Paediatric laser dentistry. Part 1: General introduction

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ABSTRACT

Knowledge of the physical characteristics of different laser lights and optical and thermal properties of oral tissues is very important to understand the interaction of dental lasers with biological tissues. Choosing the correct dental laser is crucial to match specific wavelengths with target chromophores of different tissues; this affinity makes laser irradiation selective and therefore minimally invasive. Various types of lasers are used in dentistry, offering a viable alternative to low and high-speed handpieces and surgical blades, and also minimising fear and discomfort of the patient. Lasers can provide innovative and minimally invasive therapies in different branches of dentistry including preventive and restorative dentistry, traumatic injury treatments and surgical procedures. Laser has also biostimulating and anti-inflammatory effects, as well as analgesic effect.

Keywords *Children; Laser tissue interaction; Paediatric laser dentistry.*

Introduction

The American Academy of Pediatric Dentistry (AAPD) recognises the use of laser as beneficial in restorative dentistry and soft tissues treatments for infants and children, including patients whith special health care needs [AAPD, 2013].

The term laser is an acronym that stands for Light Amplification by Stimulated Emission of Radiation. Laser technology was introduced in dentistry in the mid 1970's, and its classification in dentistry is based on the active medium used to supply electrons for the emission of laser photons. Laser photons are delivered as waves, which are typically collimated, coherent and monochromatic, i.e. of a single wavelength [Convissar, 2000; Coluzzi, 2005-2007; Moritz, 2006; Fasbinder, 2008; Olivi and Olivi, 2015]. Another classification considers the clinical use as follows: for soft tissues exclusively, for soft and hard tissues, for low level applications, for photopolymerisation, for tooth whitening and for caries detection (Table 1).

The choice of a laser depends on the optical affinity and absorption coefficient in different target chromophores for different wavelengths. Lasers in the visible and near-infrared electromagnetic spectrum are specifically absorbed by haemoglobin and melanin, and are used to treat soft tissues pathologies. The erbium family lasers (mid-infrared spectrum) are absorbed by water in the gingiva and mucosa, and within the hydroxyapatite and are therefore used on both hard and soft tissuess [Kotlow, 2004; Olivi, 2009; Caprioglio, 2010-2017; Boy, 2011]. CO_2 lasers (far-infrared spectrum) are absorbed by water in the mucosa and gingiva and are mainly used for surgery (incision and vaporisation of tissues); in addition, CO_2 wavelenghts are absorbed by hydroxyhapatite, and some studies reported also their ability to increase the acid-resistance of tooth enamel for preventive dentistry [Featherstone et al., 1997; Rechmann et al., 2013].

Soft tissue lasers	Argon 514 nm
	KTP 532 nm
	Diode 445, 803, 810, 940, 970-980, 1064 nm
	Nd:YAG 1064 nm
	Nd:YAP 1340 nm
	CO_2 10600 nm
Hard and soft tissue lasers	Er,Cr:YSGG 2780 nm
	Er:YAG 2940 nm
	CO_2 9300 nm
Low-Level lasers	Helium neon: 635 nm
	Diode 635-660 nm; 810 to 1064 nm
Photopolymerisation lasers	Argon: 488 nm
Tooth-whitening lasers	KTP 532 nm
	Diode 803, 810, 940, 970-980, 2940 nm
Caries detection lasers	Diode 405 and 655 nm

TABLE 1 Laser classification.
Legend KTP-potassium titanyl phosphate; Nd:YAG-neodymium-doped yttrium aluminum garnet; Nd:YAP- neodymium-doped yttrium aluminum per ovskite; CO_2-carbon dioxide; Er,Cr:YSGG-erbium chromium –doped yttrium scandium gallium garnet; Er:YAG-erbium-doped yttrium aluminum garnet.

Laser-tissue interaction

Laser light interacts with the target tissue in four different ways: it may be absorbed on the surface or may diffuse deeply in the tissue depending on the optical property of each wavelenght and the optical characteristic of the tissue, such as pigmentation and water content; when there is not affinity between laser light and tissue, the light is transmitted through the tissue without any effects; a small percentage of irradiation is reflected from the tissue surface and this interaction involves strict safety measures.

