Acta Odontologica Scandinavica, 2011; 69: 65–74

informa
healthcare

REVIEW ARTICLE

Application of laser technology for removal of caries: A systematic review of controlled clinical trials

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Abstract

Objective. To evaluate the scientific evidence regarding laser technology for removal of carious tissue. ***Material and methods.*** A search for literature on the effect of treatment and on economic aspects of laser technology identified 23 papers. No relevant studies on economic aspects were found. Regarding the effect of treatment, 16 papers were selected for assessment according to established criteria. ***Results.*** Cavity preparation and caries excavation by erbium laser were evaluated in three studies of medium quality. The time required to remove carious tissue was evaluated in five studies assessed as being of medium quality for this outcome. In four studies the effect of laser treatment on the dental pulp was included as an outcome but, due to the short follow-up time, the quality was assessed as low. Two studies that included the longevity of the restoration as an outcome were also assessed as being of low quality because the follow-up time was inadequate. Patient response was evaluated in three studies, which were assessed as being of medium quality with respect to this outcome. ***Conclusions.*** There is limited scientific evidence that laser treatment is as effective as a rotary bur for removing carious tissue. Treatment time is prolonged. There is limited scientific evidence that adults prefer laser treatment. No conclusions can be drawn regarding biological or technical complications, children's perception of laser treatment or the cost-effectiveness of the method.

Key Words: *Dental caries, economics, erbium YAG, evidence-based dentistry*

Introduction

Several techniques for caries excavation are available [1]. The conventional method is the use of a rotary bur. Although this is a highly efficient low-cost technique, it generates considerable noise and vibration. An alternative approach is the application of an erbium laser beam. This is a relatively new method and to date its application in most countries is not widespread.

When the laser beam encounters the tooth surface, the light is absorbed by water molecules in the dental hard tissues. As a result, the water heats up rapidly and vaporizes. The reaction creates a high localized pressure and a micro-explosion, which results in ablation of dental hard tissue. A comprehensive report on the basic science and general aspects of lasers in dentistry has been edited by Gutknecht [2].

Removal of caries is often a painful procedure and the pain is more intense in deep lesions close to the dental pulp. Compared to a rotary bur, the laser is quieter and vibrates less [3]. It is claimed that laser treatment is less painful, reducing the need for local anesthesia [2].

Instrumentation of the dental hard tissues can result in unwanted side effects. The friction developed by rotary instruments raises the temperature and thus increases the risk of thermal injury to the pulp. The peak surface temperature during ablation of enamel with erbium lasers can vary between 300 and 800°C, depending on the laser system [4]. To avoid thermal damage, continuous water-cooling is required during treatment [5,6].

The method of excavation may affect the surface properties of dental hard tissues and compromise bonding with adhesive restorative materials, thus

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(Received 14 October 2009; accepted 2 September 2010)

ISSN 0001-6357 print/ISSN 1502-3850 online
DOI: 10.3109/00016357.2010.536901

reducing the longevity of the restoration. The bond between resin composites and laser-excavated tooth structure has been evaluated in several *in vitro* studies [7–13]. However, with respect to potentially detrimental effects of laser ablation, the results are contradictory.

The aim of the present systematic literature review of controlled clinical trials was to evaluate the scientific evidence in support of laser excavation of carious tissue. The review includes erbium laser equipment of various brands, but with the same wavelengths. At the time of this review two different laser systems were commercially available:

- Er:YAG laser (erbium: yttrium–aluminum–garnet); wavelength: 2.94 μm.
- Er,Cr:YSGG laser (erbium, chrome: yttrium–scandium–gallium–garnet); wavelength: 2.79 μm.

The review addresses the following primary questions:

- Is laser an effective method for removing carious tissue? (Outcome: complete caries removal.)
- Are there potential biological complications associated with the method? (Outcome: pulpal injury.)
- Is the longevity of the restorations affected by the method of caries removal (laser versus bur)? (Outcome: longevity of the restoration.)
- Do patients respond more favorably to laser treatment than conventional caries excavation? (Outcome: comfort or subjective perception during treatment, patient preference for laser/bur, need for local anesthesia.)
- What is the cost of the laser treatment? Is the method cost-effective?

