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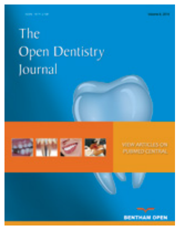

RESEARCH ARTICLE

Application of Laser Irradiation for Restorative Treatments

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Abstract: Nowadays, lasers are widely used in many fields of medicine. Also, they can be applied at many branches of dental practice such as diagnosis, preventive procedures, restorative treatments, and endodontic therapies. Procedures like caries removal, re-mineralization, and vital pulp therapy are the most noticeable effects of laser irradiation which has gained much attention among clinicians. With controlled and appropriate wavelength, they can help stimulating dentinogenesis, controlling pulpal hemorrhage, sterilization, healing of collagenic proteins, formation of a fibrous matrix, and inducing hard tissue barrier. Nevertheless, there are many controversies in literatures regarding their effects on the quality of bonded restorations. It hampered a wide application of lasers in some aspects of restorative dentistry and requirements to identify the best way to use this technology. The aim of this mini review is to explain special characteristics of laser therapy and to introduce the possible applications of laser devices for dental purposes.

Keywords: Caries, Demineralization, Laser, Restorative dentistry, Vital pulp therapy.

INTRODUCTION

Light amplification by stimulated emission of radiation (laser) was introduced into the dentistry for the first time in 1960 by Maiman [1]. Nowadays, a number of lasers are used in dentistry such as carbon dioxide (CO_2) laser, neodymium yttrium aluminum garnet laser (Nd:YAG), Erbium laser and Diode laser. Each of these lasers represent some features which make them applicable for specific dental goals [2]. They can be applied for many dental branches like diagnosis, prevention, restorative procedures, and endodontics. One classification divides them into two groups of soft lasers and hard ones [3]. CO_2 and Nd:YAG lasers were the first ones that were registered for their effect on dental hard tissues [4]. Er:YAG and CO_2 lasers, with higher wavelength, had the benefits of having much higher absorption and lower penetration depth (about 0.01 mm) into the hard tooth tissues [5]. The Er:YAG laser provides a wavelength of 2940 *nm* which can be administered for preparing dentine, enamel and removing carious tissues [6]. The Er,Cr:YSGG is another newly introduced laser with wavelength of 2.79 µm. It induces strong water absorption energy (7000 J/cm) and can be proposed for both hard tissue and soft tissue applications [7]. The aim of this mini review is to explain special characteristics and possible applications of laser devices for dental purposes.

MATERIALS AND METHODOLOGY

A data search was performed using PubMed's electronic database of dental reports, based on the following search terms in simple or multiple conjunctions: "Laser", "Restorative dentistry", "Caries", "Demineralization", " Vital pulp therapy". Some of the searched studies which had more relevance with the scope of this article were chosen. Consequently, case reports, studies with missing data, repeatedly published studies, and those in other languages than

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English were excluded. After screening both abstracts and full texts the information was gathered for summarizing.

The Effects of Laser Irradiation on Healthy Tooth Tissues

The effect of laser irradiation on enamel is observed as follows: at temperature 650°C to 1100°C, decrease in the enamel solubility would be enhanced, which highly depends on the calcium-phosphate ratio. At 1100°C, new crystalline phases would be formed by tetra Calcium Diphosphate Monoxide (alpha tri-calcium phosphate and beta-phases), which is less soluble, with less carbonate contents, and more resistant to demineralization procedures [8]. In the other aspect of view, lasers might induce surface changes in enamel like surface roughness, crazing, cracking and exfoliation [7].

Laser appliances remove dental tissues selectively by causing water evaporation that is unique for mineralized tissue. The Er:YAG laser makes thermal changes in water molecules of the hard tissue, so the absorbed energy results in superheating and evaporation. The increased vapor pressure causes exfoliation and micro explosive expansion of the hard tissue [9]. The laser irradiation influences the dental tissue by making microscopic coarse surfaces without demineralization, and provides open dentinal tubules without formation of smear layer. Also, it can sterilize the surface significantly [10].

The adverse effect of laser devices on the pulpal health might cause severe damages to the pulp due to thermal damage during tooth preparation, such as irreversible pulpitis and pulp necrosis [11]. However, due to demands for ideal laser instruments, researchers identified the appropriate wavelength that made selective impact to tooth tissue by selective absorption of pulsed radiation (Photothermolysis) [12]. Also, water cooling is recommended to reduce heat during tooth preparation [13]. Some animal [14] and human studies [15] showed appropriate response of the pulp to the Er:YAG laser. Niar *et al*. [12] observed outstanding preservation of pulpal health by means of Er:YAG laser at 2.94 μm wavelength. In another study by Nair [11], the CO_2 laser caused minimal and mild inflammatory responses to pulpal tissue.

