The use of lasers in restorative dentistry: truths and myths

ABSTRACT

Researchers have been investigating the clinical applications of lasers in dentistry, which can be operated in high and low intensity. The high intensity lasers work with increasing temperature for ablation, vaporization, cutting and coagulating of the tissue while the low level lasers therapy are used in the photophysical, photobiological and photochemical effects on the cells of the irradiated tissues. This review approaches the use of lasers of high and low intensity focused in restorative dentistry. The indications for high power lasers are for dental erosion treatment, in of carious tissue, for dentin hypersensitivity, for microbial reduction, in the conditioning of enamel and dentin for adhesive systems and for caries prevention in pits and fissures. The low power laser can be used after cavity preparation in order to reduce post-operative sensitivity, in aesthetic procedures for maintaining periodontal health and also in the photodynamic therapy, which provides microbial reduction, combining a photosensitizing agent to a light source.

KEYWORDS

Lasers; Dentistry; Operative; Anti-inflammatory agents; Photodynamic therapy; Ablation techniques.
**INTRODUCTION**

Since the development of the first LASER (Light Amplification by acronym of the Estimulated Emission of Radiation) by Maiman in 1960, researchers have investigated the clinical applications of lasers in dentistry, which can be classified into high and low intensity. The high intensity lasers treatment (HILT) are intended for ablation, vaporization cutting and coagulating of the tissue because they work with increasing temperature, while the low intensity lasers (LLLT) are used in the processes of tissue repair, inflammation and in cases in which analgesia is required. This latter therapy is based on the use of low irradiance that influence cell behavior, it is not thermal, which means that their biological effects are not caused by heat or noticeable cell damage; it works by photophysical, photobiological and photochemical effects on the cells of the irradiated tissues [1].

The LLLT used in clinical dentistry operate in the visible range of the electromagnetic spectrum, more precisely in the range of red light wavelength (approximately 600-700 nm) and near-infrared range (up to approximately 1000 nm) [2]. Among them we can mention the He-Ne laser (Helium Neon) and diode lasers. Among the HILT, we can highlight the laser Nd:YAG (Neodymium), CO	extsubscript{2}, Er:YAG (Erbium), Er,Cr: YSGG (Erbium-Chromium) and high power diodes.

The way the laser will interact with tissue will depend on the optical characteristics of the laser used (wavelength, power, exposure time, energy, etc.) as well as on the optical characteristics of the target tissue (chromophores present in the tissue, depth of structure being treated, body fat percentage, etc.) [3].

Particularly in restorative dentistry, there are many indications for high power lasers; for example, in dental erosions, in reconstitution of the canine guides, final removal of carious tissue (with the benefit to the conservative dentistry), in dentin hypersensitivity, in microbial reduction, the conditioning of enamel and dentin for adhesive systems [4,5], internal conditioning of prosthetic ceramic pieces, prior to permanent luting (lasers Er: YAG and Er, Cr: YSGG) [6] and carries prevention in pits and fissures. The low power laser can be used after cavity preparation in order to reduce post-operative sensitivity and microbial reduction after cavity preparation, combining a photosensitizing agent to low power laser or LED (photodynamic therapy); also, in aesthetic procedures in maintaining periodontal health [7-9].

**CRITICAL REVIEW**

**Truths**

**Enamel conditioning**

Since the 60s, several studies on the effects of laser in dental mineralized tissues have been conducted. The widespread use of lasers in science is promoting advances in restorative dentistry and particularly in Dental Aesthetics. In this context, the application of this technology in the selective removal of carious tissue and preparation of tooth surface for adhesive restorative procedures can be mentioned.

Among the various wavelengths available, the Er: YAG (2.94 µm) and the Er,Cr: YSGG lasers (2.78 µm) stand out as having high affinity for hydroxyl ions present in water molecules and hydroxyapatite, thus being effectively absorbed by dental hard tissues[10,11]. The use of the Er:YAG and Er,Cr:YSGG lasers for cavity preparation was approved by Food and Drug Administration (FDA) in 1997 and 1998, respectively [12,13]. Several studies in the literature indicate the TEA CO	extsubscript{2} laser (Transversely Excited Atmospheric Pressure) as a promising equipment for the ablation of dental hard tissues [14-16]. These lasers emit at wavelengths of 9.6 e 10.6 µm, and are effectively absorbed by phosphate groups present in the hydroxyapatite [17]. Despite the positive results reported for conservative cavity preparation [15,16,18], the TEA CO	extsubscript{2} laser is still not commercialized, and is only available to laboratory studies or restricted use in clinical trials.

