Laser restorative dentistry in children and adolescents

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Abstract

BACKGROUND: The idea of substituting a drill with a laser light, has led to its introduction in dentistry. Besides being more accepted to patients, in paediatric dentistry the laser has demonstrated safety compared with rotating instruments. **REVIEW:** A review of the past 20 years of the dental literature concerning laser use in dentistry, including paediatric dentistry was completed. The findings of that review are presented. **TECHNIQUES:** The various types of lasers and their uses for caries detection, tooth sealing and caries removal are described. **RESULTS:** Laser caries detection demonstrated a good reproducibility, reliability and predictability to monitor the caries process over time. Erbium lasers have been found to be efficient for caries removal, tooth cleaning and decontamination. **CONCLUSION:** The laser erbium technology represents a safe device to effectively and selectively remove carious tissues from decayed teeth. For children, all the recognized advantages of this technique play a decisive role in the successful day-to-day treatment of dental caries.

Background

The idea of substituting a drill with a laser light which has less adverse effects on patients, without vibration, noise and pain, has led to its introduction in dentistry. Lasers are extremely safe compared with rotating instruments, especially in paediatric dentistry, when used in the treatment of very young children, due to the lower risk of accidental damage to soft tissues and pulp tissue. Lasers bring new possibilities for safe and minimal removal of carious tissue with better acceptance compared with traditional techniques [Wigdor, 1997; Keller et al.,1998; Parkins, 2000; Matsumoto et al., 2002; Takamori et al., 2003; Boj et al., 2005; Liu et al., 2006; Genovese and Olivi, 2008]. It is important to observe the rules of safety, such as the use of specific protective glasses according to the wavelength used, as well as choosing the appropriate size glasses for the face of the child.

Nowadays, as reported by Martens [2003, 2011] and emphasised by Gutknecht et al. [2005], 'children are the first in line to receive dental laser treatment' and based on micro-dentistry's comment 'filling without drilling'. Thus, the philosophy of laser-supported dental diagnosis and treatment is becoming a gold-standard to treat children successfully, according to the latest extensive publications in paediatric dentistry [Olivi et al., 2010; Martens 2011].

Laser usage. Lasers are commonly used on hard tissues in paediatric dentistry in the following fields:

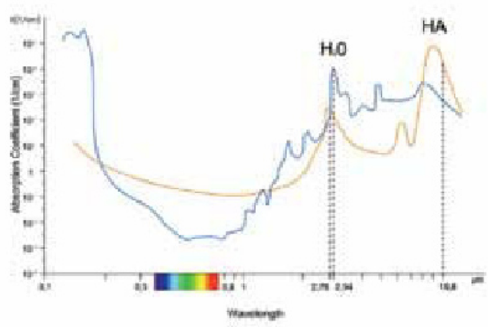
- Diagnosis,
- Preventive dentistry,
- Restorative dentistry,
- Endodontics.

For the purpose of this paper, the authors consider only the procedures limited to restorative dentistry, and also include some mention of caries diagnosis by laser and laser-assisted techniques in caries prevention.

Lasers in dentistry

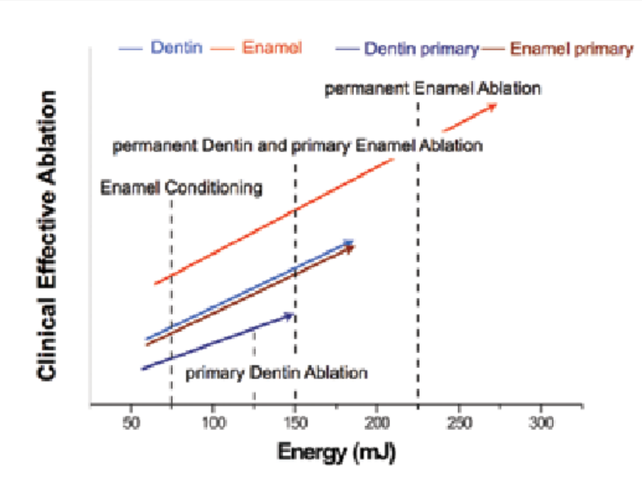
Basic physics in the use of lasers. Laser-tissue interaction depends on the effects of different wavelengths on the different hard tissue treated. The interaction is primarily determined by the wavelength's affinity for specific chromophores of different tissues [Parker et al., 2007]. The main chromophores of dental tissues are the hydroxyapatite and the water content within the hydroxyapatite crystals of enamel and dentine that highly absorb medium infrared wavelengths (2,780nm and 2,940nm), (Fig. 1).

