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FULL PAPER

Caries removal and cavity preparation using Er: Yag laser in dental practice: literature review

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Caries removal and cavity preparation are associated with restorative treatment in carious teeth. Cutting dental hard tissue is challenging to remove the carious tissue and maintain the healthy tissue to support the restoration. In recent decades, the laser has been widely used in dental practices and played a significant role in non-invasive treatment approaches. The laser with the highest efficiency for hard tissue and useful for dental caries is the Er:YAG laser, which is approved by the Food and Drug Administration (FDA). This literature review aims to list the benefits of employing Er:YAG lasers in dentistry practices for cavity preparation and caries eradication. More healthy tissue can be preserved with more precision, a clean surface, and a smear-layer-free surface thanks to use the Er:YAG laser to remove cavities. Using Er:YAG laser in dental practice can reduce the risk of infection because it provides a surface decontamination effect and generates less aerosol. Patients will also feel more comfortable and painless during the treatment. Dental practitioners and patients have significantly benefited from cavity preparation and using the Er:YAG laser to remove dental cavities.

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Introduction

In 1964, the initial lasers were invented and upon their creation, the medical field rapidly embraced the potential of employing this novel technology for various applications. Over the past 20 years, medicine has witnessed a significant advancement in the utilization and expansion of lasers. These ground-breaking developments primarily originated within the specialties of ophthalmology, dermatology, and general surgery [1-3]. Today, both patients and physicians widely acknowledge the significance of soft tissue surgical lasers in various medical specialties. This acceptance empowers surgeons to perform surgeries with minimal or no bleeding, offering an effective alternative to conventional surgical methods.

Theodore Maiman [4], a researcher at Hughes Aircraft Corporation in 1960, successfully developed the first operational laser device. This groundbreaking invention emitted a beam of dark red light, using a ruby crystal. Over the next few years, dental scientists explored potential uses of this unique laser energy. Dr Leon Goldman [5], a dermatologist who had been exploring different avenues regarding tattoo xpulsion using the ruby laser, centred two beats of that red light on a tooth of his dental practitioner sibling in 1965. The outcome was easy surface crazing of the finish.

Medicine and dentistry have utilized lasers, also known as light amplification by stimulated emission of radiation [6]. The development of the laser has significantly altered human lifestyles [7]. In medicine and dentistry, many laser wavelengths are employed. The wavelength and its absorption characteristics determine the interaction of tissues or objects with laser beams [8, 9].

Dental caries eradication and cavity preparation using lasers are two of the primary uses of lasers in dentistry [10]. Since being approved by the FDA (Food and Drug Administration) in 1997, dentistry has used lasers in some cases in the US for cavity preparation and caries eradication [11]. The FDA has shown that among dental lasers, The most effective laser group uses erbium, a cooling system, and a secure laser for cleaning and preparing dental surfaces [10]. In numerous researches, erbium lasers are effective cutters without compromising the vitality of pulpal tissues. This is caused by several elements, such as using water spray, delivering energy in pulses, and employing lasers on occasion [12,13].

Abdrabuh *et al.*, comparing a traditional rotational treatment with a 2940 nm erbium/yttrium-aluminum-garnet (Er:YAG) laser during cavity preparation in children to eradicate caries via mechanical ablation of decaying tissues with reference to restoration integrity. The Ryge criteria indicated that restorations had achieved clinical success, and there was no obvious difference between conventional and laser intervention approaches. Following class I cavity preparation in primary teeth with either procedure, over a year, there were no statistically significant variations in the clinical integrity based on the Ryge criterion [14]. Jew *et al.* investigated the use of a DPSS Er:YAG laser for the targeted treatment of natural occlusal lesions and demineralized dentin on removed teeth. Before laser ablation, 200-m thick pieces of demineralized dentin with naturally occurring caries lesions were analyzed using microradiography to detect the mineral content. Demineralized enamel and dentin have a considerably higher ablation rate than sound tissues [15]. This literature review aimed to list the benefits of using the Er:YAG laser in dental work for cavity preparation and caries eradication.

Mechanism of ablation

Several factors, including wavelength, pulse width, pulse length, repetition rate, power density, tissue's thermal resting state, and delivery method, affect how quickly dental hard tissue is abated [16]. Dental tissue's water molecules and hydroxyl groups readily absorb the 2940 nm Er-YAG laser, resulting in water vaporization and rapid heating. The ejection of dental tissue particles, many micro explosions, and tissue ablation occur due to the high stream pressure that develops inside the irradiated tissue [6].