The review was initiated by the Swedish Council on Technology Assessment in Health Care (SBU) [14].

Material and methods

Effect of treatment

Search strategies. In January 2009, in consultation with an information specialist, a search for relevant literature on the effect of treatment was conducted using the following databases: PubMed, Cochrane Library, Embase and Inspec (Table I). The reference lists of the selected articles were then manually searched for additional relevant articles. Original studies published in any language, but with an abstract in English, German, French or any of the Scandinavian languages, were accepted. Grey literature, such as textbooks, abstracts, letters, editorials and proceedings, were not taken into account. Animal studies were also excluded. The literature search resulted in retrieval of 766 unique abstracts. Two reviewers independently evaluated the abstracts for potential inclusion. A full-text version of an article was ordered if at least one of the reviewers considered it potentially relevant according to the following basic inclusion criteria:

- Study aim in agreement with the main research question.
- Prospective clinical study.
- At least two experimental groups in which the outcome of laser ablation was compared with that of conventional excavation with a rotary bur.
- At least 20 patients in each study group.
- Follow-up of at least 3 years for evaluation of long-term pulpal effects and longevity of restorations.

The papers did not have to address all the research questions in order to be selected.

Quality assessment. The two examiners read the papers independently. The quality and relevance of each study were graded as high, medium or low using a study-quality checklist. The questions focused on

Table I. Search strategies: effect of treatment.

PubMed 1950–2009 (January)		
Er yag (TW) Erbium yag (TW) Er, cr ysgg (TW) Er cr ysgg (TW)	AND	Caries (TW) Carious (TW) Teeth (TW) Tooth (TW) Dentin(e) (TW) Dental (TW) Enamel (TW)
Cochrane Library version 1, 2009		
Er yag (ti, ab, kw) Erbium yag (ti, ab, kw) Er, cr ysgg (ti, ab, kw) Er cr ysgg (ti, ab, kw)	AND	Caries (ti, ab, kw) Carious (ti, ab, kw) Teeth (ti, ab, kw) Tooth (ti, ab, kw) Dentin(e) (ti, ab, kw) Dental (ti, ab, kw) Enamel (ti, ab, kw)
Embase 1974–-2009 (January)		
Er yag (TW) Erbium yag (TW) Er, cr ysgg (TW) Er cr ysgg (TW)	AND	Caries (TW) Dental caries/exp Carious (TW) Teeth (TW) Tooth (TW) Tooth/exp Dentin(e) (TW) Dentin/exp Dental (TW) Enamel (TW) Enamel/exp
Inspec 1987–2009 (January)		
Er yag (TW) Erbium yag (TW) Er, cr ysgg (TW) Er cr ysgg (TW)	AND	Caries (TW) Carious (TW) Teeth (TW) Tooth (TW) Dentin(e) (TW) Dental (TW) Enamel (TW)

TW = text word; ti = title; ab = abstract; kw = keyword; exp = explode.

external validity, internal validity (e.g. study population, distribution of treatment, comparability of groups, blinding, loss to follow-up, compliance, reporting of effectiveness and side effects), and study precision (whether the factors and calculations used to determine the minimum number of participants were acceptable, e.g. power calculation). An overall assessment of the different quality items was then used as a basis for the intellectual discussion involved in grading the study quality. In case of disagreement between the reviewers, the paper was discussed by all authors until a consensus was reached. Studies with several endpoints could be awarded different quality gradings for each endpoint.

Scientific evidence. The scientific evidence was thereafter assessed on the basis of studies with high or medium quality/relevance. The level of evidence was set according to predetermined SBU criteria used at the time for the present study, as presented in Table II.

