Clin Oral Invest (2016) 20:65–73
DOI 10.1007/s00784-015-1470-z

ORIGINAL ARTICLE

Caries removal in deciduous teeth using an Er:YAG laser: a randomized split-mouth clinical trial

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Received: 21 November 2014 / Accepted: 3 April 2015 / Published online: 17 April 2015
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Abstract
Objectives The aim of the present clinical randomized split-mouth study was to evaluate the effectiveness and efficiency of an Er:YAG laser for caries removal in primary molars, microbiological dentin analysis, and clinical restorations after 1 year in 29 children.
Materials and methods The children's teeth were randomized into two groups: (I) an Er:YAG laser group and (II) a bur preparation group. The efficiency of the treatments (the time necessary for the removal of carious tissue) was evaluated based on the time spent on caries removal in the deciduous molars. The effectiveness (caries removal capacity) of the caries removal was determined by means of a blind test in which the examiner performed a tactile and visual examination of the dentin. Microbiological analysis was performed by counting the *Streptococcus mutans* and *Lactobacillus sp* in the remaining dentin. Clinical analysis of restorations was performed using the USPHS method in combination with photographs of restored teeth, 7 days after the restorative procedure and again after 1 year. All cavities were restored with the Adper Single Bond 2/Filtek Z350 system. The obtained data were analyzed with a significance level of 5 %.
Results The Er:YAG laser was less effective and had the same efficacy as bur preparation during caries removal at the pulpal wall of deciduous molars. In the surrounding walls, bur preparation was the more effective method. Regardless of the method employed, the affected dentin in the pulpal wall had similar amounts of *S. mutans* and *Lactobacillus sp*. The restorations were clinically accepted by the USPHS method over a 1-year period.
Conclusion It can be concluded that caries removal with an Er:YAG laser has no influence on the clinical behavior of restorations.

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Clinical relevance Irradiation with an Er:YAG laser is appropriate for caries removal in primary teeth.

Keywords Lasers · Dental caries · Deciduous tooth · Effectiveness · Efficiency · Microbiological

Introduction

Partial caries removal [1–3] involves the removal of infected dentin, which is a softened, necrotic, and moist tissue that carries a large amount of bacteria [1, 4–6]. The affected dentin on the pulpal and axial walls is dry and less disordered, with a small number of bacteria. Affected dentin is resistant to removal and is capable of remineralization [1, 6, 7] through the tubular sclerosis process and the deposition of tertiary dentin, thus reducing the permeability of the remaining dentin [5].

This procedure has been successfully performed in primary [2] and permanent teeth [3,5], with the advantage of removing a minimum of the remaining sound tooth structure, avoiding pulpal exposure, preserving the vitality of this tissue, and preventing the progression of lesions [1].

The Er:YAG laser can be used for caries removal, when its wavelength (2.94 μm) coincides with the peak of water absorption and hydroxyl radicals of hydroxyapatite [8]. This promotes the effective ablation of the carious tissue [9] via microexplosions from the evaporation of the water contained in the mineralized tissue [10]. Furthermore, the Er:YAG laser provides a conservative treatment [11] in caries removal because of the high absorption in the humid caries tissue. This allows for conservative caries excavation without extending the preparation into sound tooth structure [12]. Furthermore, it does not generate the noise, pressure, or vibration of conventional rotary devices [8, 11, 13], making dental treatment much less traumatic, especially for children.

Patients have been shown to have a reduced perception of pain during laser treatment [13] and thus require less local infiltrative anesthesia [8, 14]. Laser treatment is thus often preferred over bur preparation by patients [15–17].

The Er:YAG laser, with its bactericidal effect [18], can be employed in caries removal. Its thermal effects promote the collapse of bacterial cell structures followed by physical microexplosion [19], reducing the amount of bacteria via the ablation and vaporization of intertubular and peritubular dentin, exposing dentinal tubules, without affecting the surrounding tissues [20].

To date, there are no studies that evaluate the effectiveness of the Er:YAG laser for caries removal in deciduous teeth and for the longevity of the restorations performed in these cavities.