Enamel is destroyed by erbium laser light due to the rapid subsurface expansion of the trapped water inside the mineral substrate, which results in a familiar popping noise and a significant volume expansion and explosion of the surrounding material [11]. An audible "popping" can be heard while laser ablation happens during cavity preparation. This suggestion is more audible in healthy tooth tissue, but following caries ablation, when more water is accessible, the volume rises [12].

Results of tissue ablation from the tip's end-on laser energy emission. Surface ablation removes tissue gradually; contrast this action strategy with the rotary bur's, which primarily employs a side-cutting method. The handpiece tip should be placed at the ideal distance from the tooth surface for laser ablation of tooth tissue; while a laser emits, the target should be crossed by the tip several times to induce cavitation. It is crucial to enable the water spray to have appropriate access when it enters the tooth cavity to offer cooling and minimize the accumulation of ablation waste.

Pumping the laser tip into and out of the laser chamber is advised to create an appropriate water spray [12].

Minimally invasive preparation

Since 1997, research from 1988 to 1999 has shown that the lasers in the erbium family, including Er:YAG and Er:YSGG, are effective in chopping without endangering the health of pulpal tissues. Several elements, such as the utilization of water spray, an energy delivery system with pulses, and the employment of lasers occasionally, cause this [11]. The inherent tissue qualities enable selective ablation since carious enamel and dentin contain a significantly higher water content than healthy oral tissues. The supplied laser energy should be less than the dentin and enamel ablation threshold, but it should be high enough to remove carious dentin and enamel. Based primarily on the tissue absorption coefficients, laser technology enables targeted ablation [17].

During restorative operations, burs and excavators are most frequently used to remove damaged dental hard tissue. The precision of such instruments has been questioned due to the need for a more unbiased evaluation of demineralized water removal, defective dentin and enamel, and the potential significant volumes of sound tissue removed. In contrast, using an appropriate laser wavelength may enable a significantly more cautious approach to maintaining healthy teeth with calcified tissue, with a preference for removing caries with teeth with calcified tissue, greater precision, and fewer bacteria in the laser-prepared cavity [17].

A "minimalistic" technique is used in laser-assisted cavity preparation, with the benefit of simply removing composite resin restorative materials on damaged tissue (Figure 1) [12].

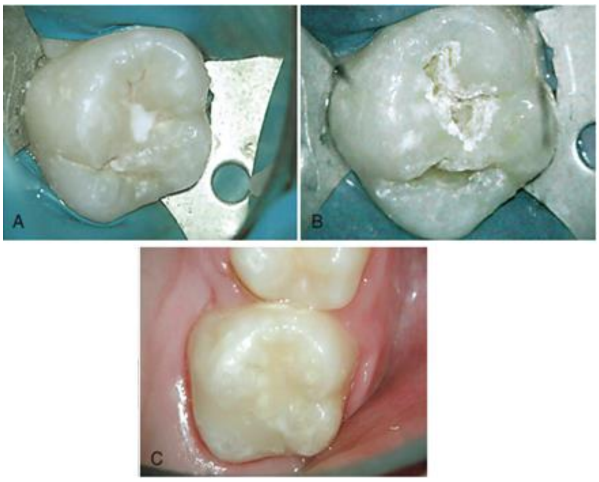

FIGURE 1 Er:YAG (2940 nm) with water spray (700 mJ/pulse, 10Hz) in clinical settings for upper molar. An intraoperative B, immediate postoperative C, composite restoration look [12]

Patient comfort

The consensus among all of the clinical investigations under consideration was that patients prefer laser caries removal over more conventional mechanical removal using a bur [17]. Patients say they feel secure and at ease and that using lasers has made them feel less uncomfortable.7 patients frequently reported receiving dental care without pain and needing local anesthetic. Dental cavity preparations using laser are a viable option for clinicians, as shown by the high percentages of procedures performed without anesthesia and with little to no discomfort reported, the fact that almost each patient would select laser use over alternative cavity preparation techniques in the future, as well as the majority of positive outcomes reported by clinicians [11].