Figure 1. *Absorption of mid-infrared Er,Cr:YSGG and Er:YAG lasers light in water (blue line) and in hydroxyapatite (orange line).*



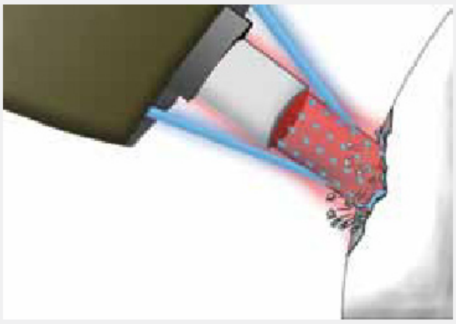
For the purpose of restorative paediatric dentistry, the application of laser energy on dental tissues takes into account only the water content of healthy, demineralised and carious dental tissues (enamel and dentine), as the interaction with hydroxyapatite has only a minor and negligible role. Consequently it is important to consider the different water content of healthy enamel and dentine, the different composition of primary and permanent teeth, both in youths and adults, when choosing the parameters of laser use. Moreover carious tissues are demineralised and richer in water in comparison with healthy and/or non-vital teeth. This concept is important to understand because more energy will be needed for enamel and less energy for carious tissue, depending on different absorption of different water content in the tooth (different ablation thresholds of dental tissues) (Fig. 2).

Figure 2. *Clinically effective ablation energy for primary and permanent dentine and enamel.*



It is also important to emphasise the ablation of the organic component of dentine (collagen) that affects the adhesion of bonding filling materials. The physical properties involved in the ablation of hard tissues by the erbium family of lasers is based on the transfer of laser energy to the tissues that causes different phenomena that rapidly occur, which are thermal and thermo-mechanical phenomena. The first mechanism of action of the erbium family lasers on hard tissues is a thermal effect on the water molecules within the tissues. Once the energy is absorbed by the water, it is converted into heat, causing superheating, and vapourisation. The increased steam pressure produces micro-explosive expansion within the hard tissue itself, causing the tissue to blast away [Hadley et al., 2000; Hirota and Furumoto, 2003] (Fig. 3).

Figure 3. *Mechanism of tooth ablation: the fast shock wave, created from erbium laser absorption, causes a massive disruptive volume expansion and enormous subsurface pressures. As a result the surrounding mineral matrix is blasted away and the fractured particles of tooth are ejected resulting in tooth ablation.*

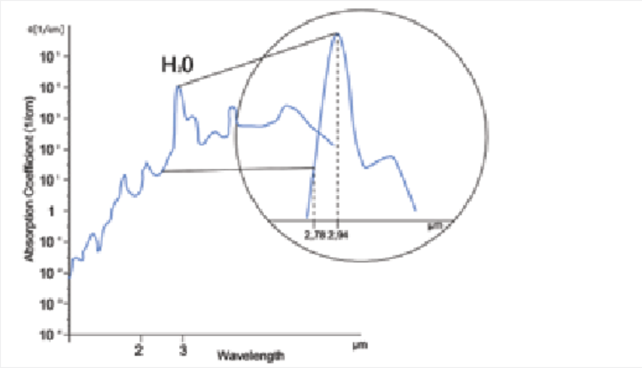


In addition, the use of an external water spray has a decisive role effectively and efficiently influencing the ablation rate, as well as for the cleaning and debriding and cooling effects on the dental tissues. Even if an unambiguous precise mechanism has not yet been demonstrated. Additional research is necessary to clearly explain the mechanism of the laser hard tissue interaction.

The two different wavelengths work in a similar way, even if with slightly lower absorption (38%) and consequently higher penetration depth into hard dental tissues (up to >15-21 µm for dentine and enamel) results for Er,Cr:YSGG laser (2780nm) compared with Erbium:YAG (up to > 5-7 µm for dentine and enamel) [Prhavec and Diaci, 2008] (Fig. 4).

A common consensus about the values of absorption coefficient and energy penetration depth has not been yet reached. The ablation threshold is currently known to be about 12-20 J/cm^2 for enamel and 8-14 J/cm^2 for dentine for Er:YAG and Er,Cr:YSGG respectively [Harris et al., 2002]. Other authors found slightly different values, respectively of 9-11 J/cm^2 for Er:YAG and of 10-14 J/cm^2 for Er,Cr:YSGG [Apel et al., 2002].

