Minimally invasive Er:YAG-laser caries treatment in primary teeth

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_Introduction

Modern dental medicine seeks to use an approach that is minimally invasive. Its aim is to prevent or detect dental caries and other diseases of the oral cavity in their initial stage in order to avoid or minimise invasive treatments. Minimally invasive caries treatment is based on four important modern concepts: early diagnosis, oral environment modelling based on caries risk evaluation, micro-invasive cavity preparation and dynamic treatment using biologically active materials and modern adhesive systems.[1]

The new rules for cavity preparation in minimally invasive caries treatment require removing the bacterial infection and only those dental structures which are irreversibly decayed.[1-3]

In recent years, new technologies have been proposed as an alternative to the conventional mechanical removal of carious tissue. For a long period, these methods used high-intensity lasers[4] and have been widely used and approved by professionals. A number of high-intensity lasers are able to remove carious tissue with minimal intervention.[5-8]

The Er-YAG laser wavelength (2.940 nm) matches the absorption peak of water in the process of this wavelength's interaction with hard tissues. The energy is converted into heat, leading to water vapour formation, which expands and produces high pressure inside the target tissue and induces instantaneous micro-explosions and ejection of particles of tissue in a process called thermo-mechanical ablation.[4]

The physical interaction of the Er:YAG laser with dental tissue has been shown to be an effective mechanism for the selective ablation of carious and healthy enamel and dentin in both primary and permanent teeth, despite the different water and mineral composition of these different substrates and different ablation thresholds of the various hard tissues.[9]

The degree of mineralisation of primary enamel is lower than that of permanent teeth, therefore its water content and thus its energy absorption is higher, a fact which requires different parameters in the ablation process in primary teeth as opposed to permanent teeth.[6,9]

It is therefore important to establish the proper energy and frequency of the Er:YAG laser that are specific to the substrates of primary teeth in order to establish protocols for laser cavity preparation and to create suitable approaches for different laser devices.

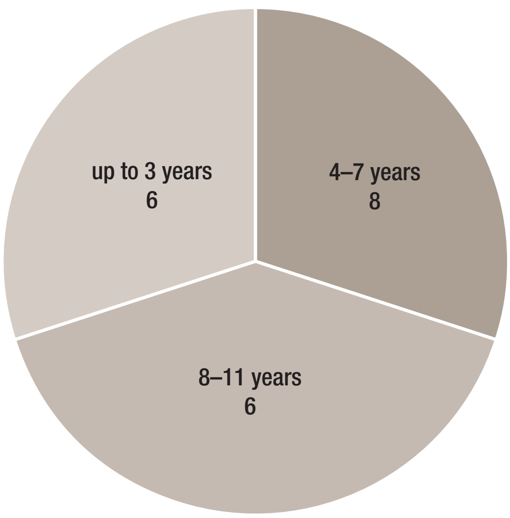


Fig. 1_Patient distribution by age.

_Aims

The aims of this study were to assess the children's attitude to laser dental treatment and to determine the best method to use when removing dental caries using an Er:YAG laser. A third aim was proposing a protocol for cavity preparation using Er:YAG laser.

_Materials and methods

Twenty children between the age of three and eleven years participated in this study. Of these, six children were aged from three to four, eight children were aged from four to eight and six children were aged from eight to eleven (Fig. 1) Informed written consent was obtained from each patient's parents, as required by the institution's ethics board. All the procedures were conducted in accordance with the guidelines established by the Bulgarian Ministry of Health's Code of Bioethics for Dentists and the Helsinki Declaration. Frankl's behaviour rating scale was used to assess the behaviour of all the children in the study group before treatment.[10]

Frankl's behaviour rating scale

Class 1: child is completely uncooperative, crying, and it is very difficult to make any progress in treatment;
Class 2: child is uncooperative, very reluctant to listen or respond to questions, some progress in treatment is possible;
Class 3: child is cooperative, but somewhat reluctant or shy;
Class 4: child is completely cooperative and even enjoys the experience.

