Review Article

The Effect of Erbium, Chromium: YSGG Laser and Fluoride Products on the Resistance of Dental Enamel to Acids

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Abstract

Even though dental erosion is preventable, it remains widespread and a public health issue. The use of lasers such as erbium chromium is one of the effective preventive tools, particularly when combined with fluoridated products. This review aimed to detect the preventive effect of laser irradiation and fluoridated product applications on inhibiting enamel demineralization. To get accurate information, we conducted a thorough literature search utilizing reliable sources, including journal databases, current systematic reviews, and research recommended by subject matter experts. Studies that met the inclusion requirements had their quality evaluated. The effect of irradiating enamel surfaces coupled with the use of topical fluoride can significantly enhance the resistance of sound enamel surfaces to acids and decrease enamel demineralization more than using laser alone or fluoridated products alone. Combining topical fluoride application with laser irradiation protects sound enamel from demineralization.

Keywords: Dental application, dental erosion, dental laser, enamel, Er,Cr:YSGG

Introduction

Modern dentistry is progressively shifting towards minimally invasive dental practice, a preservative aspect that predominantly emphasizes early identification of dental carious lesions and promotes the remineralization of teeth and conservation of nearby tooth structure.[1-3] In developing countries, dental caries and dental erosion remain prevalent oral health concerns, with the latter being a significant etiological factor of dental hard tissue loss among individuals of all ages. In particular, dental erosion substantially threatens the oral health of children, adolescents, and adults.[4-7]

Dental erosion could be prevented using fluoridated products such as acidulated phosphate fluoride (APF) gel by decreasing the rate at which the acids could dissolve the tooth's enamel, as it forms a superficial calcium fluoride. As fluoride treatment's effectiveness in minimizing dental erosion is limited, it highlights the requirement for modern technologies like laser treatments to boost its effectiveness in preventing and controlling dental erosion.[8,9]

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According to recent studies, laser therapy has been found to reduce subsurface demineralization. This discovery is of particular interest to professionals in the medical and dental fields. However, the actual mechanisms of its preventive effect remain unclear; there have been several proposed reasons, such as enamel hydroxyapatite melting, alteration, and recrystallization of the organic matrix. Many studies demonstrated that combining laser and fluoridated products had promising synergistic effects in reducing enamel demineralization.[10-12]

Using Er,Cr:YSGG laser as a surface pretreatment and remineralizing agent has recently shown improved enamel remineralization outcomes with the highest microhardness score compared to laser alone or remineralizing agents alone.[13]

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Laser technology

Laser devices produce and amplify radiation across various wavelengths, from infrared to ultraviolet. The term "laser" stands for "Light Amplification by Stimulated Emission of Radiation" and was first used by the American physicist Gordon Gould in 1957. His notes were verified on the first page of his article.[14]

Photons are the smallest quantum packets of electromagnetic energy, generally considered to possess an insignificant mass or charge. These wave-like entities represent energy and are just one component of the larger photonic energy arrangement known as the electromagnetic spectrum. Light, which travels in a wave-like manner, is a tiny portion of this spectrum.[14]

Laser technology has revolutionized medicine, surgery, dentistry, and cosmetics. In dentistry, it is used as an adjunct that supplements many hard and soft tissue procedures.[15-17]

An overview of the advent of laser technology in dentistry

The advent of laser technology in dentistry can be traced back to 1960 when Theodore H. Maiman first introduced the concept of clinical laser usage.[18,19] In 1961, yttrium-aluminum-garnet crystals were used to create a laser (Nd: YAG), which was treated with neodymium (1–3%).[20,21] The development of the argon laser in 1962 was a significant milestone that expanded the possibilities for laser use in various fields. The following year, the medical field saw a revolutionary breakthrough when the first medical laser, the ruby laser, was employed to coagulate the lesions in the retina. Following Patel's discovery of the CO_2 laser in 1964, numerous laser systems were quickly developed and the fabrication of the constantly functioning higher-power laser.[22] In 1965, Sognnaes and Stern[23] demonstrated that irradiating tooth surfaces with ruby laser increases enamel resistance to demineralization.