Figure 4. *Absorption in water (blue line) between Er:YAG and Er,Cr:YSGG lasers.*



Lasers for caries detection and diagnosis. Laser fluorescence has been proposed for the diagnosis of caries in both primary and permanent teeth (655nm). This is the application investigated most frequently and most in depth of all the laser applications in paediatric dentistry. Of the papers indexed under the subject heading 'Laser Paediatric Dentistry' in PubMed, more than 40 studied the use of this device for carious detection. This non-ablative laser (LF) emits a laser fluorescence light, visible in the red spectrum at 655nm, which has proved to be useful to complete conventional methods for occlusal caries detection (Fig. 5).

Several studies compared different caries detection methods: visual inspection alone, visual inspection with magnification, bitewing radiographs and laser fluorescence. Lussi et al. [2003] affirmed that LF could be used as an additional tool in the detection of occlusal caries in primary teeth and its good reproducibility should enable the laser device to monitor the caries process over time. Other authors [Burin et al., 2005; Mendes et al., 2006; Barberia et al., 2008] considered the fluorescence device better than bitewing radiographs for occlusal caries detection.

Figure 5. *Laser fluorescence diagnosis of the occlusal fissures in a maxillary permanent molar.*

Some studies investigated the impact of the operator on the results and concluded that the reliability, predictability and the reproducibility of the results did not depend on the operator [Bengtson et al., 2005]. Other studies reported that LF methods for occlusal caries are more efficient in primary than in permanent teeth, but concluded that laser fluorescence was not able either to detect in vitro remineralisation of natural incipient caries lesions of primary teeth nor to monitor the quantification of mineral loss in caries lesions development in primary teeth [Mendes et al., 2003]. A recent study [Braga et al., 2008] reported that a LF device performs better at the dentine than at the enamel threshold.They therefore concluded that this method does not perform well in detecting initial enamel caries lesions, confirming the previous studies of the same group that demonstrated a good performance of LF in predicting the extension of the caries lesions. LF presents a better correlation with the lesion depth than with mineral loss in smooth surface caries lesions and the quantification of mineral loss was undesirable.

Chu et al. [2010] studied the validity of three different methods for fissure caries detection in 144 second molars with intact occlusal surfaces in 41 young adults, including visual examination, bitewing radiographs, and the use of a DIAGNOdent. The combined approach of this device and visual examination was found to be superior. Huth et al. [2008] concluded that the DIAGNOdent's discrimination performance for various carious depths in permanent molars was moderate to very good and it may be recommended as an adjunct instrument in the diagnosis of occlusal caries.

Khalife et al. [2009] performed an in vivo study that assessed the correlation between the depth and volume of caries as it was removed by handpieces with DIAGNOdent readings and they also concluded that this device should be used as an adjunct in the diagnosis and treatment planning process.

Iwami et al. [2004] studied the relationship between bacterial infection of the dentine and the evaluation of a laser fluorescence device, DIAGNOdent. This in vitro study investigated the polymerase chain reaction (PCR) to a fluorescence device in the carious dentine. The values of the DIAGNOdent increased as the rates of detection of the bacteria increased reinforcing the conclusion of the relationship between the DIAGNOdent fluorescence values of dentine caries and the rates of bacterial detection. Virajsilp et al. [2005] confirmed the reliability and the diagnostic validity (sum of sensitivity and specificity) of LF as very high and also reported it as higher than that of bitewing radiography for proximal caries detection in primary teeth. Also the caries detection of approximal tooth surfaces might be influenced by the condition of the adjacent tooth surface.

Novaes, et al. [2009] in a recent study, compared the performance of various methods of interproximal caries detection in primary molars. The examiners evaluated 621 approximal surfaces of 50 children aged 5-12 years. They used visual inspection, radiographic examination, and the LF pen device. Both the LF pen and radiographic examination exhibited similar performance in the detection of the presence of cavitation on interproximal surfaces of primary molars. In a similar study by Costa et al. [2008] it was concluded that the laser device had an acceptable performance and that this device should be used as an adjunct method to visual inspection in order to avoid false positive results.

Several studies investigated particular situations that could condition the results of the readings: the presence of brown or dark spots on fissures tended to overscore discoloured surfaces [Francescut and Lussi, 2003] while the presence of plaque worsened the performance of the laser fluorescence method [Mendes et al, 2004]. Also, the presence of toothpaste residual after teeth cleansing can modify the detection, registering false readings [Lussi and Reich, 2005]. Caries detection under dental sealants was unreliable and not recommended due to a high likelihood of inaccurate readings caused by intrinsic fluorescence of sealant material [Manton and Messer, 2007].

