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Er:YAG laser or high-speed bur for cavity preparation in adolescents

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Abstract

Objectives. The aim was to evaluate the effect on cavity preparation time, the pulse changes and the patient's subjective experience during removal of healthy tooth substance with high-speed bur and Er:YAG laser. ***Materials and methods.*** Thirty-five (13 male, 22 female) 14–18-year-olds participated. After local anaesthesia, Er:YAG laser and high-speed diamond bur were used for a 2 mm deep cavity preparation on the middle of the buccal surface on contra-lateral healthy maxillary first premolars. The cavity preparation time and the pulse were measured during the treatment. Subjective experience was evaluated using a VAS-scale and a questionnaire. Wilcoxon Signed Rank test and Chi-2-test were used for statistical analyses. ***Results.*** The mean (SD) cavity preparation time was 3.7-times longer ($p < 0.001$) for the laser [59 (41) s] than for the high-speed bur [16 (4) s]. The mean pulse change during preparation differed ($p < 0.05$) between the bur (+2.2%) and laser (−4.4%). The smell was worse when laser was used ($p < 0.01$); 65.7% expressed less discomfort and 57.1% experienced a lower sound level when laser was used. Laser was preferred for future treatment in 62.9% of the adolescents. ***Conclusion.*** Laser ablation caused unpleasant smell and longer cavity preparation time, but was preferred by a majority of the adolescents.

Key Words: *dental high speed technique, laser ablation, time, visual analogue scales*

Introduction

The experience of noise, vibration and pain, from the dental bur, are contributing factors to the development of dental fear [1]. The use of laser ablation for tooth preparation has made it possible to avoid some of these discomforts and disadvantages. Many improvements have been performed since the first disappointing attempts to use lasers in dentistry were performed almost 50 years ago [2]. Previous studies have shown that 80–100% of both children and adults prefer laser when compared to the conventional bur [3–5]. Laser ablation has sometimes been described as a method to avoid pain during the preparation of teeth, but since 10–20% of the patients experience pain during the laser ablation procedure [4,6,7], it is usually necessary to use local anaesthetics during laser ablation in children and adolescents. To our knowledge, no previous studies have analysed the patients' subjective experience of discomfort during laser ablation (including sound level, smell and cavity preparation time) independent of (the otherwise confounding factor) pain.

Some dental procedures make it necessary to remove healthy tooth substance. It is therefore important to evaluate the patients' subjective experience during such treatments.

The aim of the present study was to evaluate possible differences between Er:YAG laser and conventional high speed bur regarding the cavity preparation time, the pulse changes and the subjective experience during removal of anaesthetized, healthy tooth substance among Swedish adolescents.

The hypotheses were: When healthy anaesthetized tooth substance of adolescents is removed to a depth of 2 mm from the buccal surface with Er:YAG laser ablation or high speed bur preparation:

(1) The cavity preparation time is equal for the laser and the bur.
(2) The pulse of the subject does not differ during the procedure whether laser or bur is used.

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(3) The subjective expression of discomfort does not differ whether the procedure is performed with laser or bur.
(4) The preferred choice for future similar treatment is equally distributed between the laser and the bur.

Materials and methods

The study was designed as a split-mouth study.

Patients

Patients from 14 years of age planned for orthodontic treatment at the local orthodontic clinic, including extractions of two intact contra-lateral maxillary first premolars, were consecutively invited to the study. A tooth was considered intact if it was not previously restored and not affected by caries, mineralization disturbances or other obvious pathology or abnormality. All participants should consider themselves as capable to co-operate during the described procedure of the study and were therefore considered not to suffer from dental fear. Patients and parents were informed about the study and that they were allowed to withdraw from the study at any time without any influence on further treatment. Written informed consent was achieved from each parent or guardian and from the participating adolescent. Thirty-five adolescents (13 male, 22 female) with a mean (SD) age of 15.8 (1.2) years (range: 14–19 years) participated in the study. After randomization of the patients, the first preparation was performed with laser in 18 (11 F, 7 M) and with bur in the other 17 (11 F, 6 M) of the patients. Eighteen (nine with laser and nine with bur) of the first preparations were performed in the right maxillary first premolar (14) and 17 (eight with laser and seven with bur) in the left maxillary first premolar (24).

