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Sub-ablative Laser Energy in Caries Prevention: Recent Advancement in Pediatric Dentistry: A Review

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KEYWORDS

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ABSTRACT:

Aim: The aim of the study was to assess the effects of Laser with Sub-ablative energy for prophylactic intervention to reduce the caries incidence in Pediatric population and comparing Lasers with other traditional interventions (TPI's) when used alone or together with TPI such as Fluoride varnish etc.

Methods: For a Systematic Review articles were selected using the Medline, Web of Science, Embase and Cochrane Data bases. The main terms used for search were : "Laser & Caries", "Lasers & Caries Prevention", "Lasers & Acid resistance and Enamel", Laser & Fluoride" and "Laser & Demineralization".

Eligibility Criteria: Abstracts of the Articles identified by the search and all Articles that appeared to meet the Inclusion Criteria were selected and actual Articles were collected. Inclusion Criteria: 1. Study that relates use of Laser for Caries prevention, 2. Studies related with application of Topical Fluoride, 3. Study was published in a refereed professional or scientific journal. Exclusion Criteria: Case reports and single case studies, Studies on dentin and root surface.

Result: Laser irradiation under specific conditions can change the crystallographic properties of apatite crystals increasing the acid resistance of Lased enamel. CO2 Lasers were most effective device in preventing acid demineralization. The combination of Lasers with TPI was more effective than Laser or Fluoride used alone.

Conclusion: The available data after reviewing Articles suggests that Lasers combined with fluoride is a promising treatment in caries prevention. Despite some positive indications an inadequate level of evidence was found concerning Lasers effectiveness in preventing caries.

Introduction

Laser technology is revolutionizing dental care across all age groups, but its application in pediatric dentistry holds particularly promising potential. Among the latest innovations is the subablative laser, which offers a less invasive and more comfortable treatment option for children. By combining precision with minimal thermal damage, subablative lasers provide a child-friendly alternative to conventional procedures. Unlike fully ablative lasers that remove tissue, subablative lasers operate below the ablation threshold, stimulating tissue healing, reducing microbial load, and minimizing trauma to surrounding structures[1]. Their unique properties make them highly suitable for young patients who require careful, minimally invasive care.

What Is a Subablative Laser?

A subablative laser delivers low-energy pulses that do not vaporize or excise tissue but instead induce thermal or photobiomodulatory effects within the tissue. The laser energy penetrates the soft or hard tissue at a sub-thermal or sub-ablative level, stimulating biological responses such as collagen formation, blood flow increase, and cellular metabolism enhancement[2]. These effects facilitate wound healing, reduce inflammation, and enhance tissue regeneration without causing significant discomfort or requiring extensive recovery time. The use of lasers for ablating and resurfacing is based upon the concept of selective thermolysis of the epidermal and dermal layers of the skin through the delivery of light energy[3]. Light energy emitted by the

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laser is absorbed by the skin's two main chromophores, melanin, and water, which then emit thermal energy, destroying the surrounding tissue.Laser resurfacing technology has benefited from a number of breakthroughs in the last few decades, with the use of continuous-wave carbon dioxide (CO2) lasers beginning in the 1980s[4]. The implementation of pulsed delivery of CO2 laser energy and the subsequent development of the erbium-doped yttrium aluminum garnet (Er:YAG) laser, which gained popularity in the late 1990s, further improved the precision and depth of cutaneous ablation and reduced the incidence of adverse effects[5]. Laser was first used for soft tissue incision. But, the new generation of lasers with their special function on water molecules can be used for ablation of dental hard tissue as well. Due to recent advances in laser applications in most dental fields, it is now efficiently used for caries prevention, diagnosis and treatment[6]. Pedodontists try to create a pleasant memory of the first dental visit for children by using novel, minimally invasive technologies to help the child establish good dental habits[7]. Having a less painful first dental experience through the use of a modern technology like laser would be an efficient preventive and therapeutic strategy. Laser can be successfully used for diagnosis of oral and dental conditions, treatment of the hard and soft tissues and prevention of rapidly progressive oral and dental conditions in children[8].