Lasers in preventive dentistry. Laser irradiation has been thought in preventive dentistry to provide enamel surface resistance to caries: several laser wavelengths, including 2940nm, 2780nm, 9300nm, 9600nm and 10600nm, have been proposed for superficial ultra-structural modifications and acid-resistance increase, tested by cross-sectional micro-hardness and enamel solubility analysis since 1980s [Featherstone et al., 1997; Apel et al., 2004]. Today, several studies on these applications have been done which present more or less uniform results while on the other hand clinical studies and evidences are extremely limited. Sub-ablative CO_2 and erbium family laser irradiation's ability to increase the acid resistance of permanent young healthy teeth could be an effective method of caries prevention [Featherestone et al., 1998; Apel et al., 2004]. Long-term clinical studies are necessary to validate this application before an extensive use of this procedure.

Laser-assisted pits and fissures conditioning prior to sealant application (LAS). The use of laser pre-treatment of pits and fissures, before application of fissure sealant (FS) on the occlusal surface of young teeth was investigated by several in vitro studies, performed to evaluate the bond strength and the microleakage of pit and FS, comparing invasive and non-invasive techniques to laser technique, with or without acid etching. Most of these studies reported no significant difference between the two types of enamel preparation when etching was performed [Matson et al., 2002; Borsatto et al., 2004; Moshonov et al., 2005; Francescut et al., 2006; Youssef et al., 2006; Borsatto et al., 2007; Lupi-Pégurier et al., 2007; Lepri et al., 2008 Sungurtekin et al., 2009]. These studies concluded that laser irradiation did not eliminate the need for acid etching enamel prior to the placement of a pit and FS, which remains a critical step in the bonding procedures. Nevertheless laser technology may be considered to be an additional tool in the FS application procedure (LAS) and also in preventive resin restoration (LPRR), for the conditioning (macro-roughening), cleansing and disinfecting action on the fissure and pits enamel surface. This is especially so when the laser is used in the treatment of initial lesions in combination with laser diagnosis (LF) of pits and fissures, allowing a truly minimally invasive preparation of decayed tissues (LPRR) [Olivi et al., 2011]. Used in this way, the erbium lazer can perform a fissurotomy (invasive technique at 150-200mJ, with 400-600micron tip) only in the areas showing a positive result with laser diagnosis (LF score value from 11-20mJ to 21-30mJ), or a macro-roughening (non-invasive technique at 65-75mJ) when the LF resulted in healthy enamel surface (LF score value of 0-10), with the advantage of leaving the surfaces decontaminated and clean. Care must be taken with the energy applied (65-75mJ, with 400-600micron tip) to the healthy enamel fissures, so as not to over prepare the pit and fissure enamel surfaces. By selecting a different energy for different healthy or carious areas, we are able to work selectively, ablating the carious tissue or conditioning the healthy tissue, performing a truly minimally invasive technique. (Fig. 6a-f and Table 1).

Table 1. *Suggested parameters from the authors for laser-assisted sealant (LAS) and for laser minimally invasive pit and fissures preparation.*

Parameter	LAS	PRR
Energy	65 – 75mJ	150>200mJ
Pulse repetition rate	10 – 20Hz	20-25Hz
Power	0.65 -1,5W	3.0>5.0W
Tip	400-600µ	600 µ
Pulse duration	100-300 µsecs	
Operative mode	Continuous movement – high ratio of air water spray – focused	

Figure 6a. *Pre-operative view of a 2nd premolar and first mandibular molar in a 13 year old boy, before laser detection.*

Figure 6b. *Erbium Chromium YSGG laser decontamination and debridment of occlusal fissures and pits is advisable depending on the fissure depth and the laser fluorescence value.*

Figures 6c-e. *Molar and premolar occlusal surfaces after laser conditioning and orthophosphoric acid etching (37% for 20sec).*

Figure 6f. *Application of resin sealant and post-operative view.*

Lasers in restorative dentistry. The erbium family lasers can be used in restorative dentistry for:

- minimally invasive preparation of pits and fissures, according to laser detection values (LPRR) (Fig. 7a-d),
- minimally invasive preparation of hypoplastic lesions (Fig. 8),
- gingivectomy (when needed for the restoration) (Fig. 9),
- cavity preparation: from class I to class V,
- treatment of deep dentinal caries (indirect pulp capping),
- laser-assisted pulp capping (LAPC).

