The use of Erbium:YAG laser for caries removal in paediatric patients following Minimally Invasive Dentistry concepts

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ABSTRACT: The Er:YAG laser has proven to be effective and efficient in dental hard tissue ablation. The Minimally Invasive Dentistry (MID) approach in caries removal is to stop the disease process and to restore lost tooth structure and function, maximizing the health potential of the tooth. One of the most important concepts of the MID is to preserve as much as possible the dental tissue and this approach is even more important in primary dentition where the dimensions of the crown are smaller and the dimension of the pulp chamber is bigger in relationship to the crown. After treating 30 children’s teeth (primary molars and first permanent molars) with the Er:YAG laser, we come to conclusion that laser treatment possesses the requirements of Minimal Invasive Dentistry: the possibility to ablate small area of infected layer guarantees maximum conservation of the tooth structure; using the antibacterial property of the Er:YAG laser we can decontaminate the affected layer that retains its remineralising potential; the lack of smear layer after vaporization with laser assures a better retention of the composite resin to the dentine; preparing the enamel surface with laser before etching gives a better marginal seal of the composite restoration.

KEYWORDS: Minimally Invasive Dentistry, Er:YAG laser, Caries ablation.

Introduction

In the 21st century caries is still one of the most frequent mouth disease in childhood Roman population due to the lack of information, health education and health promotion [Panetta et al., 2004]. A previous study by the National Institute for Food and Nutrition Research (INRAN), demonstrated a consistent percentage of the variability exists in DMFT related to the frequency of carbohydrates intake and dental caries [Arcella et al., 2002]. The carious dental lesion is the result of bacterial infection where the acids produced by bacteria, as they metabolize sugar and cooked starches, de-mineralise the tooth’s structure [Kleinberg, 1979; van Houte, 1980].

In the past, carious treatment approach was mainly a surgical removal of the infected and affected tissue followed by reconstruction with a dental restorative material (mostly amalgam). This approach was necessary because of the limitation of other available materials and the lack of proved alternative therapies [Laurens, 1950]. It is important to remember that, at that time, diagnosis of carious lesions was carried out at more advanced disease stages compared to the incipient lesions detected today, and instrumentation was limited to slow rotary and hand instruments [Skeie et al., 2004].

The preparation of the cavity was performed with excessive tooth structure reduction even for relatively small lesions, removing not only the caries but also healthy dental tissue in order to follow the concepts of extension for prevention, resistance and retention [Jahn and Zuhrt, 1990; Osborne and Summit, 1998].

Modern dentistry has moved to a minimally invasive approach, in which caries is managed as an infectious disease and the focus is on maximum conservation of
the tooth structures [Peters and McLean, 2001; Brostek and Bochenek, 2006].

The introduction of adhesive dental materials made possible the conservation of tooth structure using minimal invasive preparation, because adhesive materials don’t require any incorporation of mechanical retention features.

Minimally invasive dentistry (MID) adopts a philosophy that integrates prevention, remineralization and minimal intervention for the placement and replacement of restoration. MID reaches the treatment objective using the least invasive surgical approach with the removal of minimal amount of healthy tissue [Ericson et al., 2003].

In paediatric dentistry tooth structure preservation is even more important as the crowns of primary teeth are smaller than the permanent ones. The erupted permanent teeth, during childhood, have a large pulp chamber.

Using Er:YAG laser in removing carious tissue, to be restored with resin based composite, can be the right method for minimal invasive preparation.

**Materials and methods**

We treated for caries 30 teeth of children between the age of 4 and 12 years, following the requirements of MID in paediatric conservative dentistry. The teeth treated were first and second primary molars and first permanent molar. The caries treated had a depth from just in dentine to half-way of the dentine thickness (at least 1 mm from the pulp chamber).

In all the 30 treated teeth we used topical anesthesia (Emla, 5 g, AstraZeneca) applied for 3 minutes on the vestibular and lingual/palatal marginal gengiva before placing a rubber dam clamp (Ivory, Heraeus Kulzer, Usa) and a rubber dam (Dental Dam, Medium, Hygenic, Coltene/Whaledent Inc.).

No local anesthetic was used before treatment. In 4 cases, as the child complained of pain during laser treatment, we proceeded with a local anesthesia (Carbosen with adrenaline, 20 mg/ml + 10 mg/ml; Galenica Senese).