Health economics

In consultation with an information specialist, a search for relevant literature which included economic aspects of caries excavation by erbium laser was conducted in January 2009, using the following databases: PubMed, Cochrane Library and HEED (Table III). The Drummond checklist was used for quality assessment of the studies [15]. The search disclosed no relevant published studies.

Results

In all, 16 papers were selected for assessment in full-text format. Nine papers were excluded [16–24].

Table II. Criteria for grading of scientific evidence.

Evidence grade 1 (strong scientific evidence)	The conclusion is corroborated by at least two independent studies of high quality, or a good systematic overview
Evidence grade 2 (moderately strong scientific evidence)	The conclusion is corroborated by one study of high quality, and by at least two studies of medium quality
Evidence grade 3	
Limited scientific evidence	The conclusion is corroborated by at least two studies of medium quality
Insufficient scientific evidence	No conclusions can be drawn when there are not any studies that meet the criteria for quality
Contradictory scientific evidence	No conclusions can be drawn when there are studies with the same quality whose findings contradict each other

Agreement between the two examiners was good ($\kappa = 0.71$). The studies included are summarized in Table IV [25–31]. Because the studies were so heterogeneous, no meta-analyses were performed.

Cavity preparation and removal of caries

Cavity preparation and caries excavation by erbium laser were evaluated in three studies of medium quality [25–26,28].

Den Besten et al. [25] compared laser ablation and rotary bur preparation of one cavity per subject in 124 children and adolescents (age 4–18 years). The subjects were randomized 2:1, i.e. 82 teeth were prepared by erbium laser and the remaining 42 by rotary bur. The operator and a calibrated, independent evaluator assessed the cavities for caries-free status using a tactile probe. If the status was questionable, the operator repeated the procedure. No information is available as to how often this occurred, but ultimately 81/82 cavities ablated by laser and all 42 cavities excavated by bur were accepted.

A randomized clinical trial by Dommisch et al. [26] used a split-cavity design to compare the efficacy of a fluorescence-controlled laser and conventional excavation. There were 26 subjects (age 22–56 years) with a total of 102 lesions. All lesions were opened with rotary instruments. Each lesion was divided into two areas. Carious tissue from one half of the cavity was removed by laser and from the other half by a rotary bur. The diagnostic laser (fluorescence feedback) was set at threshold values between 7 and 10. The excavation was re-evaluated by a blinded, independent evaluator using a tactile probe. After treatment, dentin samples were collected from the different locations and analyzed for potential growth of *Streptococcus mutans* and *Lactobacillus*. At the threshold levels of 7 and 8 the laser removed carious tissue as effectively as the bur. The bacteria remaining after cavity preparation were regarded as clinically irrelevant.

Hadley et al. [28] compared caries excavation by laser and bur in a randomized clinical trial using a split-mouth design. The subjects comprised 68 adults aged 20–84 years, with 75 pairs of teeth. Two calibrated operators and three blinded evaluators were engaged in the trial. The cavities were assessed by the operator and an evaluator. If the outcome was regarded as unacceptable, the operator repeated the procedure until the cavity was caries-free and the preparation was satisfactory. No information is available as to how often this occurred. No significant difference was found between laser and bur for the two outcomes: caries removal and cavity preparation.

Caries removal and cavity preparation were also assessed in a study of low quality by Pelagalli et al. [31].

Table III. Search strategies: economics.

PubMed 1950–2009 (January)				
Er yag (TW) Erbium yag (TW) Er, cr ysgg (TW) Er cr ysgg (TW)	AND	Caries (TW) Carious (TW) Teeth (TW) Tooth (TW) Dentin(e) (TW) Dental (TW) Enamel (TW)	AND	Economics (MeSH subheading) Cost and cost analysis (MeSH term) Cost benefit (TW) Cost effectiveness (TW) Cost utility (TW)
Cochrane Library version 1, 2009				
Er yag (ti, ab, kw) Erbium yag (ti, ab, kw) Er, cr ysgg (ti, ab, kw) Er cr ysgg (ti, ab, kw)	AND	Caries (ti, ab, kw) Carious (ti, ab, kw) Teeth (ti, ab, kw) Tooth (ti, ab, kw) Dentin(e) (ti, ab, kw) Dental (ti, ab, kw) Enamel (ti, ab, kw)		
HEED 1967–2009 (January)				
Er yag (TW) Erbium yag (TW) Er, cr ysgg (TW) Er cr ysgg (TW)				

TW = text word; ti = title; ab = abstract; kw = keyword; exp = explode.