Figure 7a. *Class I cavity in mandibular primary tooth in 7 year old boy.*

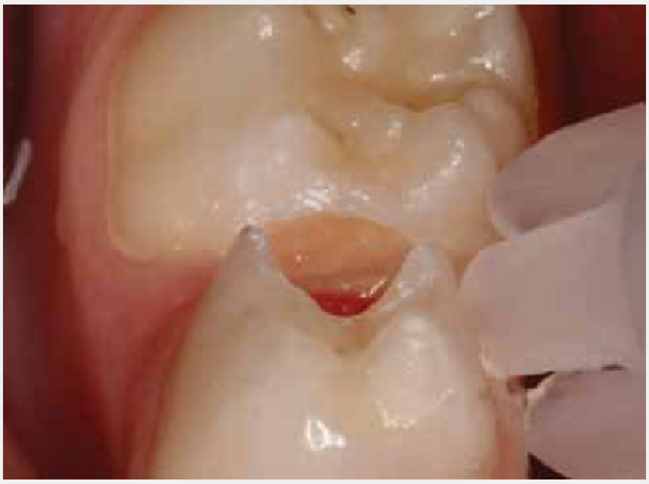
Figure 7b. *After laser fluorescence detection, an erbiumYAG laser was used for minimally invasive cavity preparation of the pits and laser conditioning of healthy fissures.*

Figure 7c. *Isolation with rubber dam prior to composite resin filling.*

Figure 7d. *Composite resin filling completed.*

Figure 8. *Mandibular incisor post-traumatic hypoplastic lesion of the enamel: erbium laser enamel preparation in 7 year old girl.*

Figure 9. *Gingivectomy to access the margins of subgingival cavities of 1st and 2nd mandibular molars in a 4 year old girl.*



Laser preparation of carious cavities compared with traditional techniques presents various advantages and some disadvantages. The advantages can be operative or clinical and include (see Table 2), these are:

- Better patient acceptance (no contact – no vibration – no noise – no or less use of anesthesia); (Fig. 10a,b),
- Better acceptance by parents, who see the high technology and the professional using it as a better therapeutic option for their children,
- Minimally invasive cavity preparation due to the selective absorption of laser light by carious tissue,
- Preparation of cavities with macro-roughened surface that increases the surface for the adhesion of composite material,
- Very clean cavities and free of smear layer,
- Cavity preparation that is highly decontaminated,
- Minimal thermal increase in the pulp chamber, less than with traditional techniques, with the possibility of less post-treatment sensitivity,
- Possibility of sealing the dentine tubules (when needed),
- Possibility of treating soft and hard tissue at the same time and with the same instrument: for example, gingivectomy to access the margins of subgingival cavities or a pulpotomy and the coagulation of the exposed pulp (Fig. 11).

Table 2. *Operative and clinical advantages of laser treatment in restorative dental treatment.*

Operative Advantages:	
Safety	No rotating or cutting instruments used in the mouth
Comfort	No contact – no vibration – no noise
Painless	Reduction of need for local anesthesia or no anesthesia
Approach	Improved patient compliance
Clinical Advantages	Minimally invasive: selective for carious tissue
Decontaminating effect: of deep caries	Micro-retentive surface: cleaned and debrided surface
Less rise in temperature	In pulp and periodontal surface during the irradiation
Direct pulp capping indication	Coagulation/bactericidal
Soft tissue application	Exposure of subgingival tooth margins during cavity preparation

Figure 10a and b. *Patient acceptance of laser therapy: four-handed laser cavity preparation in relaxed 5 year-old boy.*

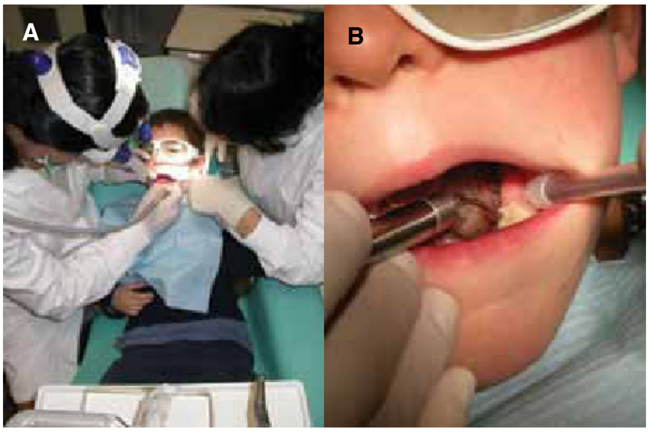


Figure 11. *Deep decay in 2nd maxillary molar in 9 year old girl needing pulpotomy, performed with an erbium:YAG laser.*

Some of the disadvantages of laser therapy compared with traditional techniques are:

- Longer learning curve,
- Equipment costs, time and cost of training,
- Cavity margins that are less finished compared to traditional mechanical techniques,
- Bond strength results lower or equal to traditional techniques,
- Microleakage results lower or equal to traditional techniques.