For caries removal we used the Er:YAG laser, produced by Fotona (Fig. 1), that is a solid state crystal laser where the host crystal is Yttrium Aluminum Garnet doped with Erbium ions that replace the Yttrium ions. The pulse repetition rate ranges between 2 Hz and 50 Hz, the laser pulse energy ranges between 40 mJ and 1000 mJ, adjustable in 10mJ increments and the power ranges between 0.25 W and 12 W. In Fotona Fidelis family of dental lasers the Er:YAG laser pulses are grouped in four pulse width (so called modes of operation): VSP (Very Short Pulses), 140 µs, SP (Short Pulses), 330 µs, LP (Long Pulses), 550 µs, VLP (Very Long Pulses) 920 µs.

The wavelength of Er:YAG laser is 2940 nm that coincides with the absorption peak of water. The Er:YAG laser is adapted for hard dental tissue ablation, where the main chromophores, for wavelength of 2940 nm absorption, are water and hydroxyapatite (HA) [Cozean et al., 1997]. Maximum absorption in water results in an effective microexplosion mechanism accompanied by an increase in pressure (hydrocinetic energy). The explosive vaporisation creates a cloud of ablation of the carious tissues. The ablative action is also due to a photoacoustic effect caused by the microexplosions of water on target tissue.

The parameters we used were: VSP mode (140 µs per pulse), Energy from 120mJ to 200mJ, Frequency from 2Hz to 20Hz, Fluence from 24 J/cm² to 40 J/cm², with the mirror handpiece R-02 (no contact) (Fig. 2).

Both patient's and operator's eyes were protected by glass lents (Univet, 705.00.00.00.BL, certificated CE, Dir. 89/686/CEE).

All the teeth were restored in the same appointment.
using acid etch Scotchbond Etchant (3M Espe, Dental Products), adhesive Scotchbond 1 XT (3M Espe, Dental Products) and composite Z100 MP Restorative (3M Espe, Dental Products). In no case was underlying used. The resin composite underwent conventional polymerisation with a halogen light 52 W, spectrum 400-515nm (Polylight 3 Steril, Castellini), curing for 40 seconds each layer of the resin composite (at least two layers for filling) with the light tip at 8 mm distance from the tooth surface.

In all the 30 treated teeth we ablated the caries in focus mode using the Er:YAG laser with the mirror handpiece R2 at a distance between 0.8 to 1 cm from the tooth with slow fluid continuous movements. The preparation of the cavities was limited to vaporising the infected layer leaving the affected one, without any ablation of healthy tooth structure.

We managed to guide the laser beam under the intact enamel in order to remove the carious dentine. We checked the removing of the amorphic dentine with the probe and in some cases we finished to remove the infected layer using a dental excavator (ASA stainless 1700-2).

The follow-ups at 7 and 28 days aimed to evaluate any post-operative complications. We checked the sensivity to temperature changes and the vitality of the treated teeth. All the clinical work was done at the U.O.C. of Paediatric Department of the University of Rome, La Sapienza.

**Results**

None of the teeth treated with the materials and method above described (Fig. 3-21) presented at the follow-up controls at 7 and 28 days any post-operative complication like pain or sensivity and all the teeth preserved their vitality.

**Discussion**

Modern operative paediatric dentistry should be based on a minimally invasive approach where caries removal and cavity preparation should be performed with minimal tissue removal. The conservation of hard dental tissue increases the life of the restored tooth [Yip and Samaranayake, 1998].

Lots of studies showed that the use of Er:YAG laser is efficient, effective, safe and suitable for caries removal and cavity preparation [Matsumoto et al., 2007; Liu et al., 2006; Freitas et al., 2007].

Many authors reported that preparation done with laser instrument generate similar heat increases under

**Fig. 3** - Female, 7 years, treated teeth 36. VSP mode, 150 mJ, 15 Hz; pretreatment.

**Fig. 4** - After laser treatment.

**Fig. 5** - Immediately after treatment.

**Fig. 6** - 7 days control.

**Fig. 7** - 28 days control.
FIG. 8 - Female, 6 years, treated teeth 55, VSP mode, 200 mJ, 20 Hz; pretreatment.
FIG. 9 - During treatment.
FIG. 10 - After laser treatment.

FIG. 11 - Treatment completed.
FIG. 12 - 7 days control.
FIG. 13 - 28 days control.

FIG. 14 - Female, 8 years, treated teeth 55, VSP mode, 150 mJ, 20 Hz; pretreatment.
FIG. 15 - Pretreatment.
FIG. 16 - During treatment.

