnet). The main differences between the Er:YAG and the Er, Cr:YSGG lasers are that the water absorption coefficient of the Er, Cr:YSGG is about one-third that of the Er:YAG laser and that the Er, Cr:YSGG laser has deeper thermal penetration into tooth structure.[8] This review will focus on the Er:YAG laser because it has higher efficiency in ablating tooth structure. The Er:YAG laser has a wavelength of 2940 nm, which is in the infrared range. It is a solid-state laser; its active medium is a yttrium aluminum garnet crystal doped with rare earth metal erbium ions. It is very precise, penetrating only a few micrometers.[9] It is the most efficient type of laser for hard tissue ablation since its ablation threshold is 6 J/cm^2 (at a 100 μm pulse) and 10 J/cm^2 (at a 700 μm pulse). [10] Among the most important reasons to prefer the Er:YAG laser over other kinds of lasers is its excellent absorption in water; it has 15 times as much water absorption as the carbon dioxide laser and 20,000 times as much as the neodymium-doped yttrium aluminium garnet (Nd:YAG) laser.[11] Therefore, the Er:YAG laser is suitable for use on both soft tissues and hard tissues.

Advantages and disadvantages of the Er:YAG laser

Er: YAG lasers offer promise in many aspects of dentistry because they cause little or no pain and can accomplish some procedures as quickly as conventional methods. The Er:YAG laser also has an antibacterial effect since its high absorption in water enables it to destroy bacterial biofilm structure.[12] Laser dentistry is considered safe for most patients; by reviewing the patient's medical history before commencing laser treatment, the dentist can ensure that the patient does not have an underlying condition for which laser dentistry is contraindicated, such as cancer, epilepsy, immunosuppression, or a blood clotting disorder.[13,14] The main disadvantages of laser dentistry are the cost and the need for training. The cost of replacing all conventional drilling and cutting with laser therapies would be prohibitive to all except the most well-funded dental clinics because it would require the clinic to purchase multiple lasers.[15] Although some commercially available laser systems come with more than one active medium, so that a dental clinic needs only purchase one device to get lasers of several different wavelengths, this equipment is still beyond the budgets of most community dental clinics.[9] The lasers used in dentistry are Class IV lasers, and they cause approximately 35 injuries per year, the category with the greatest potential to cause injury in humans; unless operated properly, dental lasers carry the risk of skin damage, eye damage, fire, electrical shock, and dangerous exposure to chemicals present in the laser plume.[16,17] The Er:YAG laser is by far the most versatile laser for dentistry; equipping a dental clinic with

Table 1. Types of lasers and their applications in dental practice

Type of laser	Wavelength	Group	Mode	Delivery system(s)	Year developed	Applications in dentistry
Argon	572 nm	Gas	Pulse or continuous wave	Optical fiber	1964	• Polymerization of resin restorations • Tooth bleaching • Removal of necrotic tissue • Gingival contouring • Treatment of herpetic lesions andaphthous ulcers • Soft tissue ablation, including frenectomy and gingivectomy • Detection of caries
Carbon dioxide (CO_2)	10,600 nm	Gas	Pulse or continuous wave	Waveguide, articulated arm	1964	• Soft tissue ablation, including frenectomy and gingivectomy • Gingival contouring in cosmetic dentistry • Treatment of ulcerous lesions of the mouth • Detection of fissure caries • Removal of necrotic epithelial tissue in regenerative periodontal surgery
Diode	810 nm or 980 nm	Semiconductor	Pulse or continuous wave	Optical fiber	1957	• Promoting the proliferation of fibroblasts to heal oral lesions or accelerate postsurgical healing • Soft tissue ablation, including gingivectomy, frenectomy, and cosmetic gingival contouring • Laser doppler flowmetry to measure blood flow
Erbium, chromium-doped yttrium scandium gallium garnet (Er, Cr:YSGG)	2780 nm	Solid state	Pulse	Optical fiber	1997	• Enamel etching • Removal of carious lesions • Cavity preparation • Bone ablation • Root canal preparation
Erbium-doped yttrium aluminum garnet (Er:YAG)	2940 nm	Solid state	Pulse	Optical fiber, waveguide, articulated arm	1975	• Caries removal • Cavity preparation in enamel and dentin • Root canal preparation
Frequency-doubled alexandrite	337 nm	Solid state	Pulse	Optical fiber	1970s	• Caries removal • Sterilization of root canals • Soft tissue procedures
Holmium-doped yttrium aluminum garnet (Ho:YAG)	2100 nm	Solid state	Pulse	Optical fiber	1960s	• Soft tissue ablation, including gingivectomy, frenectomy, and cosmetic gingival contouring • Treatment of oral lesions
Neodymium-doped yttrium aluminum garnet (Nd:YAG)	1064 nm	Solid state	Pulse	Optical fiber	1964	• Root canal therapy • Caries removal • Periodontal surgery • Killing microorganisms and removing debris during dental and endodontic procedures
Potassium titanyl phosphate	532 nm	Solid state	Continuous	Optical fiber	1980s	• Tooth bleaching