Using a CO_2 laser for enhancing the dental hard tissue resistance to acid was initially proven in 1970.[24] Four years later, Er:YAG laser was presented as a solid-state laser that produces light with a wavelength of 2940 nm.[25]

Several studies on the impact of laser irradiation have been conducted. It demonstrated that Nd:YAG laser treatment of human enamel made it more resistant to acid demineralization than a non-irradiated control.[26,27]

Infrared lasers caused a clinically substantial reduction of lesion formation, according to Nelson *et al*.[28] It has been proven that laser irradiation protects against both caries initiation and progression. Lasers have also been combined with fluoride for caries prevention; this technique is termed laser-activated fluoride (LAF) therapy.[29,30]

Application of laser in pediatric dentistry

When a synthetic material is stimulated, a monochromatic light with a single wavelength is released.[31] The wavelengths of various lasers determine their clinical application.[32] The erbium family lasers (Er:YAG and Er,Cr:YSGG) at 2940 and 2780 nm wavelengths, respectively, are the only two wavelengths that could be significantly absorbed inside bone and dental tissues when employed with healthy and specific settings because water prefers these wavelengths.[33]

In pediatric dentistry, it is crucial to encourage pediatric patients to go to the dentist to minimize oral and dental problems. Therefore, pedodontists must acquire new technologies in addition to dental concepts. Due to laser technology, children's problems with the gums, dentition, and jaws can now be diagnosed and treated more effectively. Because laser therapy is minimally invasive, parents and children accept it.[34]

According to a report by Nazemisalman *et al*.,[31] children exhibit higher compliance during laser-assisted surgical, restorative, and pulpal procedures, leading to increased treatment efficiency and care quality. There exist multiple varieties of lasers that apply to the field of pediatric dentistry, each offering unique features and benefits. This technology is set to become the widely accepted standard for dental procedures in the field of pediatrics.[31]

Erbium, chromium: Yttrium, scandium, gallium, garnet laser (Er,Cr:YSGG laser)

Numerous dental treatments can be performed using erbium lasers, and more can be done without local anesthetic. They could be used on both hard and soft tissue. Hard tissue treatments, such as cutting bones, can be performed with erbium lasers with little heat or mechanical harm to surrounding tissues. These techniques on hard tissues exhibit outstanding healing results.[35]

Compared to CO_2 lasers, erbium laser applications for soft tissue have less adequate hemostasis and coagulation. Er,Cr:YSGG treatment for depigmentation of the gums was effective.[36]

One of the newest lasers used in dentistry is the (2780 nm wavelength) Er,Cr:YSGG. The laser wavelength penetration varies depending upon the target tissue, as it penetrates enamel at a depth of 21 μm and dentin at a depth of 15 μm because of this variation, which affects the speed and ablation. The more tissue the laser passes through, the more heat will be dissipated and the longer it will take for that specific tissue to reach the needed temperature for ablation. The laser cutting speed is determined by the laser frequency and the energy of a single pulse.[37]

Because of Er,Cr:YSGG wavelength that is well absorbed by the water and the hydroxyl radical in the hydroxyapatite, it was used to prepare cavities. Several

studies, however, have proved its capacity to increase enamel acid resistance.[10,38]

In most investigations, it has been found that applying this type of laser at lower energy densities significantly reduces dental caries. This technique is highly effective in reducing the loss of enamel microhardness in carious lesions, indicating that it is a feasible and promising option for enhancing enamel's resistance to demineralization. In addition, these lasers may have an impact similar to fluoride-containing toothpaste in terms of their cariostatic effect.[38,39]

Chemical examination of the tooth structure after being irradiated with this laser indicated a reorganization of hydroxyapatite crystal and a rise in calcium ions due to the heat effect of the enamel, which could explain this[40]—according to research by Abad-Gallegos *et al*.,[41] 30 min of laser irradiation with 1 or 2 W of power resulted in a slight increase in surface temperature. Still, it was insufficient to induce harm to surrounding tissues (periodontal ligament and alveolar bone).[41]