FIG. 17 - After laser treatment.
FIG. 18 - Treatment completed.
water-cooling compared to the preparation with high-speed instruments [Cavalcanti et al., 2003]. In all the in vitro researches the intrapulpal temperature change during cavity preparation and caries removal using Er:YAG laser with water-cooling was lower than 5.5°C. This temperature is considered a critical value for pulp vitality [Cavalcanti et al., 2003; Geraldo-Martins et al., 2005; Park et al., 2007].

The aiming beam of Er:YAG laser (incorporated in the system) has an ablating spot diameter of 0.8 mm (in fact the ablating area is even smaller), so that irradiating dental hard tissue with laser in focal mode allows to ablate areas no larger than 0.8 mm in diameter (Fig. 21).

Removing such small surfaces of dental caries cannot be done with the burs because even the smallest one, when drilling, takes off more tissue. Additionally the burs remove tissue tridimensionally comparing to the laser beam that vaporises only the irradiated surface (Fig. 22).

Having the possibility to ablate small areas with the Er:YAG laser helps reaching one of the most important goal of MID that is the maximum preservation of dental tissue.

In modern dentistry the caries lesion is composed of two layers. The infected layer, which is heavily contaminated by bacteria, is composed of soft amorphic dentin (denatured collagen matrix) without any potential ability to remineralise. The underlying layer, the affected one, less contaminated by bacteria, is partially demineralised with an intact collagen matrix conserving the potential to remineralise [Banerjee et al., 2001].

Since caries affected dentin contains intact undenatured collagen fibers and has the ability to remineralise, the goal is to eliminate the infected caries layer preserving the affected one. The boundary between the two areas is not always obvious either in clinical pratice or laboratory research [Banerjee et al., 2001].

The diamond and tungsten carbamide burs usually remove the infected and affected dentine at the same time. It is impossible to distinguish between the two zones, sometime even extending into the underlying intact dentine.

When using the Er:YAG laser we have a better visual control of the ablating area and the possibility to vaporise such small areas of 0.8 mm diameter (Fig. 23-
24). It is easier to vaporise only infected tissue and to stop when the affected zone is reached. In this way, as suggested by MID, we can preserve the affected but repairable tissue.

In a study by Pereira et al. the results indicated that the bond strength of Single Bond to both normal and caries-affected dentin was not significantly different. Additionally, the thickness of the hybrid layers produced by both adhesive systems was thicker for caries-affected dentin.

The bactericidal effect of laser system on dentin surface was demonstrated by many authors and in lots of studies [Folwaczny, 2003; Schoop et al., 2004]. Various microbiological studies tested the bactericidal ability of different laser systems [Schoop et al., 2004; Sahar-Helft, 2007]. The best results were obtained with Er:YAG laser that showed a complete reduction of E. Coli in 75% of the samples and a significant reduction of E. Faecalis. These results confirm the conclusions of other bacteriological studies in that Er:YAG laser is a suitable system for the decontamination of dentin surface in cavity preparation as compared to conventional methods where it is difficult to eliminate infection from dentin even after removing all the decayed tissue.

Other studies reported the absence of bacteria up to 1 mm into the dentin, after laser irradiation [Schoop et al., 2004].

The good disinfection of the contaminated dentin prevents failure of the restoration process (secondary caries). Decontaminating the affected layer after removing the soft amorphous dentine can help in preventing possible future pulp complications.

The introduction of resin-based composite restoration in dentistry helped to reach the goals of MID. Dentine surface conditioning removes the smear layer and opens the dentinal tubules, after bur preparation, forming a defined hybrid layer and resin tags of the composite material into the opened tubules.

The ablation of dental hard tissue with Er:YAG laser leaves the dentin surface without smear layer (unlike after bur preparation) [Curti et al., 2004]. The lack of smear layer allows the formation of hybrid layer and resin tag hybridisation into the opened dentinal tubules resulting in a better retention of the adhesive composites. Additionally some studies showed an enlargement of dentinal tubules [Bertrand et al., 2004; de Souza-Gabriel, 2006].

It is important to remark that a better adhesion to the dentin surface is even more important in primary teeth where we have smaller amount of dental tissue.

When using an adhesive system after laser preparation of the tooth, the enamel surface prepared by laser should be followed by acid etching. This allows less microleakage at the interface enamel-composite [Yamada et al., 2002; Lupi-Pégurier et al., 2007; Boj et al., 2004; Borsatto et al., 2004].

**Conclusion**

The Er:YAG laser can be a very good option in removing dental caries following all the concepts of Minimally Invasive Dentistry in primary dentition.

**References**