Er:YAG laser capability would enable it to perform a variety of laser treatments without the need to purchase other lasers. Er:YAG lasers offer promise in many aspects of dentistry because they cause little or no pain and can accomplish some procedures as quickly as conventional methods. The Er:YAG laser also has an antibacterial effect since its high absorption in water enables it to destroy the structure of bacterial biofilm.[12] The Er:YAG laser is by far the most versatile laser for dentistry; equipping a dental clinic with Er:YAG laser capability would enable it to perform a variety of laser treatments without the need to purchase other lasers.

Antibacterial effects of the Er:YAG laser

One of the advantages of using lasers for cavity preparation is that they have antibacterial effects. Therefore, they can be used for the disinfection of cavity surfaces before the placement of restorations. It is important to ensure that cavity surfaces are free of bacteria before restorations. Because the Er:YAG laser is highly absorbed in water, it is absorbed by fluids in bacterial biofilm, destroying its structure. According to Baraba and colleagues, the high temperatures caused during laser irradiation, in other words, the photothermal effect, might also play a role in killing bacteria during laser irradiation, such as through the denaturation of proteins, damage to nucleic acid, and alterations to the cell wall and cell membrane of the bacterium, as well as through micro-explosions when the water in the bacterial cell absorbs the laser energy.[18] Several studies have shown that laser irradiation is effective at destroying microorganisms on cavity surfaces in dentin. Baraba and colleagues found that the Er:YAG laser achieved complete elimination of cariogenic bacteria from dentin *in vitro*, regardless of whether they used a fluorescence-feedback controlled (FFC) Er:YAG laser or one that employs variable square pulse (VSP) technology in a super short pulse, medium short pulse, or short pulse mode. They attributed the success of the laser treatment in part to the fact that the laser pulse energy (250 mJ) and frequency (10 Hz) they used were more than sufficient to remove the lipopolysaccharides of the cell membranes of the gram-negative bacteria they were studying.[18] Sancakli and colleagues found that lasers reduced the number of bacteria in dentin, but using a laser alone was less effective than using it in combination with ozone or chlorhexidine.[19] According to Sancakli and colleagues, the laser energy required for an Er:YAG laser to destroy the strong cell wall of *S. mutans* is 3 W.[19] Given its high degree of absorption in water, the Er:YAG laser can effectively destroy the biofilms of cariogenic bacteria. Aytac Bal and colleagues found that Er:YAG lasers showed similar effectiveness to other disinfection techniques (chlorhexidine, ozone, sodium hypochlorite, and diode lasers) at reducing the number of *S. mutans*. In their study, the photodynamic antimicrobial chemotherapy (PACT) involved the Er:YAG laser with indocyanine green as a photosensitizing agent.[20]