Children's attitudes to the relevant dental procedure were examined in a brief interview after the procedure. Responses were summarised in four groups:

Code 1: child allows treatment using laser only after several visits of desensitisation, after which the child's fear is overcome and the child becomes cooperative;
Code 2: child allows dental treatment using laser only;
Code 3: positive, shows interest in laser which is supported by parents as well;
Code 4: positive, conventional dental drills and laser are equally accepted.

Children's dental status was examined completely, medical records were taken, and a prevention program was drawn up. Two independent operators examined the children. One dentist conducted the children's treatment. X-rays were not taken.

For cavity preparation we used an Er:YAG laser (Syneron, Lite Touch™, Israel), that is a solid-state crystal laser with the host crystal-yttrium aluminium garnet doped with erbium ions that replace the yttrium ions. Parameters that we used were: energy ranging from 100 to 300 mJ, pulse repetition rate: 20 Hz, sapphire tip diameter: 1.3 mm, 1.0 mm, pulse duration: 50 µsec, theoretical fluence: 15.05 J/cm² for the dentin, 22.61 J/cm² for the enamel and 12.74 J/cm² for cavities' edges bevelling, non-contact mode distance: 0.5 to 1.0 mm, air-water-spray cooling: 39 ml/min. No local anaesthetic was used either before or during the treatment.

The preparation of the cavities was limited to vaporising the infected layer, leaving the treated area with one uniform colour only in the bottom of the cavity preparation, without any ablation of healthy tooth structure. During cavity preparation, a chronometer was used to time each procedure. Cav-

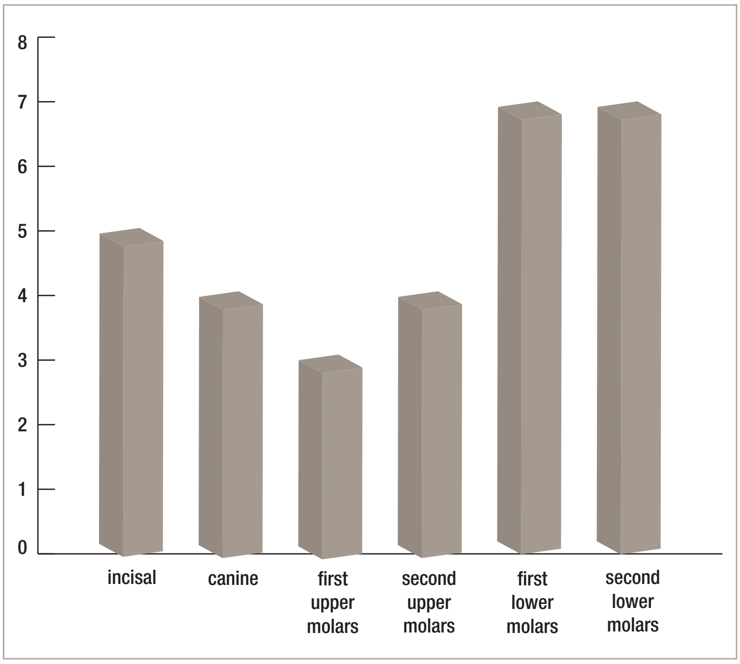


Fig. 2_Distribution of treated primary teeth.

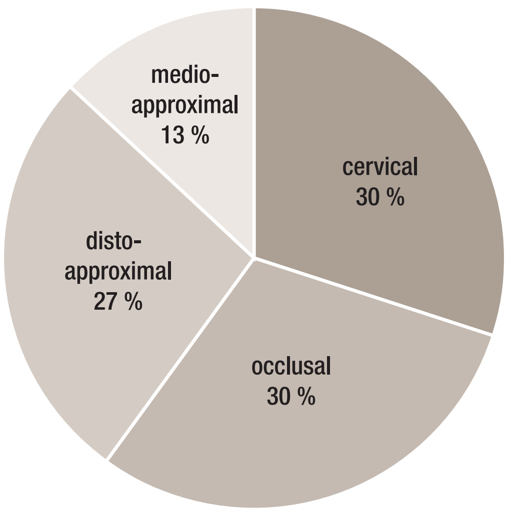


Fig. 3_Location of carious lesion.