Laser system

The Elexxion Delos® Er:YAG laser (Elexxion GmbH, Radolfzell, Germany. Software version 1.02a. IEC 825–1: 10.2003. Maximum output: 20 W; Maximum pulse energy: 1000 mJ; Laser class 4; Pulse frequency: 1–25 Hz; Emitted wavelength: 2940 nm, Pilotbeam 635 nm) with pre-set values for 'Hard Tissue Ablation High' was used during the laser ablation. The preset levels were: wavelength: 2940 nm, pulse energy: 400 mJ, pulse duration: 300 μs, frequency: 20 Hz, mean output power: 8 W. As recommended by the manufacturer, the sapphire point was close to, but not in contact with the tooth surface during the preparation. The diameter of the sapphire point (Elexxion Duros® tip 800, item-no. 00280000. Elexxion GmbH, Radolfzell, Germany) was 800 μm. Laser-protective eye wear was used by each person present in the room during the laser treatment.

High-speed bur

The high-speed hand-piece KaVo Toplight 896 was used for the bur preparation with the 1.2 mm diameter diamond round bur Drendel + Zweiling No. 801.314. A new bur was used for each preparation.

Sound level. The sound level was measured before the start of the study with the Premier Farnell Ltd, ST-805 decibel scale for the laser and the bur at a 10 cm distance from the laser and bur hand-piece, respectively.

Methods. The same dentist performed all treatments and the evaluations. Before the start of the treatment, the patient swallowed a 500 mg paracetamol (Panodil®) (GlaxoSmithKline, Brentford, UK) tablet to reduce the inflammatory response and to minimize the risk for possible post-operative pain. Application of Lidocaine APL 5% topical anaesthetic gel during 5 min was followed by local buccal and palatal injection of 4.5 mL Xylocain® Dental Adrenalin (20 mg lidocaine/mL, 12.5 μg adrenaline/mL) (Dentsply Ltd, Addlestone, UK) to avoid bias from a not fully anaesthetized premolar. The Wand™ (Milestone Scientific, Livingstone, NJ) computer-controlled anaesthetic delivery system was used for injection. Five minutes after the injection, preparation was started on the middle of the buccal prominence of the maxillary first premolar. A protocol was used to randomize the order of the laser and bur preparation to the left and right side in each patient. A cylindrical cavity with an approximal width of 1.2 mm was removed with laser and bur, respectively, on the buccal prominence of the contralateral maxillary first premolars to a depth of 2 mm, as measured with a periodontal probe from the mesial part of the inferior limitation of the cavity. The cavity size was continuously inspected during the ablation/preparation procedure and the size of the cavity was checked with a periodontal probe. The time for check-up of the cavity size was excluded from the evaluated time for ablation/preparation.

Cavity preparation time

A stopwatch was used to measure the time consumed from the first contact between bur and tooth until the preparation was finished. The time for active use of the laser was measured with the stopwatch visible on the laser unit display.

Pulse. The pulse of the participating adolescent was measured with a pulse oximeter (Nonin Medical Inc, Plymouth, MN) immediately before and after preparation.

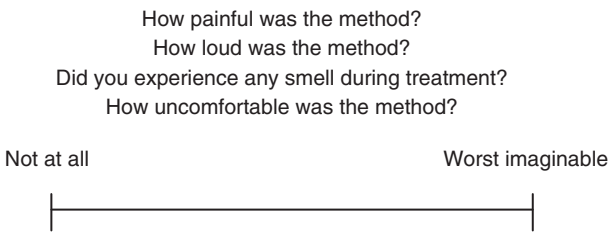

Figure 1. VAS-scales used for evaluation (1–100) of subjective experience during preparation.

Sound level, smell and discomfort

The subjects evaluated the sound level, smell, discomfort and pain in separate 100 mm VAS-scales (visual analogue scale) after each ablation/preparation, as shown in Figure 1.

The evaluation of pain was performed to enable exclusion of patients, in whom the local anaesthetic effect was regarded as unsatisfactory.