Effects of laser hard tissue ablation on surrounding enamel and dentin

The Er:YAG laser is the preferred laser for dental hard tissue applications because, when the proper parameters are observed, it is possible to complete hard tissue procedures with minimal damage to the surrounding dental tissue. When Shamsudeen and colleagues prepared cavities with the Er:YAG laser at 600W power and 300 mJ energy with water cooling and air spray, they found that the structure of enamel and dentin appeared normal in both groups, with both groups showing dead tracts in dentin below the cavity.[21] Using the correct parameters (100 mJ, pulse frequency 1-25 pps, and pulse duration 300 μsec) can prevent thermal damage to the dentin and make it conducive to successful bonding with adhesive resins; if the collagen is destroyed by heat damage, it will not be possible to form a strong bond.[22] Thermal damage to dentin is a risk when using the Er:YAG laser for cavity preparation. Bakry and colleagues used a Fourier transform infrared spectrometer to analyze hydrated and dehydrated dentin samples that had undergone Er:YAG laser irradiation to detect chemical changes in the dentin caused by the laser. They found that dehydrated dentin samples exposed to laser power higher than 100 mJ showed lower amide/carbonate ratios, but not lower carbonate/phosphate ratios, which indicated that these samples had experienced amide loss. They concluded that the thermal damage that occurs when dentin is irradiated by Er:YAG laser at 200 mJ or 250 mJ without water cooling is enough to cause chemical changes in the organic components of dentin but not its inorganic components.[23] Nahas and colleagues found that all levels of laser energy can cause deterioration of dentin fiber collagen, but that there is more alteration of the dentin organic matrix at higher levels of energy.[24] Cavities prepared in dentin by Er:YAG laser have a scaly surface with exposed orifices, no cracks, and little or no smear layer. Intertubular dentin is ablated faster than peritubular dentin, so the cavities show cuff-like protruding tubules. Subablative irradiation of the cavity surface might cause the protruding tubules to fuse or melt.[21,25,26] Using Field emission scanning electron microscopy (FESEM) analysis, Moghaddas and colleagues showed that the samples subjected to subablative Er:YAG laser irradiation show partial occlusion of dentinal tubules, similar to those treated with bioactive glass and glass ionomer.[27] Er:YAG laser irradiation can increase in the quantity of calcium, as well as changing the percentages of carbon, magnesium, and oxygen.[25,28] Du and colleagues found as the laser increased, so did the weight percentage of calcium and phosphate but decreased the oxygen and carbon effect of laser cavity preparation on bond durability.[27] The acid-base resistant zone the penetration of monomers from the self-etching adhesive into the etched dentin; these monomers interact with the partially exposed hydroxyapatite crystals in the dentin. Specifically, MDP, which is a component of both the self-etching primer and the bonding resin of SE Bond, is capable of forming a stable adhesion to these hydroxyapatite crystals. Because of the high water and hydroxyapatite content of intertubular dentin, Er:YAG ablation results in a surface that has more peritubular dentin than intertubular dentin. Because there is no smear layer with laser preparation, the dentinal tubules are open. Therefore, the monomers can penetrate into the dentinal tubules and create an acid-base resistant zone.[28]

Effect of acid resistance on the interface of bonding systems to enamel and dentin prepared by Er:YAG laser

Acid resistance to demineralization of the dentin-resin interface around restorations is one factor that protects against recurrent caries; other factors include durable adhesion, the strength of the hybrid layer, and marginal integrity.[23,29] Treating the dentin with the Er:YAG laser can give slightly better resistance of the dentin-resin interface to the acid-base challenge than bur preparation, but etching is essential to the success of restorations.[23] Chinelatti and colleagues found that the Er:YAG laser does not increase the susceptibility of the dentin to acid attack but also does not improve its acid resistance.[30] Other studies have also shown that the Er:YAG laser does not improve the acid resistance of dentin.[31,32] Some evidence suggests that Er:YAG lased dentin has greater acid resistance than conventionally prepared dentin. Bakry and colleagues measured the acid resistance of Er:YAG lased and conventionally prepared dentin by measuring the thickness of the acid-base resistant zone, which they defined as the area beyond the hybrid layer that resisted the acid-base challenge. They found that, in samples restored with the self-etching adhesive SE-Bond, which contains the monomer 10-methacryloxydecyl dihydrogen phosphate (MDP) in both the self-etching primer and the bonding resin, the hybrid layer was thicker on the Er:YAG lased surfaces than on the conventionally prepared surfaces after the samples had been subjected to the acid-base challenge for 20 min. In the samples subjected to a longer duration of the acid-base challenge, the acid-base resistant zone of the lased surfaces was slightly thicker than that of the conventionally prepared surfaces, but not enough to be statistically significant. Based on these results, the authors determined that Er:YAG cavity preparation is conducive to the formation of an acid-base resistant zone in dentin. They hypothesized that the hybrid layer might have originally been even thicker than what they observed by scanning electron microscope because the argon-ion beam etching used in preparing the samples for SEM analysis might have partially degraded this layer.[23]

Bakry and colleagues were able to demonstrate the increased acid resistance of Er;YAG lased dentin, whereas other studies were not. One reason for this is that Bakry and colleagues used parameters at which the Er:YAG laser did not cause changes to the inorganic components of dentin.[33] For example, the studies by Chinelatti et al. and Abbasi et al.[30,31] found that Er:YAG preparation of dentin did not increase or decrease acid resistance.