Types of Lasers and Their Applications in Dentistry

The most commonly used lasers in dentistry include holmium yttrium aluminium garnet (HO:YAG), neodymium-doped yttrium aluminium garnet (Nd:YAG), carbon dioxide laser (CO_2), erbium-doped yttrium aluminum garnet (Er:YAG), neodymium doped yttrium aluminum perovskite (Nd:YAP), gallium arsenide (GaAs) (diode), erbium, chromium doped yttrium scandium gallium garnet (Er-Cr:YSGG) and argon lasers. Soft and hard tissue surgery, root planning (removing calculus from the root surfaces), cavity preparation in the enamel and dentin, dental caries detection, root canal system cleaning, etching, caries prevention by altering the crystalline structure of enamel, tooth whitening, periodontal therapy, and peri-implantitis treatment are among the clinical uses of lasers in dentistry[7]. Table 1 presents different types of dental lasers and their applications[9].

Type of laser	Wavelength	Group	Mode	Delivery system(s)	Year developed	Applications in dentistry
Argon	572 nm	Gas	Pulse or continuous wave	Optical fiber	1964	• Polymerization of resin restorations • Tooth bleaching • Removal of necrotic tissue • Gingival contouring • Treatment of herpetic lesions andaphthous ulcers • Soft tissue ablation, including frenectomy and gingivectomy • Detection of caries
Carbon dioxide (CO_2)	10,600 nm	Gas	Pulse or continuous wave	Waveguide, articulated arm	1964	• Soft tissue ablation, including frenectomy and gingivectomy • Gingival contouring in cosmetic dentistry • Treatment of ulcerous lesions of the mouth • Detection of fissure caries • Removal of necrotic epithelial tissue in regenerative periodontal surgery
Diode	810 nm or 980 nm	Semiconductor	Pulse or continuous wave	Optical fiber	1957	• Promoting the proliferation of fibroblasts to heal oral lesions or accelerate postsurgical healing • Soft tissue ablation, including gingivectomy, frenectomy, and cosmetic • gingival contouring Laser doppler flowmetry to measure blood flow
Erbium, chromium-doped yttrium scandium gallium garnet (Er, Cr:YSGG)	2780 nm	Solid state	Pulse	Optical fiber	1997	• Enamel etching • Removal of carious lesions • Cavity preparation • Bone ablation • Root canal preparation
Erbium-doped yttrium aluminum garnet (Er:YAG)	2940 nm	Solid state	Pulse	Optical fiber, waveguide, articulated arm	1975	• Caries removal • Cavity preparation in enamel and dentin • Root canal preparation
Frequency-doubled alexandrite	337 nm	Solid state	Pulse	Optical fiber	1970s	• Caries removal • Sterilization of root canals • Soft tissue procedures
Holmium-doped yttrium aluminum garnet (Ho:YAG)	2100 nm	Solid state	Pulse	Optical fiber	1960s	• Soft tissue ablation, including gingivectomy, frenectomy, and cosmetic gingival contouring • Treatment of oral lesions
Neodymium-doped yttrium aluminum garnet (Nd:YAG)	1064 nm	Solid state	Pulse	Optical fiber	1964	• Root canal therapy • Caries removal • Periodontal surgery • Killing microorganisms and removing debris during dental and endodontic procedures
Potassium titanyl phosphate	532 nm	Solid state	Continuous	Optical fiber	1980s	• Tooth bleaching

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Clinical applications of laser in Pediatric dentistry