Preferred method. When preparation with both laser and bur was finished, the patient answered the three following questions with *laser* or *bur* as possible answers:

- Which method was the least uncomfortable?
- Which method was the least noisy?
- If you need to have a tooth prepared in the future—which method would you prefer?

The study was approved by the Regional Ethical Review Board at Linköping University, Sweden. The procedures followed were in accordance with the Helsinki Declaration.

Statistics

Wilcoxon Signed Rank Test was used for comparison between the two treatment methods regarding the variables; cavity preparation time, pulse change and VAS-smell. Chi-2 test was used to find possible differences between laser and bur regarding the answers from the questionnaire (discomfort, sound level and preferred future treatment). The software Minitab was used for the statistical analyses.

Results

Pain

All patients were found to have a satisfying local anaesthetic effect, why none was excluded due to pain.

Measured sound level

The laser had a stand-by sound level of 62.5 dB. The sound level was 77.1 dB without and 83.3 dB with vacuum ejector, respectively, when the laser was used. When the bur was used, the sound level was 79.7 dB without and 85.1 dB with vacuum ejector, respectively.

Cavity preparation time. The mean time (SD) spent to complete the described procedure was 59 (41) s (range: 18–190 s) for the laser and 16 (4) s (range: 4–18 s) for the high-speed bur. The difference regarding the cavity preparation time was significant ($p < 0.001$).

Pulse. The mean (SD) pulse change during preparation differed ($p < 0.05$) between the bur and the laser, with a pulse increase of 2.2% during high-speed preparation [from 80.5 (11.3) to 82.3 (12.8)] and a 4.4% decreased pulse during laser treatment [from 81.5 (11.9) to 77.9 (14.6)].

Subjective sound level, smell and discomfort

The patients' ratings regarding sound level, smell and discomfort are shown in Figures 2 and 3. No differences regarding the VAS-scale-ratings were found regarding the sound level and discomfort (Figure 2). The patients experienced significantly more smell ($p < 0.01$) according to the 100 mm VAS-scale [mean (SD)] when laser was used [33.2 (33.2)] than when the bur was used [7.7 (21.3)].

Twenty (57.1%) of the 35 adolescents experienced that laser caused a lower sound level than the bur ($p < 0.01$). Twenty-three (65.7%) found laser less uncomfortable than the bur and 22 (62.9%) of the adolescents preferred laser before bur for possible future dental treatment ($p < 0.01$).

Discussion

Teeth

In previous *in vivo* studies, preparations with laser vs bur have been performed on carious teeth. It is not possible to standardize caries lesions regarding the extension in depth and width in the clinic and, since the hardness of decayed tooth substances differ, it is impossible to perform a case-control split-mouth study *in vivo* without using healthy tooth substance. To our knowledge this is the first study where preparation of healthy teeth with laser has been compared to bur in a split mouth study among adolescents.

Patients

It was considered that the premolars had completed their post-eruptive maturation regarding mineralization at the age of 14 years. The number of girls exceeded that of the boys, but that was not considered to cause any bias, since the study was designed as a split-mouth study. As the patients included in the study were set into a protocol with previously set order

for the use of either laser or bur and for the order in which the tooth should be treated, possible bias caused by order of treatment was eliminated.

Pain

Evaluating the experience of pain, when it includes avoidance of available pain relief, is not considered to be ethical among children and adolescents. Both dental laser ablation and preparation with bur will sometimes cause pain, if local anaesthesia is not used [5]. We therefore decided not to evaluate the experience of pain from bur or laser in this study performed among adolescents.

Objective sound level

The measured sound levels were similar for both treatment methods. The stand-by sound level of the laser was considered to be relatively high.

Cavity preparation time

The first hypothesis was rejected, since the cavity preparation time was significantly (3.7-times) longer for the laser than for the bur. Similar findings have been found by several authors, with 2.35–6.8-times longer timea used for the laser than for the bur [4,8–10].