Dental caries prevention *in situ* was investigated by Jorge *et al*.,[42] who found that the preparation of a cavity by utilizing (Er,Cr:YSGG) and fluoride-containing restorations aid in enhancing the enamel to resist demineralization to acids around the prepared tooth surface. However, the optimal settings of this laser for suppressing demineralization are still unknown.[42] Laser parameters differ throughout studies, and there was no agreement concerning the ideal one.[43]

When lower energy densities are delivered for a short period of time, the enamel structure is only subjected to pressure, water heating, and vaporization. As the power of the laser device rises, the effects become evident on dental enamel, and excessive power causes unwanted ablation. The rise in enamel resistance to demineralization depends significantly on laser settings like the number of overlapped pulses, pulse duration, and energy density. Therefore, parameters need to be evaluated because it has already been established that some irradiation circumstances result in better protective benefits against erosion.[44] Setting the ideal laser parameter for clinical applications is thus necessary to maximize the acid resistance while utilizing the least amount of power.[45]

APF gel 1.23%

APF gel is composed of orthophosphoric acid, hydrofluoric acid, and sodium fluoride, with a concentration of 1.23%. It is indicated for professional use only and is not recommended for home use, mainly because the fluoride concentration is high.[46]

Products containing fluoride, such as (1.23%) APF gel, are helpful in erosion prevention because they reduce acid penetration depth into the enamel.[45] The protective activity of it is related to creating a superficial layer of CaF_2, which keeps the enamel from being exposed to acids and disintegrating.[47] However, other studies have found that fluoride therapy has a limited efficacy in reducing dental erosion.[48] This emphasizes the need for alternative approaches for controlling and preventing dental erosion, such as laser therapy.

Preventive effect of combined application of laser and fluoride on enamel

Fluoride compounds and laser irradiation combined produce stronger enamel with fewer harmful effects from the laser. This technique has the potential to enhance dental treatments.[49] Laser irradiation can cause chemical, physical, and kinetic changes that improve fluoride penetration depth and substantivity in tooth enamel.[50] However, more research is needed to confirm these findings. Some studies have indicated that laser irradiation can increase fluoride uptake by the tooth structure.[51]

The combination of laser irradiation and fluoride has a synergistic action on enamel susceptibility to demineralization, minimizing enamel erosion, increasing enamel surface roughness, and developing larger ablation zones.[52] The uptake of fluoride unequivocally increases, and the retention of compounds similar to calcium fluoride extends and maintains the enamel's resistance to erosion,[44] according to research by Moslemi *et al*. (2009), combining fluoride and laser treatment increased the enamel's resistance to acid erosion. Extensive research demonstrated no discernible difference in the enamel's acid resistance when it is subjected to laser treatment either before or after the application of fluoride. However, it is established that exposing the enamel to laser treatment before the fluoride application yields better results.[44,45,53,54]

The study by Ana *et al*.[55] supports the effectiveness of topical remineralizing agents and laser treatment in improving the enamel's resistance to erosion. According to Ramalho *et al*., the erbium lasers could be considered the most popular lasers in dentistry.[56] The superiority of Er,Cr:YSGG over Er:YAG was thought to be highly absorbed by the main component of the enamel (hydroxyapatite). Meanwhile, the water content of the enamel highly absorbs the second one, and more micro-explosions occur, resulting in an undesirable ablation. As a result, the Er,Cr:YSGG laser is thought to be more effective in minimizing demineralization due to its deeper penetration and lower ablation efficacy.[57-59]

Limitations of Laser Devices

It is vital to consider the limitations of laser devices, including the environmental factors under which they are used. Using laser devices requires:

- High equipment cost.
- The need for multiple laser devices with varying wavelengths for different procedures.

- The need for additional education and training for various lasers and their clinical applications.[19]

Conclusion

The application of laser irradiation, specifically Er,Cr:YSGG, on dental enamel has been demonstrated to significantly enhance its resistance to demineralization. When combined with fluoridated products, this treatment provides optimal protection against the initiation and progression of erosion. As a result, the combined treatment is an effective method for promoting the long-term health of teeth.

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Ethical approval

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Conflicts of interest

There are conflicts of interest.

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