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Erbium Lasers in Paediatric Dentistry

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Abstract: **Laser-assisted therapy is a modern and effective strategy. Laser technology has a wide application in paediatric dentistry for dental care and treatment of primary and permanent teeth.This review presents a overview of erbium lasers types, mechanism of action, applications in paediatric dentistry.**

Keywords: **erbium lasers, applications, paediatric dentistry.**

1. INTRODUCTION

For the application of laser energy in paediatric dentistry, the Erbium: YAG laser is considered as the most usable, all-tissue laser. The history of Erbium lasers started in late 1980s when high powered photothermal lasers failed to find their use in hard tissue procedures.

In 1988, Paghdiwala[1] tested the erbium:yttrium-aluminum-garnet (Er:YAG) wavelength for its ability to ablate dental hard tissues. For the first time, a laser was used to create preparation holes in enamel and dentin with low energies.

Hibst and Keller et al[2],[3],[4] showed that tooth structure could be removed by the Er:YAG wavelength without causing any measurable degree of thermal damage.

The first Er:YAG laser system (Kavo Key Laser, Kaltenbach and Voigt GmbH & Co., Biberach/Riss, Germany) was introduced into the medical market in Germany in 1992 and received FDA clearance in the United States in 1997. With this clearance came approval for caries removal, cavity preparation, and conditioning of the tooth.Nowadays many manufacturers are marketing Er:YAG lasers with important differences in their technical specifications. The available maximum pulse energies range from 300 mJ (DELightd), over 600 mJ(Key Laser 3), 700 mJ (Smart 2940De), up to 1000 mJ (Fidelis Plus IIc and Opus Duos)[5]

Erbium lasers family include the Er:YAG (2.94 microm) and the erbium, chromium:yttrium-scandium-gallium-garnet (Er,Cr:YSGG) at 2.78 micron. Preliminary studies looking at the safety and efficacy of using the Er,Cr:YSGG wavelength found it to be a precise tool for bone and dental hard tissues.[6-9]

All erbium lasers share a common characteristic of an affinity for the wavelengths to be highly absorbed by water, hydroxyapatite, and collagen.The highest peaks for the absorption of laser energy in water are at 3 microm and 10 microm. The Erbium:YAG wavelength at 2.94 microm exactly matches the absorption peak of water; moreover, the absorption coefficient in water for the 2.94 microm. Er:YAG wavelength is significantly higher than of the 2.78 microm Er,Cr:YSGG.[10]

2. MECHANISM OF ACTION

***On hard tissues*:**

In 1997, the US Food and Drug Administration (FDA) approved the Er:YAG laser for caries removal, cavity preparation, and laser etching of enamel.[11]This is the most effective laser in the mid infrared spectrum for the ablation of dental enamel, and the photobiology of the Er:YAG enamel interaction has been defined.[12].Water molecules within the prismatic enamel layer of a tooth make up only 4%of its chemical composition. However, they represent 11% of enamel's total volume. As the laser energy interacts with the enamel matrix, water absorbs the laser energy and rapid vaporization of the water occurs. As this photo-thermal reaction takes place, the steam generated within the enamel is associated with a volumetric expansion within the enamel matrix. This in turn produces micro-evaporative explosions that result in a thermally driven, mechanical ablation of the tooth structure.[13]

The effect of water spray and thermal tissue effects with the Er:YAG laser on both hard tissues and dental materials were investigated and described by Wigdor, Visuri, and Walsh[14],[15].They found that as long as enamel is continually hydrated with a water spray during the laser exposure(serving as a heat sink), there will be only a minimal increase in temperature of the enamel layers and deeper tissues.

Friedberg et al[16] reported on another FDA approved laser for cutting of teeth, the Er:YSGG. They found that additional energy is required from the unit to initiate enamel ablation when the laser is propagated through an aerated mixture of water droplets. This method was found to attenuate the beam as opposed to the water being sprayed directly on the irradiated area of enamel and acting as a heat sink.

***On soft tissues*:**

Yet erbium family of lasers known as hard tissue lasers, but it ablates soft tissues with same mechanism as hard tissue. The primary chromophore of the erbium lasers is water in the target tissue, and the largest component of soft tissue is water. The laser energy from the infrared beam is converted into local thermal energy, and this energy creates a massive expansion in the target chromophore of water. The resulting microexplosions result in thin layers of tissue ablation. The erbium laser soft tissue removal process results in a ‘‘shaving’’ or ‘‘planing’’ of the tissue that clinically appears different than the deeper penetrating ablation process seen with dedicated soft tissue lasers.[17]

Venugopalan et al[18] postulated that during the cutting of human mucosa, the Er:YAG targets the water molecules rather than the collagen matrix. The energy causes the water molecules to be heated into steam, which in turn strains and fractures the collagen matrix in the extracellular environment.