A higher energy level allows faster laser ablation. Higher energy also increases the risk for unwanted side-effects. Less energy is necessary to ablate carious dentin as compared to intact enamel. The laser energy has to be even higher for effective removal of tooth substance if fluoride apatite partly has replaced hydroxyl apatite in the intact enamel [11]. The fact that we only prepared intact enamel (where inclusion of fluoride apatite may have occurred) could be one reason why the laser therapy in our study was quite time-consuming. Thus, the energy used (400 mJ) was the highest standardized level for ablation in the laser device. A lower energy should be applied for caries removal. The energy transmitted to the tooth surface will be decreased if debris from the ablation process covers the sapphire point. This may be a reason for the big range in cavity preparation time for the laser in our study.

Pulse. The correlation between dental anxiety and pulse changes during dental procedures has been presented previously [12]. In our study the heart rate increased by 2.2% during drilling while it decreased by 4.4% when the laser was used. The finding may be related to the longer time used during laser ablation or that laser treatment appeared less dangerous. The second hypothesis, that there was no difference regarding pulse change during preparation with laser and bur, was found to be false.

Subjective experience of sound level

It is interesting to find that the VAS-scale rating (Figures 1 and 2) regarding the subjectively experienced sound level and discomfort did not differ significantly between the two methods, while both sound level and discomfort were rated significantly lower for the laser when the two methods were compared in the questionnaire (Figure 3).

Regarding the sound level, the VAS-ratings were quite equal between laser and bur (Figure 2). It is well known that the high-speed bur is not quiet, but these results indicate that the laser also emits sounds to almost the same degree. It is interesting that 57.1% of our study group, at the end of the treatment, in the questionnaire, considered laser treatment to have a lower sound level (Figure 3). Here the difference between the two methods was greater, which indicates the importance of how and when questions are asked for a reliable answer. The annoying sound of the bur could be terrifying to children and make patients uncomfortable [4,13–15], but a masking noise can be used for reduction of stress and fear during dental treatment [16]. Our patients did not find laser treatment quiet. It is probably more common to have negative associations (learned response) to dentistry from the sound of the dental bur than from the unusual sound of the laser.

Smell

To our knowledge, this is the first time the patient's subjective experience of smell from laser has been presented in a case control study. Aoki et al. [17] described the smell during laser treatment as a 'charring smell'. In the present study, smell was the only VAS-scale-parameter with a significant difference between the bur and the laser. The Swedish adolescents in the present study found laser ablation smell significantly worse than bur preparation.

Discomfort

The bur is known to produce uncomfortable noise and vibrations and to cause dental fear in early ages, while the laser has been found to minimize the risk for discomfort and development of dental fear [4,13–16]. In our study the bur had a similar (not significantly higher) discomfort score than the laser in the VAS-scale (Figure 2). However, two thirds of the adolescents found the laser less uncomfortable than the bur (Figure 3). In a study by Hadley et al. [18] there was a similar decrease in discomfort level for the laser as compared to the bur in patients who were treated without local anaesthesia. These results correspond well to a previous study where laser preparation was more comfortable [3]. Our results rejected the third hypothesis, since more adolescents experienced less

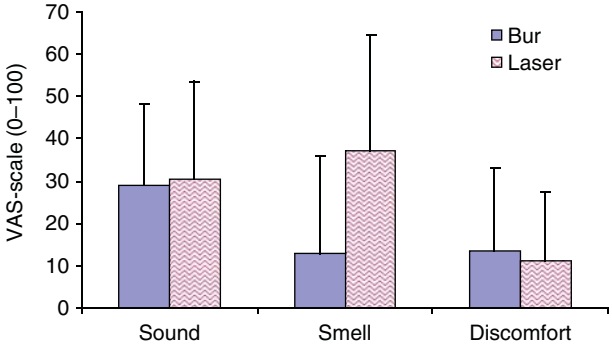

Figure 2. The patients' ratings regarding sound level, odour/smell and discomfort presented as mean values and standard deviations. The smell from the laser ablation was significantly worse than the smell from the bur ($p < 0.01$).

