Review Article

The Efficiency of Laser Application on the Enamel Surface: A Systematic Review

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Abstract:

Used in conjunction with or as a replacement for traditional methods, it is expected that specific laser technologies will become an essential component of contemporary dental practice over the next decade. The current review is designed to focus on the acid resistance of laser application and tries to introduce laser settings capable to achieve this feature for clinical application. Application of laser for its acid resistance might be a valuable adjunct to conventional acid etching for susceptible sites in high caries risk patients such as patients with rampant caries, who cannot follow oral hygiene instructions due to their systematic disabilities, or those under orthodontic treatment with plaque retentive attachment on their teeth. The key words "enamel acid resistance" and "laser" were searched in PubMed. In brief, the current paper involves the results on 5 items: A summary on laser application; Suggested mechanisms of acid resistance; Different types of laser beams used in acid resistance; Comparison of application of different laser types; and Conclusion.

Keywords: Acid Resistance; CO_2 laser; diode laser; Er YAG lasers; Nd YAG lasers

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Introduction

With the increasing popularity of composite resins application in dentistry, concerns grew up regarding their quality in clinical performance. This resulted in many study designed to evaluate the effect of different tooth preparations[1-3], factory composition of different composite resins[4-6], different environmental conditions[7,8] and methods of curing[9,10].

Laser is an acronym of Light amplification by stimulated emission of radiation and was first introduced by Gordon Gould in 1959[11]. Physical properties of laser beam are coherency, monochromatic nature, collimation and high intensity. The first clinical application of laser in dentistry was introduced by Maiman in 1960. A 3W Neodymium-Doped Yttrium Aluminium Garnet (Nd:YAG) laser was the first surgical laser specified for dentistry in 1989, followed by Erbium-Doped Yttrium Aluminum Garnet (Er:YAG) approval for use on bones and teeth 12. Laser-tissue interaction depends on tissue optical properties and laser characteristics. Three important characteristics of laser application are essential in clinical application: wavelength, power density and application mode (pulsed versus continuous, contact versus noncontact modes). All the mentioned characteristics can help the clinician in selection of the best protocol.

Used in conjunction with or as a replacement for traditional methods, it is expected that specific laser technologies will become an essential component of contemporary dental practice over the next decades.

Methods

The key words "enamel acid resistance" and "laser" were searched in PubMed. Seventy two papers were displayed. After the results date was limited to 2004 till

2012, 34 papers remained. The reason for this limitation was to gather the more recent studies on acid resistance of enamel surface with the application of laser beam. In brief, the current paper involves the results on the subject in 5 items: A summary on laser application; Suggested mechanisms of acid resistance, Different types of laser beams used in acid resistance; Comparison of application of different laser types; and Conclusion.

Laser applications

From the range of available lasers in dentistry it seems beneficial to summarize the most recent current applications for lasers in clinical practice. Including the low intensity lasers, which major diagnostic application is caries detection capability of fluorescence elicited from hydroxyapatite or from bacterial by-products. This is an effective and quantitative method for occlusal, cervical and with refinements for proximal carious lesions detection. Photoactivated dye techniques eliciting photochemical reactions can be used to disinfect root canals[13-15], periodontal pockets[16,17], cavity preparations[18-21] and sites of peri-implantitis[22-24]. Laser-driven photochemical reactions can also be used for bleaching[25,26] and photodynamic therapy; and with more powerful lasers in the treatment of malignancies[27-29].

In addition to application for several decades in caries removal[30,31], cavity preparation[18-21] and soft tissue surgery[32-34], high intensity laser can be used to improve the resistance of tooth structure to demineralization. Also lasers provide the pediatric dentistry with “a new wave of microdentistry”, filling without drilling, diagnosis of caries in combination with the preventive adhesive effects after cavity preparation[35].

The current review is designed to focus on the acid resistance of laser application and tries to introduce laser settings capable to achieve this feature for clinical application. This application is of particular benefit for susceptible sites in high caries risk patients such as patients with rampant caries, who cannot follow oral hygiene instructions due to their systematic disabilities, or those under orthodontic treatment with plaque retentive attachment on their teeth.