The depth of penetration of an Er:YAG laser using a 200- to 400-microsecond pulse width is in the range of 5 to 40 microm. There is as little as 5 microm of residual thermal damage. This penetration depth is vastly different than the soft tissue lasers (diodes, Nd:YAG), whereby tissue effects can be as deep as 500 microm or more.[19] The collateral damage produced by the Er:YAG laser is minimal because the energy is absorbed in water and thermal damage is small (no charring), which may result in improved healing of the area. Neev et al[12] discovered that there is less collagen remodelling and in turn ,faster healing with minimal scar tissue presenting after erbium lasers soft tissue surgeries.

3. APPLICATIONS IN PAEDIATRIC DENTISTRY

HARD TISSUES PROCEDURES:

1. **CAVITY PREPARATION**: Erbium lasers have been widely studied for its use on dental hard tissues. The Erbium family of lasers is the choice of laser and is most efficient and safe for deep enamel, dentin and caries removal .It is established from various studies that no change or minimal change in pulp temperature in cavity preparation in class I to V preparations[12],[21]

Takamori[22] and Rizoui[23] from their studies concluded that Er:YAG and Er,Cr:YSGG laser system ,respectively, leads to initiation and completion of pulpal repair earlier than with the high-speed drill.

Hadley[24] concluded that The Er,Cr: YSGG laser system is effective for preparation of Class I, III and V cavities and resin restorations are retained by lased tooth surfaces.

Eren[25] evaluated for pain perception during cavity preparation comparing the mechanical removal and Er,Cr:YSGG laser removal of caries from enamel and dentine and concluded that the application of the Er,Cr:YSGG laser system was a more comfortable alternative or adjunctive method to conventional mechanical cavity preparation for paediatric patients.

2. CARIES REMOVAL: In studies, it was found that the Er:YAG laser ablated carious dentine effectively with minimal thermal damage to the surrounding intact dentine (Aoki and Ishikawa *et al*., 1998). **Kotlow L A**[26] (2004) recommended settings for erbium family of lasers with total power of 6 watts for enamel removal, 4 watts for dentin preparation and 2 watts for caries removal with water spray. After ablation of tissue, slow speed handpiece can be used for removal of deep caries if required.

Er:YAG laser are also providing help in applying concept of Minimal Invasive Dentistry as it ablates small area of infected layer, conserve tooth structure maximally, decontaminate the affected layer that retains its remineralising potential.

3. RESTORATION REMOVAL: The Er: YAG laser is capable of removing cement, composite resin and glass ionomer (Dostalova *et al*., 1998; Gimbel, 2000). The efficiency of ablation is comparable to that of enamel and dentine. Lasers should not be used to ablate amalgam restorations however, because of potential release of mercury vapour. The Er:YAG laser is incapable of removing gold crowns, cast restorations and ceramic materials because of the low absorption of these materials and reflection of the laser light (Keller *et al*., 1998).[3].These limitations highlight the need for adequate operator training in the use of lasers.

4. **ETCHING:** The preparations produced by the Er:YAG and Er,Cr:YSGG lasers have a characteristically chalky surface when used on enamel. Scanning electron microscopic images show that laser irradiation produces a surface that increases the restorative material retention. The surface is ideal for the use of composite and compomer filling materials[27]

Visuri[28] showed that laser-irradiated samples had improved bond strengths compared with acid-etched and handpiece controls and concluded that the Er:YAG laser preparation of dentin leaves a suitable surface for strong bonding of an applied composite material.

5. CARIES PREVENTION: Controversial results can be found in the literature regarding demineralization and acid-resistance of enamel and dentin after Er:YAG laser treatment.

After subablative Er:YAG irradiation, a decline of 20% in calcium solubility in enamel was found, the effect was not judged sufficient to prevent caries.[29]

In addition, subablative Er:YAG radiation seemed to produce fine cracks in the enamel surface.[30].If using ablative laser energies of 400 mJ, lowest acid demineralization in enamel and dentin was found after dry laser treatment.[31]

On the enamel surface, Er:YAG laser treatment combined with APF (acidulated phosphate fluoride) resulted in the lowest decrease of surface microhardness and the Er:YAG laser influenced the deposition of CaF_2 on the enamel.A laser-induced caries preventive effect is substantiated according to the “organic matrix blocking theory”, whereas laser treated enamel confirms laser-induced blocking of the organic matrix in the micro-diffusion pathway in enamel.[32]

6. REATTACHMENT OF A FRACTURED ANTERIOR TOOTH SEGMENT: Recently Er:YAG is also used for attachment of fractured tooth segment in case of anterior tooth trauma. Fornaini C[33] et al performed in vitro study for Er:YAG Laser and Fractured Incisors restorations and concluded that Er:YAG can be used in for coronal fracture in dental traumatology. Carlo Fornaini and Jean Paul Rocca[34] suceesfully attached a Fractured Anterior Tooth Segment With Pulp Exposure via Er:YAG and Nd:YAG Lasers.