Treatment time

The time required to remove carious tissue has been evaluated in five studies assessed as being of medium quality for this outcome [25–27,29,30]. Dommisch et al. [26] showed that the laser method took three times longer than a rotary bur to remove carious tissue. Keller et al. [29] and Liu et al. [30] reported that the laser procedure took twice as long. In the study by Den Besten et al. [25] there was no significant difference in treatment time between the groups. Evans et al. [27] reported only that length of appointment for laser treatment was "significantly longer" than for the rotary bur. Treatment time was also evaluated in one study assessed as being of low quality regarding this outcome [31].

When calculating the total treatment time it is essential to take into account the need for local anesthesia. Hypothetically, if anesthesia is not required the treatment time could be reduced by 5–10 min. In the study by Den Besten et al. [25], fewer patients in the laser group than in the rotary bur group requested anesthesia.

Effect on the dental pulp

If dental treatment causes a rise in pulpal temperature, the risk of pulpal damage increases. Four studies that included an evaluation of the effect of laser treatment on the dental pulp were identified [25,28,29,31]. However, the quality with respect to this outcome was assessed as low because the follow-up time was short and the presentation of the results unclear.

Longevity of restoration

If a treatment compromises the potential for restorative material to adhere to the prepared tooth surface then there is an increased risk of failure or loss of the restoration. Two studies which included the longevity of the restoration as an outcome were identified [25,28]. The studies were assessed as being of low quality for this outcome because the follow-up times were only 3 and 6 months, respectively.

The scientific evidence is insufficient to determine whether cavity preparation by laser compromises the longevity of a restoration.

Patient perception

Patient perception has been evaluated in three studies, which were assessed as being of medium quality with respect to this outcome [25,27,29].

In the study by Den Besten et al. [25] significantly fewer subjects in the laser group needed local anesthesia. In another study [29], 6/103 patients required local anesthesia for laser treatment and 11/103 for conventional treatment. This difference was not statistically significant. However, a majority of the patients reported greater discomfort when a bur was used, irrespective of the use of local anesthesia.

The third study [27] showed that a statistically significant number of adult patients preferred laser to conventional technique. This study also included children (age <10 years). The number of children was however small and the study was therefore assessed as having low quality with respect to this patient group.

Patient perception has also been evaluated in four studies assessed as being of low quality with respect to this outcome [26,28,30,31].

Discussion

A systematic search of the literature followed by data extraction and quality assessment is today a well-established component of evidence-based medicine and dentistry. Health service staff must work in accordance with scientific knowledge and accepted standards of practice. Assessing an intervention involves evaluating its benefits and harmful effects. Relevant information about the intervention is systematically collected, and the intervention is compared with other interventions or with the absence of any intervention. When weighing different options, decisions on the best alternative can be informed by solid evidence. Thus, assessment results form a base for decision making.

Research results and comprehensive clinical experience should guide the delivery of healthcare [32]. The methodology used in this paper was based on the guidelines developed by the SBU. The principal objectives were to examine the feasibility of laser instrumentation for removing carious tissue, the risk of biological and technical complications, patient response to laser treatment, and the cost-effectiveness of the method. The selected literature consisted of clinical prospective studies with at least two experimental groups. The main reason for excluding papers assessed in full-text format was the lack of a comparison group.

Comments regarding the quality of the included studies are presented in Table IV.