A careful evaluation of the advantages/disadvantages as outlined point by point above has brought about some modifications in laser preparation techniques, since its introduction in the '90s, improving laser cavity preparation and Minimising the disadvantages.

Laser advantages in paediatric dentistry

Lasers and analgesia. A correct psychological approach to the patient also contributes considerably to the success of laser therapy, which is often seen by patients and their families as something magical. The actual absence of contact and vibration and therefore its lower impact, is suggested by some authors as the potential factor in provoking pain and discomfort during tooth preparation [Takamori et al., 2003; Tanboga et al., 2011].The laser, if used correctly, generates an analgesic effect in the irradiated area caused by a temporary loss of conductance of the nervous impulse due to the disruption of the Na^+/K^+ pump of the cell membrane of the nervous fibre. This results in a loss of impulse conduction, and therefore an analgesic effect occurs [Moritz, 2006]. There is evidence that laser irradiation causes a membrane hyperpolarisation and in order to initiate a potential action, a stimulus of greater intensity is necessary [Benedicenti, 1979, 2005] also raising the threshold of pain of the patient [Genovese and Olivi, 2008]. In addition laser irradiation may selectively target fibres conducting at slow velocities, especially afferent axons from nocioceptors. It has been estimated that the duration of the analgesic effect of the pulp is approximately 15 minutes and no adverse pulpal changes have been seen histologically over short or long periods [Moritz, 2006]. All the wavelengths at a sub-ablation power, especially those of the near infrared laser (803-980nm), can produce analgesia at the irradiated site in a defocused mode with a grating (scanner) technique and raising energy.

For the optimal analgesic effect in restorative dentistry, it has been to initially hold the laser tip 6-10 mm from the tooth and running slowly around the neck of the tooth for 40-60 sec at 25-50mJ, 10-15Hz, with a low air/water ratio of the integrated spray. Gradually increasing the energy level to 75-80mJ after the first 60 seconds, always in a defocused mode helps. Then, increasing the pulse repetition rate up to 20-25pps, the energy and the air/water up to the minimum effective threshold, the laser beam is focused and the ablation began [Olivi et al., 2011]. It is better to spend more time in inducing analgesia before starting the ablation, avoiding the stimulation of pain, than to interrupt the therapy if an incorrect initial procedure has been performed Fig. 12a-d.

Figures 12a and b. *Tell, show, do technique for visual demonstration of laser therapy in 9 year old child.*

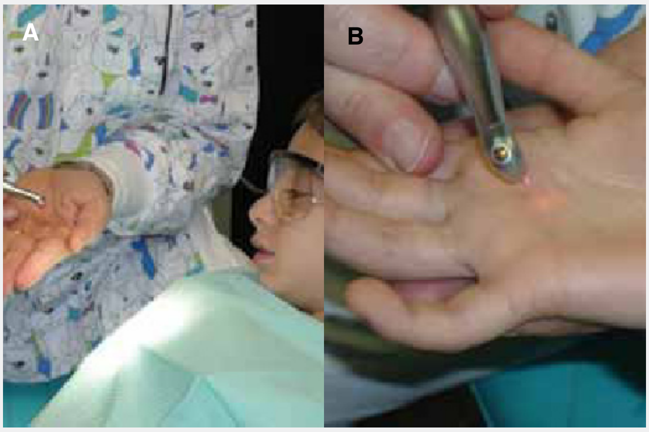


Figure 12c. *Laser analgesia, irradiating in defocused mode and low energy output at the marginal gingiva.*

Figure 12d. *Class II laser cavity preparation.*

Laser cavity design: micro-macro morphological aspects. The laser-prepared cavity does not follow the rules of cavity design by Black, but follows instead the rules of minimally invasive dentistry, as the selectivity of action on the carious tissue, using the erbium laser with the appropriate energy, allows the removal of all the carious tissue and minimally the healthy tissue. The more careful we are with the selective ablation, the more the resulting cavity design will correspond to the extent of the carious process. Therefore should we have no more pre-ordained cavity designs, but different designs for different clinical situations [Olivi et al., 2007, 2008]. The laser-prepared cavities are very clean and decontaminated, with no smear layer, and also present a macro-roughened surface that increases the surface effectively exposed for the adhesion procedure [Olivi et al., 2008].