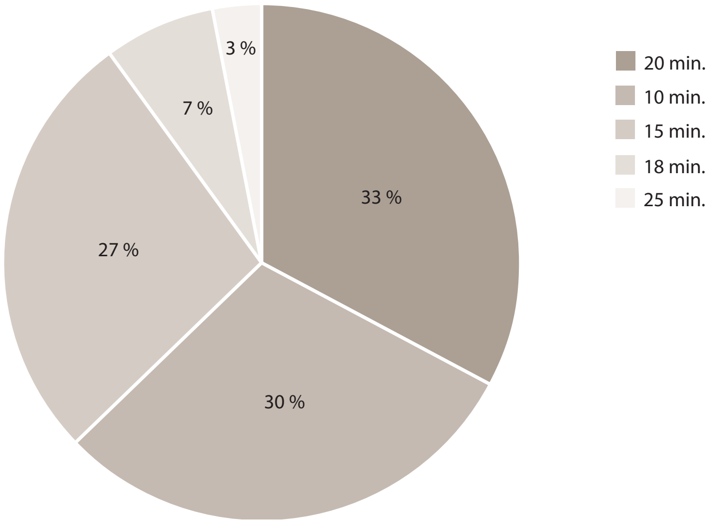


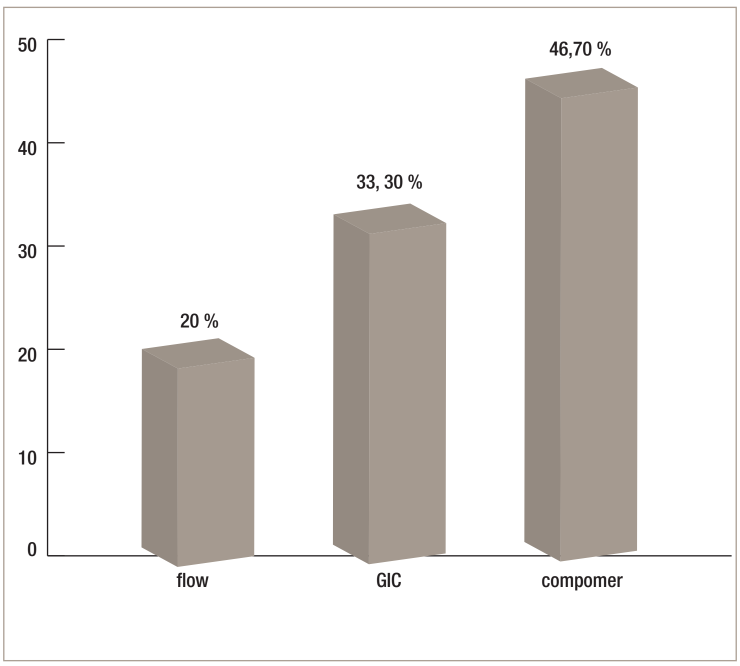
Fig. 4_Duration of laser cavity preparation.

ities were filled with a biologically active restoration material, either GIC (Triage GC), flowable composite resin (Gradia Direct Loflow GC), or compomer (Glasiosite Voco). In the deepest carious lesions, calcium hydroxide liner was used before placing one of these filling materials. Follow up was performed during a period of one year to evaluate post-operative sensitivity and possible complications. In each case, each step during laser cavity preparation was recorded and analysed. The statistical analysis was performed using the Pearson correlation coefficient.