Three studies of medium quality [25–27] concluded that a laser is as effective as a bur to remove carious tissue. An independent evaluator checked the results in all three studies. Laser ablation of dental hard tissues generates a different surface texture than caries excavation by a conventional rotary bur. Since caries removal was confirmed by tactile examination, one cannot rule out that this might have influenced the evaluation. The validity of blinded evaluation must be questioned.

In two of the studies [25,28], laser ablation was repeated if necessary in order to complete caries removal, but it was not stated how often that occurred. It is reasonable to assume that both laser and bur can generate a caries-free surface but it is not possible to evaluate to what extent repeated laser ablation and evaluation affected/prolonged the treatment time.

None of the selected studies fulfilled the basic inclusion criteria for evaluation of long-term pulpal effects and longevity of restorations. For both outcomes, an observation period of at least 3 years was required. Thus, the scientific evidence is insufficient to determine whether laser treatment may be harmful to the pulp, or whether cavity preparation by laser compromises the longevity of a restoration.

Patient perception was evaluated in seven studies [25–31], and in three of them this outcome was assessed as being of medium quality. The assessment was affected by the interaction between reports of pain during treatment and administration of local anesthetics. Information about how often anesthetics were administered was often inadequately reported, thus it is difficult to experience pain from a more comprehensive overview of the patient's perception of treatment. With respect to assessment of pain there is also an ethical aspect, especially when treating children. Best practice must be to prevent pain in every situation where it might occur.

In the paper by Evans et al. [27], the dentist's preference of laser or bur for preparation and caries excavation was evaluated and a majority of the dentists preferred a conventional bur. However, the participants had limited experience of laser ablation prior to the trial.

The cost of resource utilization is one of several parameters to be considered in the planning of dental care. The provision of erbium laser capacity increases the total cost of establishing and running a dental clinic. However, an important aspect is whether the patient's preference for treatment with minimal discomfort is such that additional costs are acceptable.

With the present uncertainty about potential treatment complications, e.g. pulpal survival, the question arises as to whether caries excavation by laser is ethically acceptable.

The evidence ranged from insufficient to low for all outcomes. Further research is therefore warranted. It must also be stressed that the results of this review cannot be extrapolated directly to every clinical situation involving removal of carious tissue. Much clinical time is spent on removing old restorations. As the laser is not effective on metals, a combination of bur and laser must often be used.

Based on our results, the following conclusions have been made according to the guidelines of the SBU. A laser is as effective as a rotary bur for removing carious tissue (evidence grade 3). Removal of carious tissue by laser takes longer than by rotary instruments (evidence grade 3). The scientific evidence is insufficient to determine whether laser treatment may be harmful to the pulp. The scientific evidence is insufficient to determine whether cavity preparation by laser compromises the longevity of a restoration. Adults prefer laser treatment to rotary instrumentation (evidence grade 3). The scientific evidence is insufficient to draw conclusions about the response of children to laser treatment.

Table IV. Clinical trials with cavity preparation and removal of caries by laser.