Depending on parameters used and tissues targeted, high power lasers can promote dental surface conditioning or even remove dental hard tissues [19-21]. The difference in composition of mineralized dental tissues results in lower ablation threshold for dentin compared to enamel, since the former has a higher organic content [10]. In other words, ablation of dentin requires lower energy densities when compared to enamel.

Irradiation of dental enamel with erbium lasers produces a morphological pattern resultant from the ablation process, with exposition/removal of prisms [10,22,23]. The surface topography
presents a micro retentive pattern that provides micro retention of adhesive restoration to dental substrate [24,25]. Although the effects of lasers on enamel are still discussed in the literature, several studies evaluating the quality of the adhesion between irradiated enamel and restorative materials show positive results [26-30]. One example of the use of high power lasers for enamel conditioning is the restoration of worn teeth for re-establishing dentition function and recovering esthetics. Enamel conditioning with Er:YAG laser followed by restoration with composite resin provides resistant and long-lasting outcomes, even in presence of intense occlusal stress [31].

Unlike irradiated enamel, for which studies show favorable results regarding adhesion, bonding to irradiated dentin is still considered controversial in the literature. Although irradiation of dentin with erbium laser lead to increased surface roughness, with the presence of open dentinal tubules [32-34], no demineralization or exposition of collagen fibrils for penetration of resin monomers is observed [35].

Considering the clinical use of erbium lasers for enamel conditioning, studies indicate that both efficiency and feasibility in daily practice can be achieved, without prejudice to the pulp tissues and with great acceptance by patients due to reduction of vibration and noise, reduction of pain sensitivity and, in some cases, no need for using anesthetics [36-38]. Moreover, one of the main advantages of high power lasers is its antimicrobial action. Due to the increase of temperature, ablation of dental hard tissue is accompanied by microbial reduction of adjacent tissues, contributing to a better prognosis when this technology is associated with the treatment [39].

LLLT applied in gingival cares during aesthetics proceedings

Currently there are numerous new technologies to improve dental treatments. The low intensity laser therapy (LLLT) was established as a non-invasive method to enhance chronic wound healing, modulate inflammatory process and promote pain relief [40-44]. In Restorative dentistry, the health of gingiva is mandatory for the success of all clinical steps [45]. During the indirect restorative treatment, correct hygiene must be performed by patients; otherwise, inflammation will occur in gingival tissue. If inflammation occurs, the restorative treatment should be paused until the gingiva gets healthy [45].

The LLLT has shown satisfactory results as a complementary alternative therapy to achieve a healthy gingiva. In the recovery of healthy gingiva, LLLT will act through its anti-inflammatory and biomodulatory effect. The anti-inflammatory and anti-edema effect of LLLT occurs, due to several outcomes, as increase in microcirculation, resulting in alteration in hydrostatic pressure in vasculature, with edema resorption [46] and modulation of molecules as PGE2, COX-2 and Interleukins [40,43]. The LLLT has shown significant effect in tissue regeneration, an important tool in gingiva repARATION.

The table below (Table 1) summarizes some studies concerning the anti-inflammatory and biomodulatory effects of LLLT related to tissue healing.