_Results

Five primary incisors, four canines, seven upper primary molars and 14 lower primary molars cavities were prepared using Er-YAG (Fig. 2). An analysis of the carious lesions according their location shows that nine were in the cervical area, twelve proximal lesions and nine occlusal lesions (Fig. 3). Thus, all three possible types of carious lesions were prepared using the laser.

Fig. 5_Distribution of restorations according to the type of filling material.



Due to the extent of the carious lesions chosen to be treated, remineralisation could not be expected and therefore those areas of decay had to be considered irreversible lesions. Six of the lesions were at the dentin-enamel junction and the remaining 24 in the second half of the dentin.

During cavity preparation using the Er:YAG laser, a chronometer was used to time each procedure. In 17 of the cases, the duration of their preparation was 10-15 minutes. In all other twelve dentin caries cases, the duration was up to 20 minutes and only in one case did the time required approach 25 minutes. The mean time for cavity preparation was 15.7 $\pm$ 4.46 minutes. The distribution is presented in Fig. 4. The distribution of the filling materials used to restore the cavities prepared with the Er:YAG laser is presented in Fig. 5.

14 of the cavities were filled with compomer (Glasiosite Voco), ten with biologically active restoration material (Triage GC) and six with flowable composite resin (Gradia Direct Loflow GC). In the deepest carious lesions, the restoration was preceded by a calcium hydroxide liner. In order to examine the children's perception of their treatment with an Er:YAG laser, they were initially grouped according to their attitude to dental treatment using the Frankl Scale (Fig. 6).

This graph shows that 2/3 of the children showed either a negative or strongly negative attitude to dental treatment in general (rating 3 and 4) and only 20 % of the children demonstrated a slightly positive attitude (rating 2). Although most of the children initially had a negative attitude to dental treatment in general, none of them had a negative attitude to laser treatment or would not allow the laser treatment at all. The distribution of children according their attitude (code 1 to 4) to laser treatment is shown in Figure 7. It shows that all of the children had a positive attitude to laser treatment, and for two thirds of the children laser treatment was the option that gained their cooperation.

Parents of children (from code 2 and code 3) were strongly supportive of laser treatment. In children with a positive attitude according to the Frankl scale, conventional dental drills and laser were equally well accepted. Despite the small number of examined children, an inversely proportional correlation between the children's behaviour in the dental office and their attitude to laser treatment was recorded (Pearson correlation coefficient = 0.821; $p < 0.01$). In other words, the more the child demonstrated an initially negative attitude to dental treatment, the greater the probability that the child would accept laser as the only possibility for dental treatment (code 3 and code 4). The treated teeth were followed up for a period of one year and during this period no adverse events were observed.

_Discussion

The protocol we used for Er:YAG-laser assisted caries treatment of primary teeth showed good results in terms of acceptance by both patients and parents and can be recommended in for use in a paediatric clinical practice. These results can be linked to specific energy parameters, which differed for enamel and dentin as follows:

Enamel treatment

The most effective energy level was 300 mJ/ 20Hz, (theoretical fluenc : 22.61 J/cm²). Preparing enamel requires the sapphire tip to be perpendicular to the occlusal surfaces (occlusal caries), perpendicular to the smooth vestibular surfaces (cervical caries), and with a 45° angle in case of proximal caries.

Dentin treatment

200 mJ/ 20 Hz, (theoretical fluence: 15.08 J/cm²). In the case of class II cavities, the floor of the box is best treated using an approach at 90° angle and the walls of the proximal box with angles ranging from 30° to 45°. The pulpal wall should be approached cautiously. Observing the rules for micro-invasive cavity preparation, calcium hydroxide liners should be applied to stimulate a possible remineralisation of the affected dentin. Moreover, the use of active filling materials such as glass ionomer restorative materials containing fluoride is recommended.