Effects of laser caries removal on nanoleakage

Nanoleakage, as defined by Sano and colleagues, refers to porosities of 50 nm or less, in the basal portion of the hybrid layer, between the unaffected dentin and the dentin-adhesive interface.[34] These porosities are small to allow the penetration of bacteria and large molecules, but water and small molecules can penetrate.[35] According to Mazzoni and colleagues, the acidic environment that results from acid etching activates Matrix metalloproteinases (MMPs) and causes them to degrade the collagen matrix, which leads to nanoleakage in the hybrid layer.[36] Since laser irradiation might inhibit the activity of MMPs, then using the Er:YAG laser for caries removal might help prevent nanoleakage around restorations. One of the challenges of using Er:YAG lasers for cavity preparation is choosing the appropriate adhesive for restorations since the adhesives currently available for clinical use were originally designed for filling conventionally prepared cavities. de Oliveira and colleagues found that when self-etching adhesives (Clearfil Tri-S Bond and Clearfil Protect Bond) were applied to dentin irradiated by Er:YAG laser, their bond strength and nanoleakage patterns were similar to what they observed for conventionally prepared dentin restored with those same materials.[37] Their laser-irradiated samples had much worse outcomes than the conventionally prepared samples when an etch and rinse system (Single Bond Plus) was applied. When they examined the samples with a transmission electron microscope (TEM), the Er:YAG cavities restored by Single Bond showed polyalkenoic acid copolymer at the adhesive layer, indicating phase separation, which occurred when the adhesive, which contains hydrophilic monomers, was applied to etched dentin.[37]

Meanwhile, with self-etching systems, the adhesive layers were consistently bonded to the laser-irradiated dentin, without gaps or debonding; therefore, the laser-irradiated samples treated with self-etching adhesive systems showed little nanoleakage. The authors hypothesized that what little nanoleakage they detected on the Er:YAG samples with the self-etching adhesives might have been due to the incomplete removal of water before applying the adhesive. Remnants of water might have led to incomplete polymerization or hydrogel formation, which might account for the nanoleakage. Another possible explanation is the deficient diffusion of adhesive monomers into the denatured collagen fibrils.[37] Comba and colleagues found restored cavities prepared with Er:YAG lasers showed more nanoleakage than conventionally prepared specimens.[38] Bakry and colleagues found more nanoleakage in the Er:YAG prepared samples than in the conventionally prepared samples. They attributed this to water seepage from the open tubules of the lased dentin to the dentin-adhesive interface; in conventionally prepared dentin, the tubules would be occluded by smear plugs. Thus, there was more water present at the dentin-adhesive interface of the lased samples, and this water was absorbed by 2-hydroxyethyl methacrylate (HEMA), leading to incomplete conversion of the bonding agent double bonds.[33]

Clinical applications of laser in pediatric dentistry

1. Caries prevention

Er:YAG lasers might be appropriate for caries prevention, either by killing bacteria present on the surface of the tooth or by increasing the resistance of the dental enamel to acid. Ando and colleagues found that laser beams have a bactericidal effect even at a low energy density; therefore, they suggested that it is possible to kill the bacteria on the tooth, thus preventing caries formation, without risking thermal damage to the pulp.[39] The conclusions of Schoop and colleagues call this finding into question. However, they determined that each species of bacteria requires a different level of laser irradiation. Therefore, it might not be possible to kill enough bacteria to prevent the formation of caries while keeping the energy density of the laser beam low enough to avoid risking damage to the pulp.[40] Meanwhile, Dostolova and colleagues found that subablative doses of laser light are sufficient to kill all species of bacteria, even anaerobic species.[41]

2. Pit and fissure sealants

Applying sealants to deep pits and fissures on the occlusal surfaces of the teeth is an effective, long-lasting way to prevent caries from forming on the occlusal surfaces.[42] Decontaminating the fissures with Er:YAG laser therapy before applying the sealant is another possible application of these lasers in pediatric dentistry. Bader and Krejci proposed that the appropriate Er:YAG laser power for fissure decontamination is less than 100 mJ.[9] Acid etching before applying sealants is still recommended, even when lasers are the means of performing fistulotomy.[43,44] Some studies have concluded that Er:YAG laser irradiation is not an adequate substitute for acid etching before sealants are applied and that water cooling during laser fissure sealing is essential to preventing the melting and recrystallization of enamel.[45,46]

3. Analgesia

Lasers can have an analgesic effect. Various wavelengths of lasers have been used to anesthetize the pulp for dental procedures. Koci and Almas reported that attempts to anesthetize pulp using a 660 nm laser to prepare class II cavities in molars have a success rate of 50-75%.[3] Bengtson and colleagues recommend anesthetizing the pulp with near-infrared lasers (803-980 nm) in concentrated mode as an alternative to anesthetic drugs. The anesthetic effect lasts for 15 min and is achieved by hyperpolarizing the nerve fiber membranes.[47]