Pulp temperature. Numerous studies agree that less thermal increase occurs in the pulp chamber during cavity preparation, demonstrating that laser treatment does not cause an inflammatory reaction of the pulp [Dostalova et al., 1997; Eversole et al., 1997]. This important data is especially so in dental trauma [Olivi et al., 2010; Caprioglio et al., 2010] and in the treatment of cavities with deep caries [Olivi et al., 2006, 2007]. This has been subsequently confirmed by other authors [Glockner et al.,1998], who also emphasised how no variation in the environmental temperature of 37°C occurred in the first 3-4 secs while subsequently there was even a decrease in the temperature that remained at about 25-30°C.

A recent study [Krmek et al., 2009] summarises all these concepts with very promising results about the efficacy and the safety of the use of the erbium laser in conservative cavity preparation. The highest rise in temperature in the pulp was achieved with the highest energy used on the enamel (400 mJ and 15 Hz) and the lowest with the lowest energy (320 mJ and 10 Hz). The temperature rise ranged from a maximum of 1.99 +/- 0.28 °C to a minimum of 0.70 +/- 0.18 °C. In dentine the highest temperature increase was achieved with 340 mJ and 10 Hz (1.37 +/- 0.42 °C), and the lowest was with 200 mJ and 5 Hz (0.43 +/- 0.18 °C). Two-way analysis showed that the influence of energy on temperature increase was stronger than that of frequency. Table 3 shows the parameters for the use of the laser erbium, chromium:YSGG and erbium:YAG in restorative procedures and also shows the suggested parameters for cavity preparation, dentine decontamination and pulp coagulation.

Erbium laser soft tissue use. The use of the erbium laser on soft tissue is extremely effective especially in conservative therapy, to expose the subgingival cervical margins of the carious cavity (Figs. 9 and 12d). The quantity of tissue to be removed is generally limited and the procedure is absolutely asymptomatic. Actual crown lengthening that invades the biological width of the gingival tissue is rare in paediatric restorative dentistry, usually only performed in the case of coronal fractures. This procedure is traditionally performed

Table 3. Suggested parameters for laser cavity preparation, decontamination and conditioning for anterior permanent teeth and primary teeth.

Er,Cr:YSGG and Er:YAG Laser settings for Primary teeth (all the cavities) and Permanent anterior teeth			
Clinical Indications	**Pulse Frequency (Hz)**	**Energy (mJ) Power (W)**	**Operative mode continuous movements**
Enamel conditioning before acid etching	10>20>50	65>75 0.65>3.75W	Contact-handpiece, at 1,5mm high air: water spray ratio
Cavity preparation enamel	20>25	150-200 3.0>4.5W	Contact-handpiece at 1,5mm high air: water spray ratio
Cavity preparation dentine	15>20	120>100 1.8>2.0W	Contact-handpiece, at 1,5mm high air: water spray ratio
Carious tissue	20>25	75>80 1.5>2.0W	Contact-handpiece, at 1,5mm high air: water spray ratio
Dentine conditioning before acid etching	10>20	50 0.5>1.0W	Defocused at 4-5mm high air: water spray ratio
Dentine melting	10>20 per 5>10 sec	25 0.25>0.5W	Defocused at 4-5mm low air: water spray ratio
short pulse duration 100-300 microseconds tip 400 µm to 600 µm			

with analgesia due to the need to remove both bone and gingival tissue to maintain the biological width. It can be performed effectively with erbium lasers, for their capacity to work on both bone tissue and gingival tissue.

Erbium laser conservative therapy of the pulp. Erbium lasers have also been found to be very effective in the performance of partial pulpotomy and coagulation of the exposed pulp, in pulp capping procedures [Olivi and Genovese, 2006; Olivi et al., 2007]. This is due to the decontaminating and superficial coagulating action, with minimum transfer of energy to the underlying pulp in reversible hyperaemia. Obviously the success of the procedure also depends on the correct diagnosis of reversible pulpitis or accidental exposure of the pulp.

Few studies are indexed in PubMed that investigate laser use in maintaining pulp tissue vitality. The common delineator has been the low laser energy applied according to the different wavelength used (from 0.5 to 1.0W), delivered in defocused mode. Preferably this should be in pulsed or super-pulsed mode with low frequency for better control of the irradiation, defocused, without water, and must not exceed 10 secs to obtain coagulation. The procedure can be repeated after 30 secs, the time needed for the pulp tissue to cool.