Suggested mechanisms of acid resistance

From the studies conducted for the evaluation of enamel resistance, outstanding mechanisms were discussed to be effective in the resistance of the enamel to acid. Below are some of these hypotheses:

1. Some emphasized on melted surfaces and crater-like holes 1-20 µm in diameter in the Carbon Dioxide Laser (CO_2) laser and Nd:YAG laser groups. They also reported positive birefringence and reversal of birefringence after acid challenge of the lased enamel[36].
2. Another finding was improvement in crystalinity after Er:YAG ablation[37]. Although others supported an increase in fluoride uptake and a reduction in acid dissolution[38], Erbium, Chromium Doped Yttrium Scandium Gallium Garnet (Er-Cr: YSGG) (6/8 W, 6 sec) showed no significant Ca/P weight ratio changes, no enamel and dentin smear layer, various micro-irregular patterns, opening of dentinal tubules were clearly visible and no melting or carbonization was seen[39].
3. Different mechanical surface alterations such as reduced enamel solubility without severe enamel alteration[40] was reported. In a comparison of various Er:YAG fluencies[41] in addition to different crack size, morphological and chemical pattern changes, interiors of the cracks were detected to be rough. Another study[42] concluded that application of subablative Er lasers causing fine enamel cracks, is a starting point for acid attack, causing deep demineralization and respectively a reduction of positive effect of enamel caries prevention. In contrast, another investigation clarified that Er,Cr:YSGG laser beam with energy density of 62.5 and 125 J/cm^2 acted in superficial enamel layers. For explanation they insisted that with water it was more difficult to reach a surface with more resistance to acid attack[43]. Also, less pronounced softened enamel layer was reported underneath carious lesion in laser irradiated samples[44].
4. Contrary opinion[45] on synergistic effect of laser and fluoride application should not be ignored.

Different types of laser beams used for acid resistance of enamel surface

Most studies used CO_2, Er:YAG, Er,Cr:YSGG and Nd:YAG for detection and comparison of the amount of acid resistance on the enamel surface with and without fluoride application. In some other few studies the investigators tried to use visible, diode and near infrared laser beams to show the same effects[46-48] although the focus is on the aforementioned laser beams.

Although some of these studies did not clearly mention the settings of laser units, the current study tries to guide the clinician to the most effective protocol.

CO_2

Most of the studies on acid resistance were conducted on application of CO_2 laser beam[36-38,44,45,49-54]. Application of contact profilometer[44], Scanning Electron Microscope (SEM)[36,38,44,49,54], Microharness (MHN) test[50], Ca-P fluoride concentration[45], electrolyte analysis[36] and controlled surface dissolution experiments[53] were the tests used for evaluation of laser beam efficiency.

Esteves Oliveria et al.[49] demonstrated that 0.4 *J/cm*^{2} at 450 Hz and 0.7 *J/cm*^{2}, 300 µsec at 200-300 Hz decreased 20% of Ca and P release, they postulated that all parameters caused surface cracking and did not recommend the application of CO_2 laser beam for this purpose.

A calcium-phosphate-fluoride could not demonstrate calcium loss from enamel and dentin[45]. This study also found no synergistic effect of laser and fluoride application.

Correa-Afonso et al. observed an increase in pit and fissure enamel resistance to acid with application of CO_2 laser beam[50]. They compared 0.4W/ 2Hz CO_2 with 1W/ 10Hz Nd:YAG and 80mJ/ 2Hz Er:YAG.

In a comparison of CO_2 laser beam irradiation (0.3 *J/cm*^{2}, 5 µsec, 226 Hz) and fluoridation, the investigators reported a decrease in tooth brushing abrasion of softened enamel[44].

Another study designed to compare the acid resistance of CO_2 laser (0.1 W, 30 sec, beam size: 0.49) application for fusion of Calcium phosphate glass (CPG) and low melting point ceramics to the enamel[51] postulated higher acid resistance and successful fusion in the CPG group.

In another study, acid resistance with CO_2 laser application (83.33 *J/cm*^{2}) was concluded to be more efficient than fluoride therapy[36]. Briefly, CO_2 laser application in conjunction with amine fluoride may increase acid resistance of not only sound enamel surface but also demineralized enamel surface[38].