Diagnostic applications

A specific red laser light (655nm, DIAGNOdent pen®, KaVo) analises the fluorescence light reflected from the detected area to quantify the amount of demineralised and decayed tooth structure. The detection can report a false positive when reading under fissure sealants. The presence of residual toothpaste after teeth cleaning can also modify reading and detection [Hibst, 2001; Lussi, 2003-2005; Mendes, 2004]. Laser fluorescence can be used as an additional tool combined with conventional methods for caries detection, as well as for longitudinal monitoring of caries and for assessing the outcome of preventive interventions during recall session in caries-risk patients, allowing to space out the x-ray examinations, thus reducing the radiation dose summation in children [Olivi and Olivi, 2015].

Hard tissues – Clinical applications

Erbium laser is the type most commonly used for restorative dental procedures. These lasers work in non-contact mode, avoiding any unpleasant vibration on the tooth. Ablation results from micro-explosion of water within enamel, dentin and caries and occurs at different speed rates, depending on the fluence (energy density) applied, the frequency (Hz), and so the power (W) [Matsumoto, 2002; Takamori, 2003]. In addition to the selectivity for carious tissue more rich in water, the main advantages of erbium lasers for cavity preparation is the reduction of bacteria to a depth of 300 to 400 µm [Hibst, 1996; Moritz, 2006; Olivi, 2007]. The decontamination effect of mid-infrared lasers is related to the generated thermal effect and shockwave that produce structural change in bacterial cells [Hibst, 1996; Krmek, 2009]. Correct laser setting is essential to prevent unwanted alterations to the dental structure and to preserve the pulp vitality. The enamel treated with proper laser setting appears macroscopically chalky and at SEM magnification exhibits typical grooves, flakes, shelves, all features more indicative of microexplosions than melting. The lased dentin shows ablation, which is more pronounced in the intertubular area – rich in water – than in the peri-tubular area, showing no smear layer and open tubules [Kohara, 2002; Bertrand, 2006; Brulat, 2009] (Fig. 1–4). Because of the high absorption in water (main chromophore of soft tissues), erbium lasers can be also used for soft tissue procedures such as gingivectomy, crown lengthening, pulp vaporisation and coagulation during deep cavity preparation and for this reasons they are very useful in dental traumatology. Erbium lasers can also induce analgesia, before starting the treatment.

Soft tissues – Clinical applications

The laser ability to remove diseased oral soft tissues finds specific application in the field of paediatric dentistry. All laser wavelengths with optical affinity for haemoglobin and water can be used for these applications. Argon, KTP, Diodes, Nd:YAG, Er,Cr:YSGG, Er:YAG and CO_2 lasers are used for soft tissue incision, vaporisation and decontamination. The laser wavelenghts with optical affinity for haemoglobin also provide an excellent coagulating and haemostatic effect. Laser treatment of soft tissues includes labial frenectomy, lingual frenotomy, operculectomy, exposure of impacted or retained teeth, gingivectomy/gingivoplasty, excisional removal of oral pathologies with biopsy, and treatment of aphthous ulcers and herpetic lesions [Crippa, 2006; Olivi, 2010-2012; Kotlow, 2011; Boy, 2011; Genovese, 2011].

Benefits and limitations

Lasers offer several benefits for children oral care. The irradiation of the affected tissues is selective and precise according to the wavelenght used, and therefore is minimally invasive. The laser-tissue interation produces minimal thermal side effects, when compared to electrosurgical instruments the unwanted thermal effect in adjacent tissues is inferior. According to the wavelength used, laser soft tissues procedures produce haemostasis, and sutures are not necessary in most of the cases. Wound healing occurs for second intention and the healing time can be reduced using low level laser therapy, resulting in less post-operative discomfort and reduced need for analgesics [Tanboga, 2011]. The non-contact irradiation with no vibration allows a more comfortable cavity preparation reducing anxiety and fear in children and parents. Moreover, the erbium lasers can remove caries effectively with minimal involvement of the surrounding tooth structure and have an analgesic effect on hard tissues, thus reducing or eliminating the use of local anaesthesia during tooth preparations. Therefore, laser therapy improves patient compliance by positively influencing both objective and subjective factors that affect the perception of pain. Also an analgesic effect is produced by irradiating with erbium laser at low level