4. Caries removal

The Er:YAG laser offers a virtually painless alternative to conventional methods of caries removal, and its adoption in clinical practice could greatly reduce children's fear of going to the dentist. Recent studies have shown that restorations in laser-prepared teeth have shown a high degree of clinical success, even at a follow-up time of several years.[22,28] If they use lasers within the proper parameters, dentists can achieve caries removal without damaging the surrounding tissues by charring, cracking, or fissuring.[48] Laser-prepared cavities in dentin have a rough surface with protruding dentinal tubules and no smear layer.[28,49] Dentists must take care, however, to protect against the failure of restorations in laser-prepared cavities. Achieving successful restorations in laser-prepared cavities requires proper conditioning of the lased surface before applying restorative materials. According to Bakry and colleagues, the appropriate parameters for using the Er:YAG laser for cavity preparation are pulse energy 100 mJ, pulse frequency 1-25 pps, and pulse duration 300 μsec. The contact probe should have a sapphire tip 0.63 mm in diameter, and the contact tip should be positioned perpendicular to the target tissue.[23]

5. Removal of restorative materials

When it is necessary to remove existing restorations in order to remove the caries and place new restorations, Er:YAG lasers can remove composite resin or glass ionomer restorations, but they are not capable of removing metal restorations.[50] Lizarelli and colleagues reported that using lasers to remove composite restorations is slower than laser ablation of dentin but faster than laser ablation of enamel.[51] Bader and Krejci recommend against using lasers for ablation of amalgam, because the process could cause mercury evaporation.[9]

6. Pulp capping

According to Pillai and colleagues, laser indirect pulp capping can achieve disinfection up to 300 μm and does not require local anesthesia.[52] For direct pulp capping, Shanthi recommends the Erbium, chromium-doped yttrium, scandium, gallium and garnet (Er,Cr:YSGG) laser at 1 W and 20 Hz, with 20% air and 15% water.[48] Thermal damage to the pulp is a risk associated with laser caries removal, especially when the prepared cavity penetrates deep into the dentin. Because lasers are capable of hard tissue ablation at 100°C, they can remove caries from enamel and dentin without causing thermal damage to the pulp of the tooth.[5,15,53] Various studies have measured the change to the temperature of a tooth's pulpal chamber when lasers remove carious lesions from that tooth's dentin. To avoid damaging the pulp is by using the lowest possible settings capable of achieving the desired ablation, especially when applying the Er:YAG laser to deep dentin.[54] Shamsudeen and colleagues observed that, both in conventionally prepared teeth and in laser prepared teeth, the pulp architecture appeared normal in terms of odontoblasts, connective tissue, blood vessels, and fibers. Neither the conventionally prepared teeth nor the laser-prepared teeth showed inflammatory cells in the pulp chamber.[21] The Er:YAG laser does not seem to harm pulp vitality or healing. Valerio and colleagues found that, at a 4-year follow-up, there was no statistically significant difference in pulp vitality between the Er:YAG prepared group and the bur-prepared group.[28]

7. Pulp therapy

The US Food and Drug Administration has approved the use of diode lasers for pulpotomy and apicoectomy. Carbon dioxide lasers, Er:YAG lasers, and Nd:YAG lasers can also be used to achieve pulpotomy; lasers are suitable for pulpotomy, pulpectomy, and pulp coagulation in primary teeth, as an alternative to formocresol, which is carcinogenic.[55,56] According to Olivi and colleagues, Er:YAG for pulp coagulation has better results at 2-year follow-up than calcium hydroxide.[57] According to Neena and colleagues, in laser pulpotomy of a vital tooth, the laser can clean the pulp chamber in 10-20 s.[58] For amputation of coronal pulp, Toomarian and colleagues recommend using the Er, Cr:YSGG laser at 30-40 mJ, 3-4 mm away with 30% air and no water.[59] Ramazani and colleagues reported that erbium lasers have an antimicrobial effect on the root canal system.[60] Galui and colleagues recommend using lasers in combination with plus 5.25% sodium hypochlorite or 14% ethylenediaminetetraacetic acid to disinfect the root canal.[15] Shanthi cautions that, although lasers generally work well for root canal preparation, some root canals are so narrow and curved that total disinfection and debris removal are not possible.[48]

Conclusion

Laser application has various parameters of use, and the literature describes varied experimental outcomes that might falsely perturb the beginner practitioner from investigating laser technology. In addition, it is important to highlight that the operator factor is crucial to present the literature that authenticates the laser treatment. Understanding of laser technology and the correct application of energy are essential to achieve minimally invasive treatment, in addition to the hand skill of the operator who should learn to act on the tissues with accuracy. Knowledge and training are both fundamental for using laser technology. The psychological factor to the pediatric patient also significantly affects the success of laser dental treatment, which is usually comfortable to the patients and their parents, since lasers can minimize the discomfort of the caries removal process and reduce, or even eliminate, the need for local anesthetics.

Lasers are a technological wonder; they have potential applications in almost every aspect of the pediatric dental clinic, from diagnostic applications and caries prevention to caries removal and pulp therapy. The Er:YAG laser is by far the most versatile of the lasers used in pediatric dentistry. Laser dentistry can help the new generation of children experience dental treatment without pain or fear and associate dental treatment with efficiency and comfort.