Authors, year, reference, country	Study design	No. of patients in intervention and control groups	Aims	Results	Quality assessment	Comments
Den Besten et al. 2001 [25] USA	RCT (two clinics) Er:YAG (I) and bur (C)	124 patients (4–18 years of age) I: 82 C: 42 **Dropouts**[a] No. of dropouts at 3-month check-up: 12/124	Caries removal and cavity preparation Time consumption Patient and parental perception (pediatric scale) Restoration longevity Treatment adverse effects	**Caries removal/ cavity preparation** I: 81/82 acceptable C: 42/42 acceptable **Time consumption** No difference between groups ($P = 0.299$) **Patient perception** *Need for local anesthesia* I: 4/82 (5%) C: 11/42 (26%) ($P = 0.002$) *Comfort during treatment or subjective perception of treatment* No difference between groups **Symptoms after treatment** No difference between groups **Pulpal effects** No difference between groups after 3 months	**Caries removal/cavity preparation** Medium **Time consumption** Medium **Patient perception** Medium **Restoration longevity (3 months)** Low **Pulpal effects (3 months)** Low	Randomization not clearly described Unclear description of results. Not stated to what extent treatments were repeated in order to complete caries removal or adjust cavity preparation Treatment evaluated by independent, calibrated evaluator Difference in laser settings between the two clinics and difference in time consumption Parental perception not stated
Dommisch et al. 2008 [26] Germany	RCT Split cavity One operator and one independent blinded calibrated examiner Er:YAG (I) and bur (C)	26 patients (22–56 years) 102 teeth I: 26 C: 26 **Dropouts**[a] No follow-up No dropouts	Caries removal Time consumption Patient perception (VAS) Bacterial infection	**Removal of caries at fluorescence feedback threshold levels 7 and 8** I: 94%**Time consumption** Three times longer with laser ($P < 0.005$) **Patient perception** *Comfort during treatment or subjective perception of treatment* No statistical analysis of difference in perception of laser versus bur treatment (better comfort and less pain by laser are indicated) **Bacterial infection** No significant difference in contamination by *Lactobacilli* or *S. mutans* at fluorescence feedback at thresholds 7 and 8	**Caries removal/cavity preparation** Medium **Time consumption** Medium **Patient perception** Low	Randomization not satisfactory All treatments started with bur, which may affect patient perception Perception of comfort, noise and vibration was evaluated by 16 patients not requesting anesthesia The study evaluated fluorescence feedback in relation to persistent bacterial infection which is beyond the scope of the present report

Table IV. (*Continued*).

Authors, year, reference, country	Study design	No. of patients in intervention and control groups	Aims	Results	Quality assessment	Comments
Evans et al. 2000 [27] UK	Multicenter RCT Split mouth (two matched primary caries lesions) Er:YAG (I) and bur (C)	77 patients (3.5–68 years) I: 77 C: 77 **Dropouts**[a] 5/82 patients did not complete	Time consumption Patient preference (<10 years: pediatric scale; ≥10 years: questionnaire) Dentist preference for treatment method (questionnaire)	**Time consumption** Longer appointment time needed for laser ($P < 0.001$) **Patient perception** *Patients ≥10 years* Patients preferred laser treatment ($P < 0.001$) The patients who preferred laser perceived less pain and vibrations ($P < 0.05$) The patients who preferred bur experienced laser as slower ($P < 0.05$) *Patients <10 years* No significant difference between groups **Dentists' preference** Dentists preferred bur ($P < 0.001$)	**Time consumption** Medium **Patient perception** **≥10 years** Medium **Patient perception** **<10 years** Low	Not possible to assess recruitment bias 15 dentists: 4/15 did not recruit any patients and 4/15 recruited ≥10 patients Time consumption based on length of appointment Treatment by bur and laser were performed at two different treatment sessions In 40/77 laser treatments additional treatment was performed with bur
Hadley et al. 2000 [28] USA	RCT Split mouth Two operators and three blinded evaluators Er,Cr:YSGG LPHKS (I) and bur (C)	68 patients (20–84 years) 75 pairs of teeth I: 75 C: 75 **Dropouts**[a] Three patients at Day 2 and additionally six at 6 months	Caries removal and cavity preparation Patient perception (Likert scale) Treatment adverse effects Restoration serviceability Risk for secondary caries	**Caries removal/ cavity preparation** No difference between groups **Patient perception** Higher no. of patients stated discomfort during and after bur treatment ($P < 0.01$) **Pulpal effects** No difference between groups	**Caries removal/cavity preparation** Medium **Patient perception** Low **Pulpal effects (6 months)** Low **Restoration serviceability (6 months)** Low	Not possible to assess recruitment bias Operators were calibrated regarding laser technique. Single-blind evaluation of caries removal, cavity preparation and patient perception No information about the use of anesthetics, which makes it impossible to evaluate patient comfort Unclear description of results: to what extent were treatments repeated in order to obtain complete caries removal or acceptable cavities?