Laser reliably eliminates the discomfort, drill, and needle from dental operations. The laser's power is adjusted throughout therapy to destroy decaying tissue, which is softer than unaffected enamel. It uses the variations in hardness of the tooth's constituent elements. It works so quickly that it does not even need to be used very often or with anesthesia [7].

At least one study discovered that when the Er:YAG laser was used to cut robust tooth structure, positive neurological responses were obtained in both the A and C intradental fibres, suggesting that there is not an induced alteration in the nociceptor's ionic balance. The lack of tactile and thermal stimulation compared to rotational instruments during laser-assisted tooth preparation is particularly pertinent concerning claims of pain avoidance. Additional patient-centred criteria include prior turbine use and various emotional and conditioning states[12].

Aerosol particles

A dental procedure generates a lot of aerosols and splatters, especially when utilizing high-speed handpieces, which could be contaminated with blood, bacteria, viruses, and fungus. Particles less than 50 μm comprise the aerosol produced during treatment in the dental office. Patients and employees in dental offices are particularly at risk of contracting viral infections from particles smaller than 10 μm and passing the virus to them through inhalation. The use of the aerosol removal systems must be simultaneous as a result. Another strategy for reducing aerosolization during dental treatment is to switch to hard tissue lasers from traditional dental handpieces. Compared to both traditional handpieces, Er:YAG lasers reduced aerosol formation by around a factor for both of them [18].

Water spray contributes significantly to aerosolization and splatter in dental offices, which can spread harmful viruses, including the herpes virus, pathogenic *streptococci*, and *staphylococci*. Dental lasers use between 67 and 83% less water and 74% less air pressure than drills. Therefore, compared to a drill, the likelihood of COVID-19 and other viruses spreading by aerosolization and spatter is much lower when utilizing a dental laser. Utilizing the Er:YAG Laser is safer than high-speed and electric or slow-speed drills. Dentists are qualified to perform some of these procedures using a laser with just an air-spray-free cooling water system, lowering the danger of aerosol contamination [7].

The water pressure applied to the tip and the rotor torque speed influence the aerosol output of traditional dental handpieces. Even though erbium laser operation necessitates constant cooling with a water spray, the laser tip's stillness prevents further centrifugal dispersion of water spray particles when inserted into the applicator socket [18].

Surface decontamination

In the scientific literature, the benefits of lasers in dentistry have been demonstrated concerning various treatment modalities and the eradication of germs, fungus, and viruses [6]. The dental laser eliminates any viruses or bacteria that come into touch with it since viruses and bacteria cannot survive over 60 °C. It affects cellular structures directly, damaging cell walls, changing DNA, altering metabolic processes, and dissolving the polysaccharide structure of the biofilm. Bacterial infections are less likely since the laser sanitizes the region. High temperatures all significantly impact membranes, RNA, DNA, ribosomes, proteins, and enzymes on sporulating and non-sporulating bacteria's structural and physiological characteristics [7].

Less postoperative pain and a decreased risk of caries recurrence are tied to two benefits of bacterial decrease with bur use versus laser treatment. According to studies, using the laser reduces bacterial strains that cause caries, such as *Streptococcus* mutans, furthermore to other strains, like *Escherichia* *coli* and *Enterococcus faecalis*. Although "total" sterilization cannot be achieved, reducing bacteria (combined with less tactile trauma) may lessen postoperative discomfort and lower the risk of recurrent decay when using lasers [12].

Tooth surface characteristics

The patterns of laser-irradiated tissue's morphology dentin and enamel present an intriguing component of adhesive bonding techniques, which call for a smooth surface with micro-retentive properties [17]. According to microscopic investigations, laser ablation creates distinct surface patterns with uneven micro-retention distinguished by wide-open dentinal tubes, exposed enamel prisms, and a lack of a smear layer. In addition, it was demonstrated that on laser-prepared dentin surfaces, an even thicker hybrid layer with a more pronounced resin tag manufacture could be produced in contrast to bur-cut surfaces (Figure 2) [19].