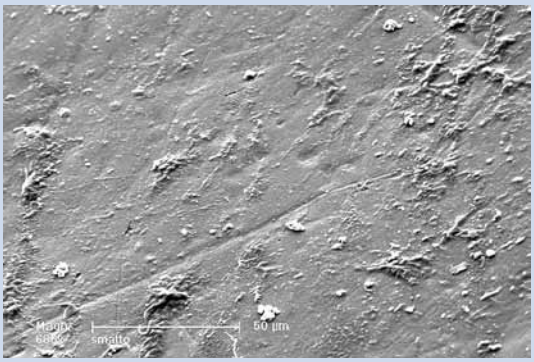
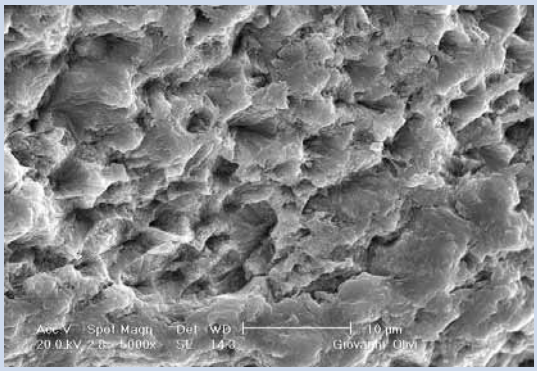


FIG. 1 SEM image (686x) of primary enamel showing the typical absence of prismatic pattern.



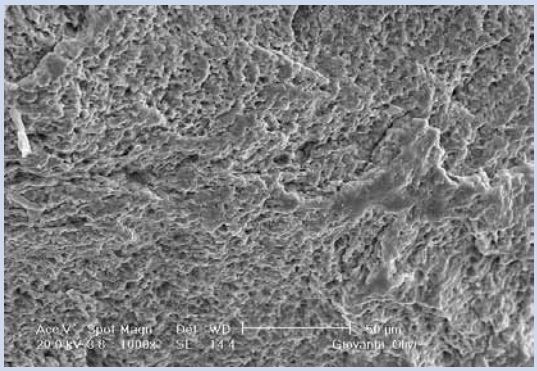


FIG. 2, 3 SEM images (1,000x and 5,000x) of primary enamel surface irradiated with Er,Cr:YSGG laser (2780nm) at 250 mJ, 10 Hz, 140 µs, showing roughened surface.

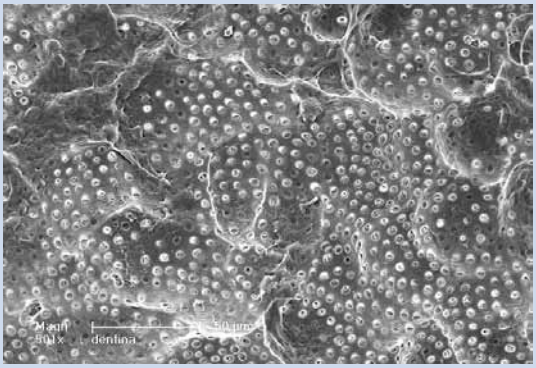


FIG. 4 SEM image (501x) of primary dentin irradiated with Er:YAG laser (2940nm) at 80 mJ, 20 Hz, at 1.5 mm distance with a 600 µm tip, showing a clean dentin surface without smear layer. The tubule orifices are open and collagen structure are preserved.

energy the area before the treatment. As a result, a good level of patient acceptance is reported during hard and soft tissue therapy [Genovese, 2008]. When using dental lasers, adequate training and education is important for the dentist. Since different wavelengths are necessary, the practitioner may need more than one laser and the investment costs required can be a limit. Additionally, during all the laser procedures specific protective eyewear must be correctly worn by the patient, the dental team, and any observers [Parker, 2007; ALD, 2009].

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