Clinical significance and recommendations

- The Er:YAG laser offers a virtually painless alternative to conventional methods of caries removal, and its adoption in clinical practice could greatly reduce children's fear of going to the dentist.
- Sub ablative CO2 doses of laser light on sound teeth could be an effective method for caries prevention because they are sufficient to kill all species of bacteria, even anaerobic species. Also, Er:YAG Laser has Antibacterial Effects in cavity preparation, and this is important in reducing the risk of secondary caries. Long term clinical studies are required to confirm these applications.
- Teeth prepared with Er: YAG laser were more resistant to acid attack and to secondary caries than conventionally prepared teeth. More research is needed to evaluate the capability of Er: YAG lasers to increase the dentin acid resistance compared to conventional method.
- Caries removal by Er:YAG laser may inhibit the MMPs activity, and that may help to prevent nanoleakage around restorations. Further clinical studies are needed to evaluate the efficacy of laser caries removal in nanoleakage prevention.

Financial Disclosure: Nil.
Conflict of Interest: None declared.

References

1. Gross AJ, Herrmann TR. History of lasers. World J Urol 2007;25(3):217-220
2. Javan A, Bennett Jr WR, Herriott DR. Population inversion and continuous optical maser oscillation in a gas discharge containing a He-Ne mixture. Physical Review Letters 1961;6(3):106-110
3. Koci E, Almas K. Laser applications in dentistry: an evidence-based clinical decision-making update. Pak Oral Dent J 2009;29(2):409-423
4. Nazemisalman B, Farsadeghi M, Sokhansanj M. Types of lasers and their applications in pediatric dentistry. J Lasers Med Sci 2015;6(3):96-101
5. Verma SK, Maheshwari S, Singh RK, Chaudhari PK. Laser in dentistry: An innovative tool in modern dental practice. Natl J Maxillofac Surg 2012;3(2):124-132
6. Bhatta N, Isaacson K, Bhatta KM, Anderson RR, Schiff I. Comparative study of different laser systems. Fertil Steril 1994;61(4):581-591
7. Bornstein ES, Lomke MA. The safety and effectiveness of dental Er: YAG lasers. A literature review with specific reference to bone. Dent Today 2003;22(10):129-133
8. Diaci J, Gaspirc B. Comparison of Er: YAG and Er, Cr: YSGG lasers used in dentistry. J Laser Health Acad 2012;1(1):1-13
9. Bader C, Krejci I. Indications and limitations of Er: YAG laser applications in dentistry. Am J Dent 2006;19(3):178-186
10. Apel C, Franzen R, Meister J, Sarrafzadegan H, Thelen S, Gutknecht N. Influence of the pulse duration of an Er:YAG laser system on the ablation threshold of dental enamel. Lasers Med Sci 2002;17(4):253-257
11. Walsh JT, Cummings JP. Effect of the dynamic optical properties of water on midinfrared laser ablation. Lasers Surg Med 1994;15(3):295-305
12. Turkun M, Turkun LS, Celik EU, Ates M. Bactericidal effect of Er, Cr: YSGG laser on Streptococcus mutans. Dent Mater J 2006;25(1):81-86.
13. Garden JM, O'Banion MK, Bakus AD, Olson C. Viral disease transmitted by laser-generated plume (aerosol). Arch Dermatol 2002;138(10):1303-1307
14. Parker S. Laser regulation and safety in general dental practice. Br Dent J 2007;202(9):523-532
15. Galui S, Pal S, Mahata S, Saha S, Sarkar S. Laser and its use in pediatric dentistry: a review of literature and a recent update. Int J Pedod Rehabil 2019;4(1):1-5
16. Montedori A, Abraha I, Orso M, D'Errico PG, Pagano S, Lombardo G. Lasers for caries removal in deciduous and permanent teeth. Cochrane Database Syst Rev 2016;9(9):CD010229 doi:10.1002/14651858.CD010229.pub2
17. Sweeney C. Laser safety in dentistry. Gen Dent 2008;56(7):653-767
18. Baraba A, Kqiku L, Gabrić D, Verzak Ž, Hanscho K, Miletić I. Efficacy of removal of cariogenic bacteria and carious dentin by ablation using different modes of Er:YAG lasers. Braz J Med Biol Res 2018;51(3):e6872 doi:10.1590/1414-431X20176872
19. Sancakli H, Siso S, Yildiz S, Gokce Y. Antibacterial effect of surface pretreatment techniques against Streptococcus mutans. Niger J Clin Pract 2018;21(2):170-175
20. Aytac Bal F, Ozkocak I, Cadirci BH, Sirin Karaarslan E, Cakdinleyen M, Agaccioglu M. Effects of photodynamic therapy with indocyanine green on Streptococcus mutans biofilm. Photodiagnosis Photodyn Ther 2019;26:229-234
21. Shamsudeen S, Thavarajah R, Joshua E, Rao U, Kannan R. Evaluating and comparing the morphological and histopathological changes induced by erbium:yttrium-aluminum-garnet laser and diamond bur on enamel, dentin and pulp tissue. J Investig Clin Dent 2019;10(4):e12475 doi:10.1111/jicd.12475
22. Nerushay I, Krejci I, Ryabova A, Bortolotto T. Influence of pulse duration when performing Er:YAG laser irradiation on dental tissues. Am J Dent 2019;32(2):61-68
23. Bakry AS, Sadr A, Takahashi H, Otsuki M, Tagami J. Analysis of Er:YAG lased dentin using attenuated total reflectance fourier transform infrared and x-ray diffraction techniques. Dent Mater J 2007;26(3):422-428
24. Nahas P, Zeinoun T, Namour M, Ayach T, Nammour S. Effect of Er:YAG laser energy densities on thermally affected dentin layer: Morphological study. Laser Ther 2018;27(2):91-97