Applying self-etch adhesive systems is advised since laser treatment produces rough, uneven surfaces without a smear layer. However, treating laser-cut tooth surfaces with phosphoric acid in addition appears to be beneficial. In this context, Kiryk *et al.*, unequivocally demonstrated that better adhesion qualities are obtained by combining laser-based preparation using er:YAG with traditional conditioning for acid [19-21]. Er:YAG laser-lasered enamel surfaces have a micro-retentive structure akin to type I etching patterns, are roughened and lack smear layers. A rough surface is produced by the microexplosive ablation of minerals, which, when combined with an acid-etch process, allows for a reliable connection for composite-resin restorations, frequently with less of a need for actual undercuts at the cavity's edge [12].

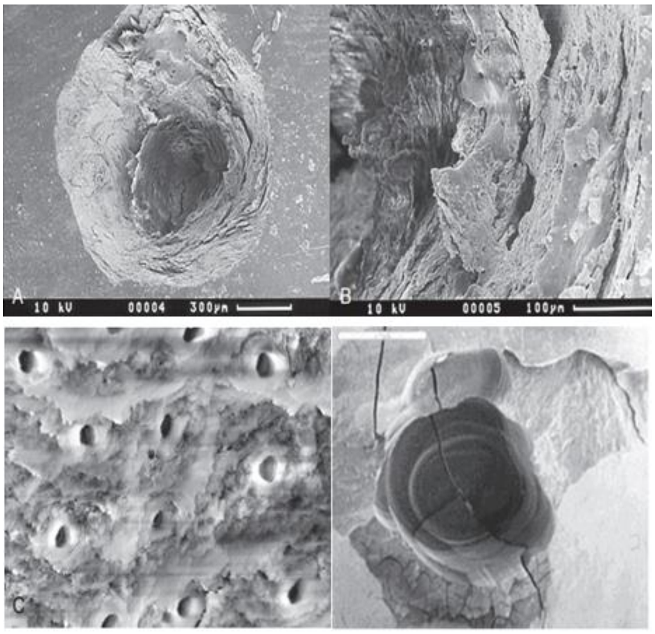

FIGURE 2 Effects of water spray and pulsed Er:YAG laser intensity on human dentin and enamel can be seen in the scanning electron micrograph (SEM). (A) Laser-enamel interaction. Note the impact of spallation and the lack of thermally-induced changes to mineral composition or cracking. (B) Higher power SEM (300x) of the same specimen. (C) Laser-dentin interaction. Take note of the open dentinal tubules, lack of a smear layer, and lack of heat damage. (D) Human enamel created with high-speed rotary instrumentation as seen in SEM. Vibration-induced note breaking [12]

Excavators and burs are still the most often used instruments for cavity preparation and caries removal, although the usage of hard tissue lasers in dentistry is thought to replace them due to their many benefits [7]. All lasers preserved their well-known advantages even during the pandemic. However, using lasers' potential and adaptation to the current circumstances utilizing previously accepted safety recommendations necessitates knowledge of their individual functions and characteristics [8].

Prepare cavities for the Er:YAG laser and removing caries can lower the risk of infection because they produce less aerosol and have a surface cleaning impact compared to traditional burs. Reduced bacterial populations due to the surface cleaning can lessen the risk of postoperative discomfort and subsequent caries. It pointed out that a tooth's clean without a smear layer and the surface can increase the bonding system's bond strength [22-25]. The vibration, noise, and pressure produced by traditional bursts cause patients to feel uncomfortable, which is why using an Er:YAG laser helps to alleviate this. The laser does not induce vibration or pressure because there is no direct contact between the laser tip and the tooth surface. Because of the precision and selective elimination of caries, the Er:YAG laser preparation produces more conservative results. According to Strakas and Gutknecht, the optical characteristics of the tissue significantly impact how the laser interacts with the tissue [17]. Therefore, an analysis of the makeup of enamel and dentin is required to determine the best laser wavelengths [17, 18].

Clinicians should adhere to the manufacturer's instructions when creating laser therapy protocols for a particular laser, considering the various operating conditions of air, and water, the size of the area, the choice of the delivery tip, and any potential power losses between the delivery systems. Most lasers contain a "power meter test" port that can measure the energy released by the delivery system before being used in a therapeutic setting. The effectiveness of the energy delivery system will also be evaluated during the laser test fire [16,26].

Conclusion

There are many benefits to use the Er:YAG laser in dental practice for cavity preparation and caries treatment for both clinicians and patients.

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Conflict of Interest

The authors declare that there is no conflict of interest.

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