1. **Caries Prevention**
   Caries prevention depends significantly on the tooth surface's resistance to penetration by cariogenic substances. Erbium and CO2 lasers have been used successfully to boost acid erosion resistance in freshly erupted permanent teeth in children and teenagers[10]. Studies show that CO2 lasers at 9600, 9300, and 10 600 nm wavelengths, erbium lasers at 2780 and 2940 nm wavelengths, and argon lasers can protect enamel surfaces from caries. Several studies have shown that using laser and fluoride therapy together increases tooth resistance even more[11]. For example, using an argon laser in conjunction with acidic phosphate fluoride (APF) reduces caries depth by 50% when compared to using the laser alone.
2. **Caries Removal**
   The Er:YAG laser offers a virtually painless alternative to conventional methods of caries removal, and its adoption in clinical practice could greatly reduce children's fear of going to the dentist. Recent studies have shown that restorations in laser-prepared teeth have shown a high degree of clinical success, even at a follow-up time of several years[12]. If they use lasers within the proper parameters, dentists can achieve caries removal without damaging the surrounding tissues by charring, cracking, or fissuring[13]. Laser-prepared cavities in dentin have a rough surface with protruding dentinal tubules and no smear layer. Dentists must take care, however, to protect against the failure of restorations in laser-prepared cavities.
3. **Restoration, Pit and Fissure Sealants**
   Lasers can also be used to prepare the tooth surface before applying pit and fissure sealants. Lasers can also be used to treat, clean, and disinfect pits and fissures[14]. For example, after determining the existence of caries in pits and fissures using LF values ranging from 11-20 to 21-30, an erbium laser can be utilized for fissurotomy and caries removal. LF values between 0 and 10 indicate a sound tooth; in this case, only macro-roughening is achieved using an erbium laser at lower wavelengths[15]. Studies have shown that using a laser without acid etching to prepare enamel cracks and fissures leads in a significant rate of microleakage. Thus, laser treatment does not eliminate the requirement for enamel acid etching[16]. On the other hand, some researchers reported that application of laser in conjunction with acid etching resulted in microleakage in 80% of specimens due to the formation of enamel cracks and debris at the sealant-enamel interface. They have recommended the use of argon laser for curing of the sealant material at the enamel-sealant interface to possibly increase enamel resistance to acids[1].
4. **Endodontic**
   Laser technology can be utilized to perform pulpotomy, pulpectomy, and pulp coagulation instead of formocresol, which is carcinogenic and mutagenic and is used for primary tooth pulpotomy. Researchers obtained superior clinical results in pulpotomy of primary teeth with CO2 laser compared to formocresol, demonstrating that pulpal inflammation decreased following laser therapy and had a negative connection with the quantity of energy received[17]. The efficient use of laser technology in cleaning and sculpting the root canal system has also been shown. For example, the Er,Cr:YSGG laser offers cleaning and shaping efficacy comparable to that of rotary instruments but superior to that of hand instruments. Furthermore, this laser works faster than the previously described two ways. Application of Er:YAG, Er,Cr:YSGG and CO_2 lasers for pulp coagulation has also shown more favourable results after 2 years in comparison with calcium hydroxide. Studies have indicated that vital pulp therapy and pulp hemostasis after pulpotomy with the help of CO_2 laser had 98.1% clinical success and 91.8% radiographic success[18].
5. **Analgesic Effects, Alleviation of Pain and Discomfort**
   Laser enhances patients' pain thresholds and reduces the need for local anaesthetics. Studies have shown that anaesthesia can be obtained by employing a non-concentrated laser in the near infrared wavelengths (803-980 nm). This action can be produced on the pulp for 15 minutes by hyperpolarizing the nerve fiber membrane. Using a 660 nm probe, this technology achieved a success rate of 50%-75% on primary molar teeth for the preparation of class II cavities without aesthetic administration[14]. The CO2 laser can be used locally to reduce pain caused by orthodontic forces, while

LLLT increases orthodontic tooth movement with no harmful effects. Laser/LED irradiation around the orthodontic site or temporomandibular joint has been shown to effectively reduce discomfort[19].

6. **Pulp Vitality**

Trauma to the teeth can have adverse short-term and long-term consequences and may compromise pulp vitality. Laser Doppler flowmetry (LDF) indicates the pulp blood flow (PBF) and can be used to assess pulp vitality. This method is accurate, non-invasive, reproducible, reliable and painless and is well tolerated by children. It appears that LDF can also be helpful for monitoring of revascularization and mobile teeth[17]. Other applications of laser for traumatized teeth include preparation of the broken edge of injured teeth prior to restoration, exposed pulp coagulation, pulpotomy and pulpectomy (with erbium laser) after trauma, if necessary. Moreover, Er:YAG and Er,Cr:YSGG lasers can be used for fusion and sealing of dentinal tubules in case of fractured teeth or open dentinal tubules. By doing so, the permeability of tubules and the consequent tooth hypersensitivity will decrease[20]. Soft tissue trauma, facial wounds and swelling can also be alleviated by the application of laser/LED to the area. This method can also be used in severely traumatized areas to decrease post-traumatic discomfort.

Conclusion

Laser technology for hard tissue application and soft tissue surgery is at a high state of refinement, having had several decades of development, up to the present time, and further improvements can occur. The field of laser-based photochemical reactions holds great promise for additional applications, particularly for targeting specific cells, pathogens, or molecules. A further area of future growth is expected to be a combination of diagnostic and therapeutic laser techniques. Looking to the future, it is expected that specific laser technologies will become essential components of contemporary dental practice over the next decade.

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