Table IV. (*Continued*).

Authors, year, reference, country	Study design	No. of patients in intervention and control groups	Aims	Results	Quality assessment	Comments
Keller et al. 1998 [29] Germany	Multicenter RCT (five universities) Crossover design (two matched caries lesions) Er:YAG (I) and bur (C)	103 patients (18–72 years) 206 preparations in 194 teeth I: 97 C: 97 **Dropouts**[a] 13 patients (incomplete scoring records) and 2 patients (cavities involving pulp exposure)	Time consumption Patient perception (simple three-option score) Treatment adverse effects	**Time consumption** Treatment time twice as long with laser ($P < 0.002$) **Patient perception** *Comfort during treatment* Patients preferred laser due to better comfort ($P < 0.002$) *Need/request for anesthetics* I: 6 C: 11 **Pulpal effects** All teeth vital after 1 week (follow-up only of patients who had received anesthetics)	**Time consumption** Medium **Patient perception** Medium **Pulpal effects (1 week)** Low	Not possible to assess recruitment bias Not evident if evaluation of patient perception is based on patients not receiving anesthetics Differences between universities not analyzed
Liu et al. 2006 [30] Taiwan	CT Split mouth One operator Er:YAG (I) and bur (C)	40 patients (3–12 years) 80 preparations (maxillary incisors) I: 40 C: 40 **Dropouts**[a] No follow-up. No dropouts	Time consumption Patient perception and acceptance (pediatric scale)	**Time consumption** Treatment time twice as long with laser ($P < 0.001$) **Patient perception** *No pain* I: 33 C: 7 *Comfort* Higher comfort with laser ($P < 0.001$)	**Time consumption** Medium **Patient perception** Low	Randomization not satisfactory The number of treatments for which patients received anesthetics is not stated

Table IV. (*Continued*).

Authors, year, reference, country	Study design	No. of patients in intervention and control groups	Aims	Results	Quality assessment	Comments
Pelagalli et al. 1997 [31] USA	RCT Er:YAG (I) and bur (C)	60 patients (12–60 years) 106 teeth I: 24 patients, 45 teeth (34 caries removal, 36 cavity preparation) C: 36 patients, 61 teeth (51 caries removal, 64 cavity preparation) Teeth with caries lesions, scheduled for extraction: 1/3 immediate extraction, 1/3 extracted after 48 h and 1/3 after 1 month to 1 year **Dropouts**[a] Dropout rate at follow-up not stated	Caries removal and cavity preparation Time consumption Surface morphology Patient perception (questionnaire) Treatment adverse effects Operator preference	**Caries removal/ cavity preparation** Unclear description **Time consumption** Approximately equal procedural time. Laser was faster in anterior teeth, and bur was faster in occlusal surfaces **Patient perception** No patients treated with laser received anesthetics (most patients treated with bur were given anesthetic) All patients treated with laser preferred laser No abnormal postoperative pain in either treatment group **Pulpal effects** No difference between groups **Operator preference** *Caries removal* No difference *Cavity preparation* Laser less efficient than bur (statistical analysis missing)	**Caries removal/cavity preparation** Low **Time consumption** Low **Patient perception** Low **Pulpal effects** Low	No proper randomization The status of the individual teeth at intervention is not stated Incomplete and insufficient presentation of results. No statistical analysis is performed. Defective descriptive statistics

RCT = randomized controlled trial; CT = controlled trial; I = intervention group; C = control group; VAS = visual analog scale; LPHKS = laser-powered hydrokinetic system.
[a]None of the studies stated the number of patients who were excluded or who declined to participate.

Declaration of interest: The authors report no conflicts of interest. Declarations are available at SBU (The Swedish Council on Health Technology Assessment), PO Box 3657, SE 103 59 Stockholm, Sweden, or via e-mail: info@sbu.se.

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