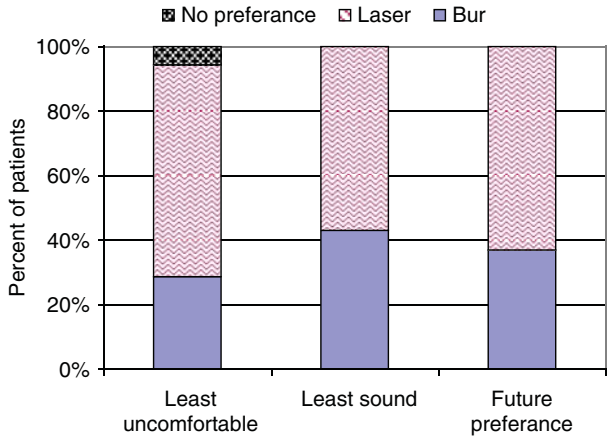

Figure 3. Patients' preferences regarding least uncomfortable, least noisy and eventual future dental treatment.

discomfort during removal of tooth substance with Er:YAG laser than with high speed bur (Figure 3). This statement was also supported by the pulse changes during the treatment.

Future preference

In spite of the noise, the smell and the long time used for laser treatment, a significant majority of our patients (62.9%) preferred laser technique for possible future treatment. The fourth hypothesis was therefore rejected.

VAS-scales

VAS-scales are valid and reliable tools, but interpretation of the results can be misunderstood or misused [19]. Some patients may give extreme VAS ratings for certain variables. The design of our split mouth case control study reduced the risk for such systemic errors. The way to ask a question will influence the answers from the patients. This was obvious in our study where the rating on the VAS-scale showed no significant difference between laser and bur, neither regarding the experienced sound level nor the discomfort, while the questions with only two options for answers showed that significantly more adolescents experienced that the laser had a lower sound level and was less uncomfortable than the bur.

Previous reports have found that 80–90% of the children don't express any pain from laser ablation, when treatment is performed without local anaesthesia [4,6,7]. Therefore, several authors have suggested that laser ablation should be an alternative to bur preparation in children with dental fear. The remaining 10–0% of the patients, who may feel pain when treatment is performed without local anaesthesia, must anyhow be considered when the treatment is planned. Every effort should be made to avoid pain in paediatric dentistry. A combination of local anaesthesia and laser ablation should therefore be considered to minimize the risk for pain.

In a study by Pelagalli et al. [5], where cavity preparation was performed, all the 60 participating patients expressed that they preferred laser to the bur. They explained that, by their finding, that local anaesthetics could be avoided when the laser ablation was used. In our study all patients were anaesthetized. This may have influenced the results from our study where only 62.9% of the patients preferred laser before the bur.

Vibrations and the reduced need for anaesthesia has been suggested to be causative factors for the better compliance to laser found among paediatric dental patients [5,20]. Liu et al. [4] recognized less body and head movements during laser preparation in children as compared to when conventional mechanical preparation was used. These advantages are probably due to the reduced permeability of dentin and enamel found after laser treatment leading to a decreased hypersensitivity and an analgesic effect [20,21].

Since the study was not possible to perform as a blind-study, we cannot exclude the influence of placebo effect on the patients' subjective evaluations.

It is difficult to compare different studies because the effectiveness of lasers depends on a complex interaction of wavelength, pulse duration, frequency and energy. Another influencing factor (not evaluated in the present study) is the hardness of the tooth substance. The teeth included in the study were evaluated as healthy and without any visible mineralization disturbances or fillings, which is why the influence of possible different micro-hardness of enamel and dentin is expected to be of minor importance.

We know that the adolescents in the present study preferred laser treatment, but we did not ask why. Many advantages are seen and have been described for laser in dentistry like enhanced comfort [3], less vibrations and pressure [4,15] and a noise not connected to pain and dentistry. The extra time consumed for laser ablation [8,9] and inspection [22]

and the need of a bur for removal of metals and ceramics [23] and for polishing of restorations [4] are some of the remaining disadvantages with laser ablation.

In conclusion, laser ablation caused an unpleasant smell and was more time-consuming than preparation with a high speed bur, but was preferred by a majority of the adolescents, when a 2 mm deep cavity on the buccal surface of a healthy premolar was performed.

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***Declaration of interest*:** The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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