### Table 1 - In vitro findings of LLLT effects on tissue

<table>
<thead>
<tr>
<th>Effects</th>
<th>Author</th>
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<tr>
<td>Increase in fibroblasts and epithelial cell proliferation</td>
<td>Walsh, 1997 [47]; Almeida-Lopes et al., 2001 [48]; Pereira et al., 2002 [49]; Azevedo et al., 2006 [50]; Saygun et al., 2008 [51].</td>
</tr>
<tr>
<td>Increase in leucocytes phagocytosis</td>
<td>Walsh, 1997 [47]</td>
</tr>
<tr>
<td>Increase in endothelial cell proliferation</td>
<td>Walsh, 1997 [47]</td>
</tr>
<tr>
<td>Increase in myofibroblasts differentiation</td>
<td>Pourreau-Schneider et al., 1990 [52]</td>
</tr>
<tr>
<td>Increase in ascorbic acid levels in fibroblasts, leading to increase in hydroxyproline, and collagen synthesis.</td>
<td>Walsh, 1997 [47]</td>
</tr>
<tr>
<td>Biostimulation of cytoskeleton proteins, leading to higher stability from lipoprotein layer in cellular membrane</td>
<td>Walsh, 1997 [47]</td>
</tr>
<tr>
<td>Increase in neovascularization</td>
<td>Salate et al., 2005 [53]</td>
</tr>
<tr>
<td>Increase in growth factors, as bFGF, IGF-1</td>
<td>Walsh, 1997 [47]; Saygun et al., 2008 [51]</td>
</tr>
<tr>
<td>Inhibition in Prostaglandin E2, e Interleukin 1-β</td>
<td>Shimizu et al., 1995 [40]; Sakurai et al., 2000 [43]</td>
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</table>

Some recent clinical studies confirmed the results found in other in vitro studies and showed that LLLT is an efficient additional tool for the conventional treatment of gingival inflammation and has shown satisfactory outcome in the control and maintenance of a healthy gingiva. Table 2 summarizes these clinical studies.
It’s important to point out that LLLT has shown positive results when applied as a therapy. This means that only one application has not shown beneficial results. It must be applied in several sessions[7-9].

**LLLT applied after cavity preparation**

Regularly, patients relate a post-operative pain after cavity preparation for both direct and indirect restorations. Restorative procedures can be a source of injury to the pulp tissue and can occur due to several factors, such as heat generated during cavity preparation, the method of restorative material placement, among others [54-55]. To prevent sensitivity, small pellets of composites should be inserted into the cavity to avoid polymerization shrinkage and materials should be biocompatible with the tissue [56].

The dental pulp of human teeth is profusely innervated [57]. Fearnhead (1957) [58] have shown that small nerve fibrils with an approximate diameter of 0.2 µm were in close relationship with the odontoblast process extending as far as 1.5 mm into the dentin. Consequently, stimulus applied during the restorative procedure will be captured by the pulp though this system. Brännström et al (1960) [60] have provided evidence that the main cause of dentinal pain is a rapid outward flow of fluid in the dentinal tubules, which is initiated by capillary forces. Temperature was found to have a great effect on the hydraulic conductance of dentin. Increasing the temperature by 40º C resulted in a 1.8 fold increase in fluid flow in unetched dentin and in a 4 folds increase in acid-etched dentin. Therefore, a high temperature increase occurring in a dental treatment will lead to stimuli transmitted to the pulp, and sensitivity will certainly develop. Dentists should take special care to prevent inducing high temperatures in etched dentin.

The literature has demonstrated several advantages of the use of low intensity lasers in restorative dentistry though in vivo studies. Godoy et al., (2007) [55] used a laser wavelength of 670 nm; 30 mW and 2 J/cm², applied directly and perpendicularly in Class V cavities in premolars in a single visit, and restored the teeth with composite resin. After 28 days the teeth were extracted and transmission electron microscopy analysis showed that the lased groups presented the odontoblast process in greater contact with the extracellular matrix and the collagen fibrils appeared more aggregated and organized than those of the control group. It was concluded that laser irradiation accelerated the recovery of dental structures involved in cavity preparation in the pre-dentin region. Ferreira et al., (2006) [60] used a 670 nm laser wavelength; 50 mW and 4 J/cm² in Class V cavities in premolars, and after this, performed restorations with glass ionomer. The teeth were extracted after 14 and 42 days. Histological changes were observed by light microscopy; less intense inflammatory reaction was found in the irradiated group when compared with the control group. Only in the group of teeth extracted 42 days after laser application, an area associated with reactionary dentinogenesis was shown. The immunohistochemical analysis also revealed that expression of Collagen type III, Tenascin and Fibronectin was greater in the irradiated group.