The Effect of Lasers on Carious Structures

Detection

Laser-induced fluorescence (LF) opened a new aspect in the early diagnosis of hidden occlusal caries. DIAGNO dent is an LF-based devise which detects mineral loss according to quantitative optical methods. A red light, produced by a diode laser at 655 *nm* wavelength, illuminates the tooth surface and the optical fiber transmits the fluorescence of mineralized tooth tissues for detection. So, the intensity of the detected fluorescence indicates the extent of caries [16]. The reliability of DIAGNO dent, in detecting secondary caries under composite restorations, is reported to be similar to digital radiographs [17], however, the Cone beam computed tomography seemed to represent the best accuracy [18]. Near-infrared laser transillumination (NIR-LTI) is another new generation of caries detectors which have shown promising results compared to DIAGNOdent however the researches are not vast enough to make a determined conclusion [19].

Re-mineralization and Caries Removal

Dental caries can be installed by laser irradiation due to its effect on chemical, physical and crystalline properties of the enamel. Enamel remineralization can be induced by laser irradiation at a specific wavelength. Laser irradiation might reinforce the enamel structure by causing physical fusion of the surface and reducing enamel solubility by melting, sealing and re-crystallization [7]. Ultra-structural alterations in the enamel crystals might end in reduced enamel solubility. These noticeable enamel alterations are: reduction of water and carbonate content, increased amount of hydroxyl ion contents, formation of pyrophosphates, and decomposition of proteins [20]. Esteves-Oliveira *et al*. stated that CO_2 laser was capable to eliminate the enamel caries progression [21]. Also, it is reported that Pulsed CO_2 laser irradiation caused enamel surface fusion and inhibition of the subsurface caries-like lesions with 50% success rate [22]. Moreover, increased micro-hardness of enamel surface was detected by several studies after laser application [7, 23].

Laser removes selectively the carious lesions because they contain higher amounts of water than sound dentinal tissue. Laser can produce three sets of absorption bands in dentine, however the 6 μm absorption band attributes to the dominant organic materials of carious structure. More specifically, 5.8 μm of wavelength can positively remove the carious tissue with minimal damage to healthy dentine [24]. Whereas, the Er:YAG and Er,Cr:YSGG lasers operate at 2.94 and 2.79 μm [25], and pulsed CO_2 laser prepares high-speed and precise ablation of dental caries at wavelengths of

9.6 and 9.3 μm [26]. Short pulses and high dentinal absorption reduce the over heat and thermal damage of the pulp tissue. Ishii *et al*. tried out a nano second pulsed laser at wavelength of 5.85 μm for selective caries removal. Their results manifested minimal damage to sound dentin and successive removal of less Ca content substrates, like carious structure [27].

The ideal cavity preparation relies on removing the affected dentin without sacrificing some healthy or at least potentially remineralizable tissues [28]. However, literature disputes about the mentioned fact for the Er:YAG. Raucci-Neto *et al*. reported that Er:YAG laser remained demineralized dentine with a network of ultra-structural collagen matrix [29]. Whereas, another study [30] has claimed that Er:YAG laser removes carious tissues non-selectively in which high volume of residual caries is remained in some specimens, and tissues are removed excessively in some others. Different irradiation parameters, specially the frequency, have remarkable effects on the quality of caries removal. For instance, higher frequencies reduce the selectivity removal of the demineralized dentin tissues [29].

Restorative Qualities after Laser Irradiation

The Er:YAG laser tends to leave dentinal tubules open with minor smear layer production during cavity preparation. Hence, higher dentin permeability could be achieved by laser rather than the rotary device or the manual excavation [31, 32]. The Er:YAG laser makes dentinal water evaporates. Also, it causes some structural changes in composition of collagen (incorporation of an OH radical) [33, 34], which may in turn promote the increased dentin permeability.