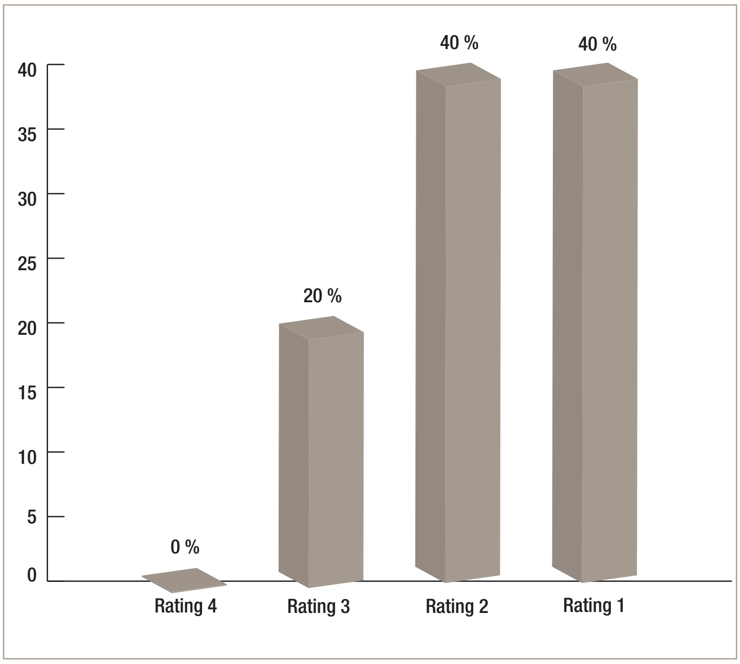
Finishing the periphery of the cavities with the laser at a lower energy setting (100 mJ/ 20 Hz, theoretical fluence: 12,74 J/cm²) and the angle between the laser beam and the enamel surface at 45° assures the regularisation of the enamel prisms before acid etching.[11]

We defined parameters for primary hard tissue ablation using an Er:YAG laser (Syneron, Lite Touch™, Israel) based on scanning electronic microscope and IR spectroscopy results (Zhegova and Rashkova, 2012) as follows: fluences ranging from 15 J/cm² (dentine) to 22 J/cm² for enamel, with a pulse duration of 50 µsec and pulse repetition rate of 20 Hz.

Minimally invasive treatment with an Er:YAG laser depends on two main parameters:

Spot size diameter: decreasing the spot size diameter leads to an increase in the energy delivered to the target tissue (Fluence F= J/cm²). Pulse repetition rate (Hz): the more the pulse repetition rate is increased, the greater the ablation rate.[9]

It is well known that the degree of mineralisation of primary enamel is lower than that of permanent teeth, therefore its water content is higher and thus its energy absorption is higher, a fact which requires using different parameters in the ablation process in primary teeth.[6,9] Giusti suggests using high parameters of laser energy in order to reduce the ablation time, which is a worthwhile goal in treating children.[12] Nevertheless, there should be an individually tailored approach in order to avoid negative results.[6,13] Using higher repetition rates leads to the ap-