The inflammatory modulation capacity of LLLT has been proved by several studies [40,43,61]. LLLT can also show beneficial effects on pain control [62-64]. All the beneficial effects of LLLT, such as pain control, inflammatory and reparative tissue modulation can

### Table 2 – Clinical studies using laser as a tool for gingival health recovery

<table>
<thead>
<tr>
<th>Study</th>
<th>Description</th>
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<tbody>
<tr>
<td>[Qadri et al., 2005][7]</td>
<td>Evaluated 17 patients submitted to periodontal treatment. In the lased group (1x/week during 6 weeks; 635 nm; 10 mW; 90 s; 9 J; 4.5 J/cm²; 50 mW/cm²; and 830 nm; 70 mW; 25 s; 1.75 J; 8,75 J/cm²; 350 mW/cm²) a significant positive result was found. There was a significant periodontal pocketed depth reduction and gingivitis level reduction. A decrease in the crevicular fluid was also described, as well as the reduction of MMP8 (metalloproteinase 8)</td>
</tr>
<tr>
<td>[Pejic and Grujicic, 2007][8]</td>
<td>performed in their clinical study, histological analysis from the gingival tissue removed from 15 patients that were submitted to conventional periodontal treatment and also conventional treatment associated with LLLT (1 session/day during 5 days - 670 nm; 4-15 mW; 2 min; 100-200 mW/cm²). The analysis showed that in the irradiated tissue there were complete regeneration and less inflammatory cells when compared to the group submitted only to conventional treatment. The irradiated tissue also showed better collagen fibers organization. The authors concluded that LLLT, when associated to conventional treatment is effective in inflammation reduction.</td>
</tr>
<tr>
<td>[Pejic et al., 2010][9]</td>
<td>Evaluated LLLT (10 sessions - 670 nm; 150 mW/cm²; or 18 J/cm²) associated with conventional periodontal treatment in 30 patients with gingival inflammation. The results have shown that these patients had less plaque, less gingival index and less gingival bleeding in all the follow-up periods: 1, 3 and 6 months. Interestingly, in all the periods, the LLLT results obtained were maintained, differently from the control groups (conventional periodontal treatment), where some recurrences from the gingival inflammation occurred. The authors concluded that LLLT is an additional tool to periodontal treatment that presents long lasting satisfactory results in the management of gingival inflammation.</td>
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bring advantages to restorative procedures, helping in pulp tissue recovery as well as providing patients with comfortable post-operative condition.

It can be concluded that LLLT can bring several advantages to restorative dentistry after cavity preparation as a co-adjuvant in conventional treatment. Nonetheless, dentists should not forget the factors that induce tissue damage, such as the use of old burs that induce abrasion and excessive heat increase during cavity preparation, the restorative material placement method, chemical irritants among others, and must control them to prevent post-operative sensitivity.

The status of laser in erosion prevention

Tooth wear is becoming increasingly significant [65]. The tooth surface loss due to dental erosion refers to the pathological loss of tissue without the involvement of bacteria. Dental erosion may be caused by a series of extrinsic and intrinsic factors [66]. Extrinsic factors largely include the consumption of acidic foods and carbonated beverages, sports drinks, red and white wines, citrus fruits and, to a lesser degree, occupational exposure to acidic environments [65]. Soft drink consumption in the USA increased by 300% in 20 years [67]. Nowadays there is a consensus that four or more acid intake per day are associated with high risk of dental erosion [68]. The most common intrinsic factors include chronic gastrointestinal disorders such as gastro-esophageal disease as well as health issues like anorexia and bulimia, where regurgitation and frequent vomiting are common [65,69,70].

The strategies to control erosive tooth wear include the early diagnosis of hard tissue defects and the evaluation of the different etiological factors to identify persons at high risk [71]. The elimination of the causative factors may be difficult, since they are associated to habits or lifestyle, and depend on nutritional, medical, psychological and professional factors, that predispose individual to dental erosion. Erosive lesions frequently require preventive and restorative treatments [72]. However, restorative procedures do not prevent further progression of erosive/abrasive wear [73].

Researchers have been focused in finding new methods for dental erosion prevention. The possibility of increasing the enamel resistance to demineralization after laser irradiation was first demonstrated in 1965 with a ruby laser [74]. Over time and with the increasing knowledge about the interaction of laser with dental hard tissues, other wavelengths were tested.

As research methodologies used to study high intensity lasers in erosion prevention varies among them, concerning laser wavelengths, dosage, pulse width, erosion challenges, etc, it’s not possible to compare the results between the studies. Some studies showed partial beneficial results with Nd:YAG lasers [75-79].