High scanning speed (6 mm/sec) of Transversely Excited Atmospheric (TEA) CO_2 laser (9.3 µm, 30 *J/cm*^{2}, 300 Hz) demonstrated enhanced resistance of enamel to acid dissolution[53]. Fifteen seconds continuous CO_2 laser in conjunction with fluoride application may be useful for effective caries prevention[54].

In conclusion, the application of CO_2 laser must be used with great concern for probable crack propagation on the enamel surface.

Nd:YAG

Four studies evaluated acid resistance of the enamel surface with Nd:YAG laser beam[36,54-56]. The teeth were tested for microhardness of the enamel surface[55,57], fluorescent radiance and evaluation with laser confocal scanning microscope[56] as well as electrolyte analysis[36]. Azevedo et al investigated smaller demineralization depth in all treated groups (laser with fluoride application, fluoride gel and fluoride varnish) compared with the untreated control[57]. They could not show that Nd:YAG laser combined or not with fluoride gel/varnish was more effective than fluoride alone in prevention of enamel demineralization within their experimental period. Three other studies postulated that Nd:YAG laser therapy was beneficial in the increase of acid resistance in permanent[36,56] and deciduous[55] teeth. Chen and Huang[36] demonstrated that the laser beam with the power density of 83.33 *J/cm*^{2} can act better than fluoride application.

In brief it can be mentioned that Nd:YAG laser beam with 80 mJ energy and 0.8 W power or with an energy density of 83.33 *J/cm*^{2} is useful for reduction of enamel demineralization. This laser beam can be effectively used with or without fluoride gel/varnish.

Er:YAG

Twelve studies[37,40-42,47,50,52,55,58-61] were conducted on the application of Er:YAG laser beam for caries prevention. Miscellaneous tests were adopted to measure acid resistance of enamel surface, such as: MHS[50,55], SEM, AFM and EOS[41], evaluation with polarized light microscope[58], measurement of microleakage[61], shear bond strength[47], spectrophotometery and atomic absorption spectrometery[40,52], changes in crystal structure[60], mineral content and atomic - Ca ion – distribution[37,60] and confocal laser scanning microscope[42].

Apel et al upon using Er:YAG (2.94µm, 6 *J/cm*^{2}) postulated that subablative Er family lasers can cause fine enamel cracks, a starting point for acid attachment, which may cause deep mineralization and reduce the positive effect of enamel caries prevention[42]. So they concluded that the clinical use of subablative Er laser irradiation to prevent caries formation is not logical.

In another study the investigators demonstrated the improved crystalinity after Er:YAG ablation[37]. In comparison of 3 settings of Er:YAG laser, Cecchini et al showed that 60mJ, 2Hz, 33.3 *J/cm*^{2} and noncontact application mode is the best setting for reduction in polymerization[40]. They found different surface alterations with different settings. Their results and recommended settings were later certified by Waidyasekera study[60].

In addition to laser application on permanent teeth, Er:YAG (2Hz, 60mJ, 40.3 J/cm^2) was proved to be successful for increasing deciduous enamel acid resistance[55]. BevilÃ¡cqua et al concluded that among different fluencies of Er:YAG, 1.8 J/cm^2 and 0.9 J/cm^2 showed increase in fluoride uptake and reduce acid dissolution[52]. Lessa et al[47] found no differences between variable distances of 12, 14, 16, 17 mms for Er:YAG (80 mJ, 2Hz). Lepri et al[59] could not show the increase of the bonding effectiveness with the Er:YAG (80 mJ, 2Hz). Correa-Afonso used the Er:YAG with the setting as Lessa and Lepri adopted[58]. They found it efficient in preventing enamel demineralization with cooling and 4 mm distance.

In a comparison of laser etching with Er:YAG and Acid etching group, the authors reached the conclusion that 1.5 & 2.1 watt Er:YAG laser may be an adjunctive method for acid etching before bonding orthodontic brackets[61].