SOFT TISSUE PROCEDURES:

Treatment for ankyloglossia.- For tongue tie revision in neonates, Er: YAG laser wavelength is preferred without sedation or local anesthetic. Laser settings are Er: YAG 30 hz, 50mj, without water or Er,Cr:YSGG 20 hz, 1 watt without water. Eye goggles should be worn as safety measures.

Treatment for high maxillary frenum in infants and in mixed dentition:

According to **Kotlow L A**[26] (2004), an optimal result occurs when treatment is done between 8 and 18 months of age. He recommends the lasers settings same as ankyloglossia.

In mixed dentition, in addition to soft tissue-revision, the procedure may require the lasing of bone between the two maxillary central incisors. In that case, the erbium lasers are an ideal choice of instrument, and water spray must be used.

Exposure of teeth for orthodontic treatment:

Laser settings recommended by **Kotlow L A**[26](2004) are Er: YAG 30 hz, 45 mj; Er, Cr: YSGG 20 hz, 70 mj; both in contact and noncontact mode. Therefore, as the enamel is exposed the laser tip must be held parallel to the surface of the tooth.

Gingival recontouring and gingivectomies in paediatric patients:

Guelman *et al.*, [35](2003) suggested that laser treatment could be carried out to reshape gingiva.in case of gingival enlargement induced by medicaments like dilatin sodium.

Erbium lasers help in removing hyperplasic tissues present during orthodontic treatment . Erbium lasers with 20 to 30 hz and 55 to 80 mj, without water spray is used.

For pericoronal flap problems associated with erupting tooth*:*

Erbium lasers can be used in a noncontact mode to ablate the involved tissue and expose the clinical crown of the involved tooth water. Kotlow L A[26] (2004) suggested Erbium laser with settings of 20–30 hz and 45 to 55 mj in a noncontact mode.

For treatment of aphthous ulcers and herpetic lesions Erbium lasers can be used at minimum hz with 30 to 40 mj. The involved area is lased in 15- to 30-second intervals, no local anesthesia is used, and the procedure is repeated three or four times until the patient reports relief.

For pulp therapy in primary teeth:

Kotlow L A [26](2004) treated more than 150 teeth over the period of 2 years and found that use of Erbium laser gives equal to or better results than with conventional formocresol.

According to him, in vital teeth, the laser could be set at 20 to 30 hz, 50 to 70 mj, can clean the pulp chamber in 10 to 20 seconds. He concluded that it provides sufficient hemostatis and leaves some vital tissue at apex.

Erbium lasers has a bactericidal effect and, thus, can be used to help reduce the bacterial count in general. In addition, erbium lasers can be used specifically to reduce bacteria in the root canal during endodontic therapy.[36-43].These studies have shown that all lasers including the erbium family of lasers are effective in significantly reducing bacteria in the canals.

Low Level Laser Therapy:

Low-level laser therapy (LLLT) is suggested to have biostimulating and analgesic effects through direct irradiation without causing thermal response.

According to Tuner and Hode[44], five main indications in pediatric dentistry are given:

1. The eruption of both deciduous and permanent teeth are sometimes painful. Therefore, irradiating the lymph nodes in the area is recommended for relief.

2. A radiation dose of 2 J has a brief anesthetic effect in the mucosa, allowing painless injection with a needle.

3. Direct application of a dose of 46J into an exposed cavity of a deciduous tooth can be used for pain reduction.

4. Posttraumatic treatment after lip and anterior tooth trauma to reduce swelling and pain can be achieved by applying a dose of 34J.

5. A dose of 0.52 J as an additional treatment in pulp capping will improve the outcome of treatment.

4. CONCLUSION

Erbium lasers, after research of 20 years, are now considered as safe and effective device in dentistry and for children as well. Yet erbium lasers are known as hard tissues lasers, they can be effectively used in soft tissues surgeries.

In hard tissue applications in children, Er:YAG is one of the best suited laser types for cavity preparation because its efficiency, especially in dentin, is very good without any danger of pulpal damage if working under sufficient water cooling. In addition, important pain reduction in comparison to bur-assisted preparation has clearly been demonstrated making it possible to work without local anesthesia in most instances.

In the field of paediatric dentistry, Er:YAG helps in application of concept of minimal invasive dentistry as cuts hard tissue conservatively. In addition to this, Erbium lasers are also help in caries prevention by decreasing acid demineralisation upto some extent.

When used with low radiation energies, Er:YAG can be used for analgesic effect in low level laser therapy.

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