Carbon dioxide lasers have been mostly tested in erosion prevention among other wavelengths, due to its efficient interaction with hydroxyapatite [80-84]. Depending on the parameters used some studies showed complete or partial negative effect of CO₂ laser in erosion prevention [85-88], as well as others studies showed positive results [89-91].

The erosion preventive effect of CO₂ laser with the parameters: 10.6 μm, 0.3 J/cm², 5 μs, 226 Hz, have been confirmed by several studies with different erosion challenges [89-91].

In situ studies are also very important concerning dental erosion, once some modified biological factors presented in oral cavity, such as saliva, regulate the progression of the disease. The single in situ study with CO₂ laser on the topic of laser and erosion, confirm the positive result of CO₂ laser, taking account the biological modifying factors in the results [92].

In conclusion, based on the published researches, CO₂ laser when applied with the wavelength of 10.6 μm, low energy density (0.3 J/cm²), and short pulse width (5 μs), seems to be a promising tool in the prevention of tooth erosive wear. Nevertheless it’s important to point out that this parameter is not available at the moment in any clinical laser equipment.

Pits and fissures cleaning

Occlusal surfaces are more susceptible to caries attacks and have been responsible for 84% of caries lesions in 5-17-years-old children Council on Access, Prevention and Interprofessional Relations [93]. Several explanations may be proposed, such as constant biofilm formation on this tooth surface, pH fluctuations stemming from metabolic processes within these films, [94] immaturity of the tooth substances, when they are recent erupted in the oral cavity, [95] the lower diffusion of the fluoride ion in the deepest regions of the crevice minimizing the effect of this ion upon caries progression [96] and difficulties in oral hygiene due to the posterior position of the molars in the dental arch. A delay in recession of the operculum eventually leads to an accumulation of plaque that is inaccessible to a toothbrush and reduces the chance of effective and timely application of caries preventive measures such as fissure sealants and fluoride therapy [97].

The use of laser for the prevention of dental caries is based on the reduction of microorganisms [98-99], due to its action on the dental plaque, chemical [100-103] and morphological modification of the enamel structure [103-
105] turning them more resistant to acid demineralizing.

Several high power lasers - CO₂, Er:YAG and Nd:YAG have been tested with the purpose of treating the pit and fissure surfaces [100,106-112]. Some characteristics and the main findings of some researches are shown in Table 3.

### Table 3 - Findings of the HILT on pit and fissure treatments

<table>
<thead>
<tr>
<th>Laser type and parameters</th>
<th>Effects</th>
<th>Author</th>
</tr>
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<tbody>
<tr>
<td>CO₂ laser, 10.6 μm, 2-5 W</td>
<td>Physicochemical alterations in enamel which may have preventive benefits for sealing pits and fissures</td>
<td>Walsh and Perham, 1991 [106]</td>
</tr>
<tr>
<td>Nd:YAG laser</td>
<td>Nd:YAG laser irradiation was effective in increasing the acid resistance of the pit and fissure enamel, while removing the pit and fissure debris contents and increasing the fluoride uptake into the pit and fissure enamel.</td>
<td>Bahar and Tagomori, 1994 [100]</td>
</tr>
<tr>
<td>CO₂ laser, 10.2 W, pulsing emission at 7 pps and pulsing and 20 msec</td>
<td>Occusal caries prevention with CO₂ laser only was not effective. When associated with photoactivated sealants, effective preventive action; irradiation of CO₂ laser over occlusal fissures, prior to the application of a photoactivated fissure sealants, improved their retention.</td>
<td>Brugnera Jr. et al., 1997 [107]</td>
</tr>
<tr>
<td>Nd:YAG, 2.0 W, 20 Hz and 124.3 J/cm² for 3 minutes</td>
<td>In shallow fissures, the sealing was total but in narrow and deep fissures, the sealing was partial or incomplete.</td>
<td>Myaki et al., 1998 [108]</td>
</tr>
<tr>
<td>Er:YAG laser, handpiece 2051, water spray-cooled, 200 mJ, 2 Hz; handpiece 2055 with a quartz fiber optic 50/10, air cooled, 350 mJ, 2 Hz and 400 mJ, 2 Hz</td>
<td>Morphological changes suggesting that the irradiation by Er:YAG laser produced melting and recrystallization of the enamel fissures</td>
<td>Matson et al., 2002 [109]</td>
</tr>
<tr>
<td>CO₂ laser, 9.6 μm, 2.0 or 3.0 J/cm²</td>
<td>Percentage of caries inhibition progression with laser and/or F ranged from 87-170%</td>
<td>Nobre dos Santos, 2002 [110]</td>
</tr>
<tr>
<td>CO₂ laser, 10.6 W, 0.3 watt;10 msec; 15 Hz, energy density, 15 J/cm²</td>
<td>Effective treatment in the prevention of pit and fissure caries in partially erupted permanent molars covered with opercula</td>
<td>Kato, 2003 [111]</td>
</tr>
<tr>
<td>Er:YAG - 80 mJ, 2 Hz; Nd:YAG Laser - 1W, 10 Hz; CO₂ Laser - 0.4 W, 20 Hz</td>
<td>CO₂ laser should be selected in order to increase the enamel resistance to acid in pits and fissures</td>
<td>Correia-Afonso et al., 2012 [112]</td>
</tr>
</tbody>
</table>