In another study, 10 Hz Er:YAG lasers (100mJ, 12.7 J/cm^2), (100mJ, 7.5 J/cm^2) and (150mJ, 11 J/cm^2) were compared[41]. In addition to different crack size, morphological and chemical pattern changes, interiors of the cracks were detected to be rough.

It can be concluded that the range between 33.3 J/cm^2 and 40.3 J/cm^2 and 60 mJ pulsed noncontact mode can be effective in acid resistance effect of Er:YAG laser beam on enamel.

Er,Cr:YSGG

Some studies[39,42,43,62-64] applied Er,Cr:YSGG laser beam. Different tests for evaluation of acid resistance of enamel surface were adopted: Knoop MHN[43], MHN test[63], dye penetration[64], atomic absorption spectrophotometry[39] and confocal laser scanning microscope[42].

Based on confocal laser scanning microscope, Apel et al did not recommended Er,Cr:YSGG (Phi: 8 J/cm^2) for caries prevention due to the possibility of crack initiation on enamel surface[42]. Although the full paper was in chineese, from the abstract we could get that Qiao et al upon application of 6 and 8 W Er,Cr:YSGG for 6 sec introduced them to be effective for enamel acid resistance[39]. Evaluation of dye penetration with image analysis software could not demonstrate any effective reaction on microleakage resistance of fissure sealants[64]. In another study, de Freitas et al[63] compared different power and fluencies of Er,Cr:YSGG laser and concluded that the best result of enamel resistance to acid was observed with 8.5 J/cm^2, 0.75 W, 20 Hz. They postulated that the enamel resistance to acid with laser beam application was better than application of dentifrice fluoride.

More reduction in enamel demineralization was showed with Er,Cr:YSGG laser therapy in combination to fluoride application compared with laser application alone[62]. Geraldo-Martins et al[43] adopted the energy density of 62.5 and 125 J/cm^2 as the best of all other settings for increase in acid resistance.

Other groups

In small amount of studies the investigators adopted Diode lasers, Infrared and visible lights to achieve acid resistance of enamel[46,48,65]. They tested with VHN[46,65] and FE-SEM[48]. Vlacic et al with adoption of 15 J/cm^2 energy density and 5 mm spot size demonstrated that active laser activated fluoride effect extends across the visible and near infrared spectrum to reduce caries susceptibility[46]. They later[65] confirmed their previous study with the same energy density and spot size as mentioned[46] for abrasion lesions. Kato et al could not show any promotion of reduction in Ca solubility in the comparison of 960nm Diode laser and fluoride application[48]. Their adopted laser settings were as follows: 6.5 W, 5 msec pulse duration, 10 Hz, 33mJ.

Discussion

In some of the aforementioned studies, some types of lasers were compared for their effectiveness in the acid resistance of enamel. In a comparison between Er:YAG (6 J/cm^2) and Er,Cr:YSGG (8 J/cm^2), Apel et al did not recommended clinical application of none of the laser beams because of the possibility of enamel fine crack initiation[42].

In a comparison of four groups, a reduction in Ca loss was observed in two groups of "fluoride after Er:YAG application" and "CO_2 after Er:YAG application"[37].

Castellan et al postulated that both Nd:YAG and Er:YAG laser beams can be used as alternatives for increase in deciduous enamel acid resistance[55]. An increase in acid resistance of laser activated fluoride therapy was supposed to be effective according to Chen et al[36]. They adopted CO_2 and Nd:YAG lasers with energy density of 83.33 J/cm^2 and found melted surface and crater like holes in their samples.

Testing with MHN, Correa-Afonso[50] valuated the acid resistance effect of CO_2 (0.4 W, 20Hz), Nd:YAG (1W, 10 Hz) and Er:YAG (80 mJ, 2Hz). They concluded that CO_2 laser beam was the best option for increase in pit and fissure resistance to acid.

Conclusion

Used in conjunction with or as a replacement for traditional methods, it is expected that specific laser technologies will become an essential component of contemporary dental practice over the next decade. Resistance to acid can be achieved with the application of all the mentioned laser beams if suitable power settings are applied. Application of laser beam with the best gathered evidence can help us to run the horse of treatment plan with more confidence and serves our patients as an invisible servant.

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