25. Moosavi H, Ghorbanzadeh S, Ahrari F. Structural and morphological changes in human dentin after ablative and subablative Er:YAG laser irradiation. J Lasers Med Sci 2016;7(2):86-91

26. Du Q, Ge L, Zhang S, Zhang Q. Effects of erbium:yttrium-aluminum-garnet laser irradiation on bovine dentin contaminated by cariogenic bacteria. Photobiomodul Photomed Laser Surg 2019;37(5):305-311

27. Moghaddas MJ, Moosavi H, Yaghoubirad S, Chiniforush N. The effect of the bioactive glass and the Er:YAG laser on the remineralization of the affected dentin: a comparative *in vitro* study. J Lasers Med Sci 2020;11(2):160-166

28. Valério RA, Galo R, Galafassi D, Corona SAM, Borsatto MC. Four-year clinical prospective follow-up of resin composite restoration after selective caries removal using Er:YAG laser. Clin Oral Investig 2020;24(7):2271-2283

29. Tsuchiya S, Nikaido T, Sonoda H, Foxton RM, Tagami J. Ultrastructure of the dentin-adhesive interface after acid-base challenge. J Adhes Dent 2004;6:183-190

30. Chinelatti MA, Rocha CT, Colucci V, Serra MC, Rodrigues-Júnior AL, Corona SAM. Effect of Er: Yag laser on dentin demineralization around restorations. Lasers Med Sci 2017;32(2):413-418

31. Abbasi M, Nakhostin A, Namdar F, Chiniforush N, Tabatabaei MH. The rate of demineralization in the teeth prepared by bur and Er: YAG laser. J Lasers Med Sci 2018;9(2):82-86

32. Hajizadeh H, Nemati-Karimooy A, Babaee-Rishkhori P. Effect of erbium:yttrium-aluminum-garnet laser combined with mineralizing agents on microhardness of demineralized dentin. Eur J Dent 2019;13(1):11-16

33. Bakry AS, Nakajima M, Otsuki M, Tagami J. Effect of Er:YAG laser on dentin bonding durability under simulated pulpal pressure. J Adhes Dent 2009;11(5):361-368

34. Sano H, Takatsu T, Ciucchi B, Horner JA, Matthews WG, Pashley DH. Nanoleakage: leakage within the hybrid layer. Oper Dent 1995;20(1):18-25

35. De Moor RJ, Delme KI. Laser-assisted cavity preparation and adhesion to erbium-lased tooth structure: part 2. present-day adhesion to erbium-lased tooth structure in permanent teeth. J Adhes Dent 2010;12(2):91-102

36. Mazzoni A, Tjäderhane L, Checchi V, Di Lenarda R, Salo T, Tay FR, et al. Role of dentin MMPs in caries progression and bond stability. J Dent Res 2015;94(2):241-251

37. de Oliveira MT, Reis AF, Arrais CAG, Cavalcanti AN, Aranha ACC, de Paula Eduardo C, et al. Analysis of the interfacial micromorphology and bond strength of adhesive systems to Er:YAG laser-irradiated dentin. Lasers Med Sci 2013;28(4):1069-1076

38. Comba A, Baldi A, Tempesta RM, Cedrone A, Carpegna G, Mazzoni A, et al. Effect of Er: YAG and burs on coronal dentin bond strength stability. J Adhes Dent 2019;21(4):329-335 doi:10.3290/j.jad.a42932