Final carious tissue removal

Several studies have been conducted on the effects of laser in dental mineralized tissues and developments in research continue to review new techniques and parameters for the treatment of tooth surfaces with different laser wavelengths. In this context, the application of this new technology in the selective removal of decayed tissue and on tooth surface preparation for adhesive restorative procedures, have brought promising results within the current philosophy of minimally invasive treatments.

Among the various wavelengths, lasers Er: YAG and Er, Cr: YSGG stand out as for the mechanism of action, that is associated with the phenomenon of the ablation process in which the incident laser beam is absorbed by water molecules present in dental tissue, causing rapid heating and evaporation of the same, being followed by successive microexplosions with ejection of the mineral tissue [10,13,23]. Thus, it is possible to use erbium lasers in conservative cavity preparations [10,11,114] and the selective removal of caries [115].

In vitro studies have also been conducted to elucidate the high intensity lasers on carious tissue removal. Rizzella et al., (2012) [116] have evaluated the influence of air pressure, water flow rate, and pulse frequency on the removal speed of enamel and dentin as well as on their surface morphology. Irradiation at 25 Hz for enamel and 30 Hz for dentin provided the best ablation rates within this study, but efficiency decreased if the frequency was raised further. Greater tissue ablation was found with water flow rate set to low and dropped with higher values. Fine-tuning of all parameters to get a good ablation rate with minimum surface damage seems to be key in achieving optimal efficiency for cavity preparation with an Er:YAG laser. Another in vitro study [117] have evaluated the extent of microleakage in cavities prepared with bur and Er:YAG laser, hybridized with different bonding systems. The cavities were prepared with bur or with laser parameters of 250 mJ, 4 Hz, 80.6 J/cm²; the cavities were restored with a micro-hybrid composite resin using either with AdheSE or Clearfil SE Bond as adhesive system. The results have confirmed the
Er:YAG laser to be as effective as the conventional methods for preparing adhesive restorations.

Clinical studies [118] have evaluated the effect on cavity preparation time, the pulse changes and the patient’s subjective experience during removal of healthy tooth substance with high-speed bur and Er:YAG laser in thirty-five 14 to 18-year-old patients. After local anaesthesia, Er:YAG laser and high-speed diamond bur were used for a 2 mm deep cavity preparation on the middle of the buccal surface on contra-lateral healthy maxillary first premolars. Laser ablation caused unpleasant smell and longer cavity preparation time, but was preferred by a majority of the adolescents. Hadley et al. (2000) [119] have randomly selected subjects for cavity preparation with conventional air turbine/bur dental surgery or an Er,Cr:YSGG laser-powered system using a split-mouth design. They prepared Class I, III and V cavities, placed resin restorations and evaluated sixty-seven subjects on the day of the procedure, 30 days and six months postoperatively for pulp vitality, recurrent caries, pain and discomfort and restoration retention. There were no statistical differences between the two treatment groups. The Er,Cr:YSGG laser system was effective for preparation of Class I, III and V cavities and resin restorations were retained by lased tooth surfaces.