Olivi and Genovese [2006] first reported the advantages of in vivo use of the Er,Cr:YSGG laser, as a single minimally invasive instrument for carious removal and pulp coagulation. Laser irradiation avoided over-preparation and overheating of the residual dental tissue, with tooth survival of 80% after 4 years. In another study [Olivi et al., 2007] conducted at the Paediatric Department of the University of Tor Vergata (Rome) a comparison was presented of the efficacy of Er,Cr:YSGG and Er:YAG lasers, with conventional calcium hydroxide procedure. An 80% success rate was reported in the Er,Cr:YSGG group, 75% in the Er:YAG group, while the control group presented 63% success after 2 years.

Other wavelengths have been suggested for this procedure, mainly by Moritz et al. [1998a, b], with the CO_2 laser, who reported 89% and 93% success rates after 1 and 2 years compared with 68% and 66% for the calcium hydroxide control group. This was due to the purely thermal effect on the tissue due to CO_2 that is absorbed by a fine tissue layer (100µ) and transformed into heat.

Critical evaluation of disadvantages

Education, cost and investment return. Even if laser technology is intuitive, it also requires specific knowledge and a refined performance technique because it is a non-contact procedure. Instruction at a university or other academic site together with a period of training is necessary before approaching a patient, especially a child, The costs of equipment, the time it takes to train and the relative costs are however generously repaid by the clinical results and the range of procedures that can be performed in a simple, safe and efficacious way in diverse branches.

Lasers and adhesive dentistry. The studies in the literature on this topic have taken into consideration tests both of microleakage and of bond strength, performed by laser alone, with or without acid etching and compared with traditional techniques. The reported results are very disparate and contrasting, both with permanent and primary teeth. Based on these references, it is difficult to arrive at any conclusions, because the studies cannot be compared for various reasons, as the variables occur in multiple areas: different power density and fluence used are only one aspect of the energy delivered to the target tissue. Air/water flow and pressure of the integrated spray, the pulse length, the beam profile, are other parameters that affect the results of the laser tissue interaction, together with operator factors such as laser angulation, focus mode, hand speed movement: if incorrect, all these factors can cause sub-structural damage, overall to the dentine.

A selection of indexed papers in Pubmed studies is presented here; the effectiveness of laser irradiation to influence the bond strength and microleakage on the enamel and dentine of primary teeth was investigated. Some reported favourable results using only the laser without etching with orthophos-phosphoric acid [Yamada et al., 2002; Kohara et al., 2002; Wanderley et al., 2005; Sung et al., 2006], while others found that even in primary teeth, acid etching of the enamel and dentine was necessary to obtain results equal to those obtained with traditional techniques [Monghini et al., 2004; Borsatto et al., 2006; Lessa et al., 2007]. Even the diverse materials and adhesives used have not been evaluated critically [Quo et al., 2002].

Combining the traditional technique of cavity margin refinishing, acid etching of the enamel and the dentine with the laser preparation technique, the advantages of both techniques can be employed. Minimising the disadvantages that are correlated with the thermal effect of the laser at the dentinal level, where the organic matrix is vapourised with the ablative energy used, and of the enamel, make a final conditioning advisable at low wattage both on dentine and enamel.

The principle disadvantage of the laser technique in terms of microleakage and thus of adhesion at the enamel margins can be avoided with a mechanical finishing of the cavity margins, with manual, rotative or ultrasonic instruments followed by etching with 35-37% orthophosphoric acid. Currently, the procedure using 35-37% orthophosphoric acid for 20-30 secs, remains the only common denominator that makes the diverse results obtained with different instruments uniform, eliminating the thin layer of dentine substructural damage, exposing the collagen fibres and creating a substrate for the formation of the hybrid layer. Acid etching also modifies the Silverstone classification of type 2 and 3 enamel lesions, allowing a better composite resin adaptation to the enamel margins of the cavity [Olivi et al., 2009].

Conclusion

The laser erbium technology, introduced in restorative dentistry in 1997 by Keller and Hibst, after 20 years of research, improvement and increasingly widespread clinical use, represents today a safe device, to effectively and selectively remove carious tissues from decayed teeth. Beside the laser itself, the human factor, with each operator's differing level of skill and knowledge, represents both the limit and the widespread acceptance of this therapy. For children, all the recognized advantages of this technique play a decisive role in the successful day-to-day treatment of carious pathologies and beyond.

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