39. Ando Y, Aoki A, Watanabe H, Ishikawa I. Bactericidal effect of erbium YAG laser on periodontopathic bacteria. Lasers Surg Med 1996;19(2):190-200

40. Schoop U, Moritz A, Kluger W, Patruta S, Goharkhay K, Sperr W, et al. The Er: YAG laser in endodontics: results of an *in vitro* study. Lasers Surg Med 2002;30(5):360-364

41. Dostálová T, Jelínková H, Houšová D, Šulc J, Němeć M, Dušková J, et al. Endodontic treatment with application of Er: YAG laser waveguide radiation disinfection. J Clin Laser Med Surg 2002;20(3):135-139

42. Cvikl B, Moritz A, Bekes K. Pit and fissure sealants—a comprehensive review. Dent J (Basel) 2018;6(2):18 doi:10.3390/dj6020018

43. Lepri TP, Souza-Gabriel AE, Atoui JA, Palma-Dibb RG, Pécora JD, Milori Corona SA. Shear bond strength of a sealant to contaminated-enamel surface: influence of erbium:yttrium-aluminum-garnet laser pretreatment. J Esthet Restor Dent 2008;20(6):386-394

44. Mohammad Y, Yassin O, Hardan L, Hamadah O, Abbara MT. An evaluation of Er: YAG laser in an intact enamel treatment on bonding to the resin cement compared to four traditional techniques. J Contemp Dent Pract 2019;20(9):1014-1018

45. Lupi-Pégurier L, Bertrand M-F, Genovese O, Rocca J-P, Muller-Bolla M. Microleakage of resin-based sealants after Er:YAG laser conditioning. Lasers Med Sci 2007;22(3):183-188

46. Matson JR, Matson E, Navarro RS, Bocangel JS, Jaeger RG, Eduardo CP. Er: YAG laser effects on enamel occlusal fissures: an *in vitro* study. J Clin Laser Med Surg 2002;20(1):27-35

47. Bengtson AL, Gomes AC, Mendes FM, Cichello LRD, Bengtson NG, Pinheiro SL. Influence of examiner's clinical experience in detecting occlusal caries lesions in primary teeth. Pediatr Dent 2005;27(3):238-243

48. Shanthi M. Laser prescience in pediatric dentistry. Int J Sci Stud 2015;3(2):197-203

49. Cozean C, Arcoria CJ, Pelagalli J, Powell GL. Dentistry for the 21st century? Erbium:YAG laser for teeth. J Am Dent Assoc 1997;128(8):1080-1087

50. Aljdaimi A, Devlin H, Dickinson M. Effect of the Er: YAG laser on the shear bond strength of conventional glass ionomer and Biodentine to dentine. Eur J Dent 2018;12(3):380-385

51. Lizarelli RFZ, Moriyama L, Bagnato V. Ablation of composite resins using Er:YAG laser?comparison with enamel and dentin. Lasers Surg Med 2003;33:132-139

52. Pillai R, Sujathan U-N, Jacob A, Abdulsalim A, Sainudeen S. Hard tissue lasers: An insight. J Interdiscip Dentistry 2014;4(3):110-117

53. Armengol V, Jean A, Marion D. Temperature rise during Er:YAG and Nd:YAP laser ablation of dentin. J Endod 2000;26(3):138-141

54. Karadas M, Çağlar İ. The effect of Er:YAG laser irradiation on the bond stability of self-etch adhesives at different dentin depths. Lasers Med Sci 2017;32(5):967-974

55. De Coster P, Rajasekharan S, Martens L. Laser-assisted pulpotomy in primary teeth: a systematic review. Int J Paediatr Dent 2013;23(6):389-399

56. Olivi G, Genovese MD, Caprioglio C. Evidence-based dentistry on laser paediatric dentistry: review and outlook. Eur J Paediatr Dent 2009;10(1):29-40

57. Olivi G, Genovese MD, Maturo P, Docimo R. Pulp capping: advantages of using laser technology. Eur J Paediatr Dent 2007;8(2):89-95

58. Neena IE, Poornima P, Edagunji G, Roopa KB, Bharath KP. Lasers in pediatric dentistry: a review. Int J Contemp Dent Med Rev 2015:030115 doi:10.15713/ins.ijcdmr.29

59. Toomarian L, Fekrazad R, Sharifi D, Baghaei M, Rahimi H, Eslami B. Histopathological evaluation of pulpotomy with Er,Cr:YSGG laser vs formocresol. Lasers Med Sci 2008;23(4):443-450

60. Ramazani N, Ahmadi R, Daryaeian M. Oral and dental laser treatments for children: applications, advantages and considerations. J Lasers Med Sci 2012;3(1):44-49