Regarding the clinical use of erbium lasers for caries removal, some authors have reported that the treatment performed with the laser technique can be considered efficient and feasible in daily practice, without prejudice to the pulp tissues and with great acceptance by patients due to reduction of vibration, noise, reduction of pain sensitivity and, in some cases, no need for using anesthetics [36,37].

**Microbial reduction in carious tissue—antimicrobial photodynamic therapy**

Antimicrobial photodynamic therapy is a technique that consists of the use of photosensitive agents associated with a light source that is able to reduce the microflora associated with dental caries. The use of hand or rotary instruments does not guarantee the cleanliness of the infected dentin and residual bacteria that are normally present in the cavity before the restorative procedure [120]. Therefore, this treatment can be recommended for teeth with deep caries and reversible pulp inflammation, provided that the tooth is restored with a good marginal sealing.

The antimicrobial photodynamic therapy involves the use of photosensitive agents that are activated by a light source with a wavelength specific to generate cytotoxic species, including singlet oxygen and free radicals [121]. These products can damage critical components of cells or modify the metabolic activity irreversibly and may result in bacterial killing [122,123]. This mechanism of action avoids the development of bacterial resistance, since this is a limitation of conventional antimicrobials [124].

In vitro studies have already demonstrated that the most cariogenic microorganism group, the Streptococcus mutans, may be removed under conditions similar to those found in a caries lesion [125]. It was also verified the ability of this therapy to eliminate bacteria embedded in collagen matrix in carious dentin in bovine and human carious dentin in vitro [126-128].

In vivo studies conducted on ex vivo carious dentin using ortho-toluidine blue and red LED light source ($\lambda = 630 \text{ nm}$) (47 or 94 J/cm$^2$) found that this therapy was effective in reducing microorganisms present in carious lesions produced in situ [129]. Another study was performed, in vivo [130], in 26 adult patients with deep carious lesions in permanent molars using methylene blue as a photosensitive agent and red low power laser (InGaAIP, $\lambda = 660 \text{ nm}$, 100 mW, 320 J/cm$^2$, 90 s, 9 J). The authors have also evidenced reduced cariogenic microorganisms in the carious dentin after treatment.

Antimicrobial photodynamic therapy is an important technique and may decrease risk of pulp exposure, resulting in a less traumatic treatment for patients. However, further studies are necessary to investigate new associations between photosensitive agents and various light sources, both in deciduous or permanent teeth.

**Miths**

**Prosthetic preparations in Dentistry**

Extensive prosthetic preparations, for example, metal-ceramic crowns, veneer, onlays, crowns and laminates free or not from metal are not a reality with the use of high power lasers. This happens because these types of preparations require meticulous level of details such as expulsive walls, suitable angle of the endings, depending on the type of material of choice for crowns and still smoothness and polish of the surface properly prepared to receive the settlement part, either with cement or adhesive system. The high power lasers, as already mentioned earlier in this article, operate associated with the phenomenon of
the ablation process in which the incident laser beam is absorbed by water molecules present in dental tissue, causing rapid heating and evaporation of the same, being followed by successive microexplosions with ejection of the mineral tissue. In this process, using the available lasers, there is no way of carefully controlling the amount of tissue or the cavity boundaries eliminated. This way, it is still hard to perform ideal preparations for crowns or laminates with high power lasers.

However, there has been a great technological development in the field of high power lasers, especially CO₂ laser prototypes with wavelength of 9.6 µm and also ultrashort pulsed lasers (see more details in the section “Dental cavities prepared with ultrashort pulsed lasers”) that are being considered promising for the future of preparations for cosmetic dentistry.

**Extensive caries removal and traditional cavity preparations in Dentistry**

Basically, for the same reasons explained above for the preparations of prosthetic crowns, the conventional cavity preparations with angled walls or sharp edges are hard to be performed with high power lasers. The highest percentage of caries removal is still performed by traditional methods, such as rotary instruments (tungsten - carbide) and extremely sharp curettes; however, the final removal of decayed tissue, by ablation of the carious tissue and subsequent microbial reduction, currently associated with photodynamic therapy with low-power lasers and LED. Although many of these procedures are performed by traditional methods, the final removal of carious tissue with lasers represents a step forward, because they are able to strictly remove the damaged tissue, being very conservative, and also, with the advantage of promoting microbial reduction. This extremely conservative binomial - caries removal and microbial reduction, when applied using correct protocols that do not cause heating of the pulp above the tolerance limits, is already a reality for the conservative and restorative dentistry.