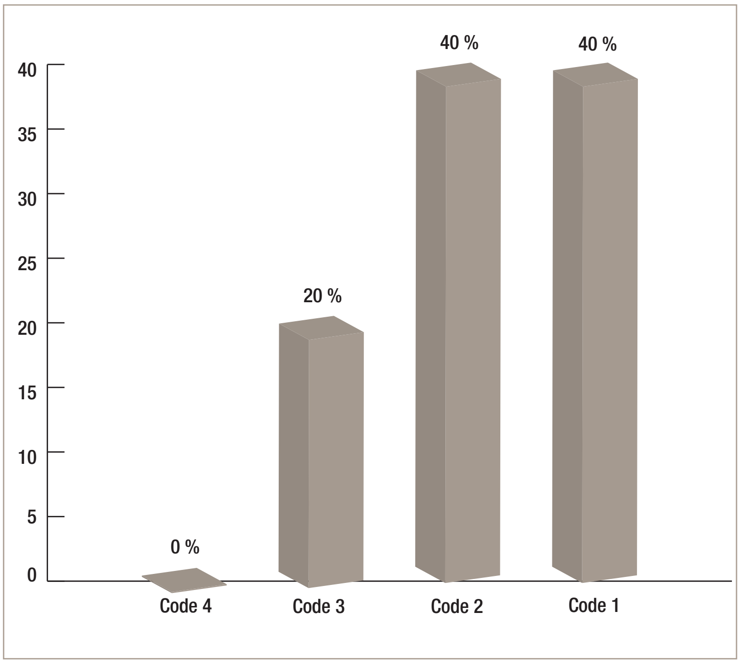


Fig. 6_Children's attitude (%) to dental treatment using the Frankl Scale.

Fig. 7_Distribution of children according to their attitude to laser treatment.

Fig. 8_Er:YAG laser treatment of dental caries shows good acceptance among both small children and their parents. Courtesy of Prof Anna Minovska, Eternadent Clinic Skopje, Macedonia.

pearance of more cut enamel prisms, more loosely bound particles, more irregular cut surfaces and a decrease in the tissue removal selectivity.[9,14] With regard to the energy level used, increases in energy level lead to the removal of proportionally more enamel.[6,9,14]

In our SEM investigation, primary enamel patterns after use of the Er:YAG laser at a setting of 300 mJ/20 Hz showed relatively smooth surfaces without the removal of big particles of the enamel prisms.[15] Thus, the morphology of the enamel prisms was preserved. An increase in the energy used resulted in more irregularities and fused areas. Similar findings were reported by other authors.[12,16] They observed via SEM the primary enamel patterns resulting from the use of an Er:YAG laser with different parameters and hypothesise that the crater depth is a linear function of radiant exposure per pulse. As the energy increases, more water in the enamel is vaporized during cavity preparation, promoting faster laser penetration per unit of time. The short duration of the procedure seems to be an important condition in children caries treatment but it should be matched with the choice of the optimal energy parameters, thus avoiding possible negative effects of Er:YAG laser ablation.

SEM observation of dentin shows an irregular topography with opened dentinal tubules without a smear layer after the use of the Er:YAG laser set at 200 mJ/ 20 Hz. An increase in energy (300 mJ/ 20 Hz and 400 mJ/ 20 Hz) leads to the formation of more scaly dentin surfaces and greater ablation of intertubular dentin, leaving the peritubular dentin with a protruded appearance. These data indicate that Er:YAG laser action is more intensive on substrates with a higher water content. Other authors reported a dentinal surface with greater dentinal tubule obliteration, larger gaps, and greater ablation of intertubular dentin in comparison with the peritubular dentin after applying higher energy.[13,14]

The correct direction of the laser beam (sapphire tip) is very important in order to control the ablation process in enamel prisms and dentinal tubules, since the goal is to achieve minimally invasive cavity preparation by removing only fully-destroyed dental structures and infected dentin.

Er:YAG laser finishing and bevelling of the enamel edges with lower energy parameters (100 mJ/ 20 Hz and angle between the laser beam and the enamel surface at 45°) assures good adhesion of the restorative material and a microleakage-free interface.[11,17,18] The proper choice of restorative materials for primary teeth, such as GIC or compomers, is also a prerequisite for a good final restoration in Er:YAG-laser assisted caries treatment in primary teeth.

The psychological effect of Er:YAG laser-assisted caries treatment in children shows a good acceptance of the laser as a treatment tool. Our investigation shows that notwithstanding the prolonged duration of the laser procedure in some cases, the most apprehensive children prefer it to conventional cavity preparation.

_Conclusion

Er:YAG laser cavity preparation allows minimally invasive treatment of dental caries and also shows excellent acceptance among both small children and their parents (Fig. 8). The choice of optimal energy parameters is a requirement for successful laser caries treatment in paediatric dentistry._

_contact laser

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