Some experiments are focused on the marginal leakage and bonding strength of composite resins to prepare dentin by laser irradiation. Korkmaz Y *et al*. studied the marginal leakage of different adhesive systems in cavities prepared by Er:YAG laser. Their results reflected higher microleakage in cervical margins specially in cementum and dentin [35] which might be related to the technique sensitivity of bonding systems and the quality of formed hybrid layer in that regions [10]. Kimyai *et al*., surveyed the microleakage of three different adhesive systems in class V cavities prepared by Er,Cr:YSGG laser. They found higher microleakage of gingival margins rather than occlusal margins, specifically in self-etched adhesive system rather than etch and rinse two step (total etch) [36]. In contrast, Baghalian *et al*. conducted a study to compare the microleakage of restored class V cavities prepared by Er:YAG laser and conventional burs. They claimed that preparation by Er:YAG laser demonstrated a better marginal seal on occlusal and gingival margins [37]. Another study confirmed mentioned results, too [38]. It has been noticed that the degree of microleakage might be affected by several factors such as the type of adhesive systems, the type of self-etching adhesive, the cavity margin location, and the technique of preparation [37]. Also, higher microleakage of cervical margins might be due to the lack of dentinal tubules in the first 100 nm of cervical margins and higher organic content of the dentine [39].

Bond strength of composite resin is another concerning issue in released literature [40 - 44]. Some studies experienced “laser etching effect” by irradiating laser to prepare sufficient surface roughness and permitting mechanical interlocking with adhesive resins [22, 45]. However, for two or three step etch-and-rinse adhesives, phosphoric acid etching has been suggested prior to the application of mentioned adhesive systems to enhance higher bond strength [46].

Parhami *et al*. compared the effect of Er:YAG laser and high speed diamond burs on the shear bond strength of flowable composite to enamel. The final conclusion was that the Er:YAG laser preparation reduced shear bond strength of tested composite resin compared to the conventional cavity preparation [40]. Shirani *et al* reported negative effects of Er:YAG laser irradiation on shear bond strength of composite resins, either [42]. In contrast, Altunsoy *et al*. evaluated the effect of different modes Er:YAG laser on the micro tensile bond strength of two different self-etch adhesive systems and flowable composite resins to dentin. Their final results indicated that pulse mode laser irradiation increased the micro tensile bond strength of both adhesive systems and flowable composite resins [44]. Moreover, other researches notified the improved bond strength of composite resins after laser irradiation [47 - 49]. Both peri- and intertubular dentine would be demineralized during acid etching and collagen exposure. This procedure needs enough surface moisture after etchant removal, otherwise hybrid layer formation would decrease because of the collapse of collagen fibers [50]. On one hand, the Er:YAG laser does not demineralize dentin surface and no collagen will be exposed [10], in the other hand, remaining peri tubular dentin after irradiation might be helpful to obtain stronger adhesion to the dentin due to its more mineral content in comparison with inter tubular dentine [51].

Vital Pulp Therapy

Application of laser instruments was studied on vital pulp therapy and pulpotomy of primary teeth. Low intensity lasers can be indicated for vital pulp therapy with the success rate up to 90% in comparison with traditional methods

[52]. The advantage of laser therapy is based on its bactericidal activity, hemostatic activity, reduction in elevated pulp temperature, reducing inflammation, stimulating dentinogenesis [53, 54], healing improvement by enhancing collagenic protein, formation of a fibrous matrix, and inducing hard tissue barriers [54 - 56]. In an animal study by Handa *et al*. [57], three different strategies for Direct Pulp Capping were evaluated. They concluded that there was no significant difference among utilization of Er:YAG laser + MTA, Er:YAG laser + $Ca(OH)_2$, and MTA. However, Er:YAG + MTA had better results. Based on this study, Er:YAG laser could be useful in combination with two common Direct Pulp Capping materials.

In some animal study the effect of lasers on the pulpotomy process was evaluated. An investigation by Shoji *et al*. [58], showed that the CO_2 laser led to no detectable damages to the dogs' dental pulp. In some human studies, laser application in comparison or with incorporation of some common methods was evaluated. In a study by Elliott *et al*. [59], the CO_2 laser had comparable response than formocresol in human primary teeth. In another study, the clinical success rate of palpotomy was compared between the Nd:YAG laser and formocresol. The results revealed that the Nd:YAG laser had significantly higher success rate than formocresol [60].

CONCLUSION

Lasers can be applied for remineralization and caries removing processes. They have some favorable effects on damaged pulp with controlled heat and wavelength. However, some adverse and controversial effects on quality of bonded restorations have limited their common usage in restorative dentistry. This technology needs to find its niche in dental practice by clinical and controlled research.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

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