The restorative dentistry walks to minimally invasive procedures. The traditional cavity preparations for current generations, who already benefit of water fluoridation, are increasingly conservative. We arrive in a future where the removal of small spots of caries and the use of any technique for adhesive restorations will be widely used.

**Future perspectives**

**Dental cavities prepared with ultrashort pulsed lasers**

The interaction of lasers with biological tissues depends not only on the affinity between chromophore and wavelength, but also on the irradiation parameters used. The influence of these parameters on the ablation process with high power lasers is well known. Recently, the effect of pulse duration on this interaction has been studied.

Lasers currently available for cavity preparation have pulse duration in the order of microseconds. Even when the thermal relaxation time of dental tissues is considered, residual temperature increase may occur, causing undesirable thermal changes in underlying structures [35,131-133]. Studies evaluating the effect of pulse duration on the ablation process indicate that for short pulses, not only the energy necessary for the occurrence of ablation decreases, but the improvement of the ablation process is also observed due to rapid ablation of tissue irradiated [134]. This fact is attributed to the reduction of residual thermal damage due to the minimization of heat diffusion.

The ultrashort pulsed lasers emit photons with pulse durations in the order of pico and femtoseconds (1 ps = 1x10-12 s e 1 fs = 1x10-15 s). Dental hard tissue ablation with longer pulses (microseconds) is based on thermomechanical mechanisms, while shorter laser pulses (pico and femtoseconds) are based on non-thermal ablation mechanisms [135]. The reduction of thermal damage to dental substrates with the ultrashort pulsed lasers is based precisely on this aspect of non-thermal ablation process. The irradiated material is ejected rapidly, and consumes most of the absorbed energy. Therefore, efficient ablation is achieved without obtaining significant residual heat, avoiding thermal and mechanical damage to the remaining material [136]. The use of ultrashort pulses reduces ablation threshold, requiring less energy to remove the substrate, and resulting in less volume of heated material [137-140].

The effect of ultrashort pulsed lasers on dental substrates results in patterns that indicate the absence of damages to adjacent tissues and precise removal of dental tissue [136,138,140]. Cavities prepared with picosecond and femtosecond lasers are well-defined [140-143]. The surface morphology varies according to irradiation parameters used. Either areas of melted and solidified dentin and enamel or rough surfaces without melting or carbonization can
be observed [140,144]. To date, there are no reports in the literature of clinical use of ultrashort pulsed lasers in the oral cavity. Its use is already common in ophthalmology and vascular surgeries, and several studies with different wavelengths and pulse duration have been conducted in enamel and dentin. However, much still needs to be studied so that these lasers will become a reality in clinical dentistry.

Conclusions

High and low intensity lasers have been used for a long time in many procedures in dentistry. Low intensity lasers can bring several benefits to restorative dentistry such as satisfactory outcome in the control and maintenance of a healthy gingiva, after cavity preparation to prevent post-operative sensitivity and erosion of pit and fissures, and maintenance of a healthy gingiva, after cavity preparation to prevent post-operative sensitivity and erosion of pit and fissures. The high temperatures achieved with these equipments also vaporize debris and biofilm that may be present in the pits and fissures. The high temperatures achieved with these equipments also vaporize debris and biofilm that may be present in the pits and fissures. The erbium lasers can be used for final caries removal, without prejudice to the pulp tissues and with great acceptance by patients due to reduction of vibration, noise, reduction of pain sensitivity and, in some cases, no need for using anesthetics.

There is always an evolution regarding the techniques and procedures of traditional dentistry. The most important thing is to associate the technological innovations of dentistry to traditional procedures. The key to success for the future is to associate both clinical procedures and innovations, based on evidences and research published in journals with high impact factors, which have strict protocols and can be used in clinical practice. New technology always brings the fears of its use. The goal is to gain scientific knowledge that can support the appropriate use of these technologies, which can bring benefits to patients.

It is still not a reality to perform traditional prosthetic preparations, total removal of caries, as the most significant examples. However, recent researches with CO_2 lasers of 9.6 μm and ultrashort pulsed lasers contribute to future procedures in the area of clinical dentistry.

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