The aim of the present clinical randomized study (split-mouth) was to evaluate the efficiency [13, 21] of the Er:YAG laser according to the time needed for caries removal in deciduous molars. The effectiveness [13, 21] of the Er:YAG laser in caries removal was evaluated by means of a blind test in which the examiner performed a tactile and visual examination of the dentin in deciduous molars. Microbiological analysis was completed by counting *Lactobacillus sp* and *Streptococcus mutans* in the remaining dentin. Clinical and photographic restorations were evaluated based on modified USPHS criteria along with photographs of the restored deciduous molars after 7 days (baseline) and 1 year after the completion of the restorations.

The null hypotheses to be tested were (1) that caries removal using the Er:YAG laser is of similar effectiveness and efficiency as bur preparation, (2) that the remaining dentin has the same number of microorganisms, and (3) that the clinical longevity of the restorations after 1 year is similar between the two methods of caries removal.

Materials and methods

Experimental design

The study factor method was employed for caries removal using (I) the Er:YAG laser (250 mJ/4 Hz) and (II) bur preparation (low speed turbine-control). The experimental samples for the randomized split-mouth clinical study consisted of 42 children (n=42) and 84 counterpart primary molars with active carious lesions and cavitation reaching the dentin, located at the occlusal surface (class I). Twenty-nine children were evaluated 1 year after the restorative procedure. The experimental design used a randomized complete block, and the response variables used to test the efficiency of the caries removal were evaluated by means of the time needed for the procedure, the effectiveness of the partial caries as assessed by visual and tactile information, microbiological analysis by counting *Lactobacillus sp* and *S. mutans* and clinical (modified USPHS method) and photographic analyses of the restorations.

Ethical aspects

The present study was approved by the Committee of Ethics in Research at the Ribeirão Preto School of Dentistry – USP (2010.1.159.58.3). The children's parents or guardians were informed about the purpose of the study and signed the Terms of Consent agreeing to participate in the research.

The sample size calculation was based on the amount of children examined over a 9 month period at the Pediatric Dental Clinic (2100 children/9 months, all of whom met the inclusion criteria for this research). The confidence level was estimated to 95 % with an error of 5 %, representing 1.0 % of the population of Ribeirão Preto, São Paulo, Brazil. This analysis included 33 children. The calculation of n real

samples included 29 children. Thus, after the sample calculation, the sample was established in $n=29$ children for the present research.

Two thousand and one hundred children of both genders and between the ages of 6 and 10 were examined. Of these, 42 (22 boys and 20 girls) met the inclusion criteria and were accepted to take part in the study.

The CONSORT guide [22] for randomized clinical trials was followed for the study design. Figure 1 represents the CONSORT diagram, which discriminates in detail the recruitment form, allocation, monitoring, and analysis of the research subjects. During the monitoring period, 11 children were lost to follow-up, leaving a total of $n=29$ participants (13 girls and 16 boys) for the final analysis.

Clinical examinations were performed under adequate illumination, followed by standardized radiographic examination with bitewing radiographs, using positioned (Jon, São Paulo, SP, Brazil) radiographic film #2 (Kodak, New York, NY, USA), with an exposure of 50 kV, 10 mA, and 0.6 s (Spectro 70X, Dabi Atlante, Ribeirão Preto, SP, Brazil). The radiograph processing was performed automatically (A/T2000 XR, Air Techniques, Melville, New York, NY, USA).

The inclusion criterion for the children included the presence of at least two active carious lesions into the dentin that were located on the occlusal surfaces (class I) of contralateral deciduous molars, with vital pulps and no sealants, amalgam, glass ionomer cement, or composite resin restorations. The selected teeth all had positive responses to the thermal pulp test performed with Endofrost (Roeko, Langenau, Germany).

Children were excluded if they clinically presented tooth pain, spontaneous sensitivity, fistulas, swelling, or mobility not compatible with the root rizolisis stage or if they radiographically presented with furcal or periapical radiolucencies, increased periodontal space or internal/external dental reabsorption.

Caries removal

Subject randomization was conducted using a computer spreadsheet. With the aid of a random number generator available at http://randomnumbergenerator.intemodino.com/pt/, the selected children had their names numbered to order their treatment. Teeth were randomly assigned to the experimental group (Er:YAG laser) or the control group (bur preparation) by coin toss. The different methods of caries removal were performed in separate sessions.

The operative field was isolated with a rubber dam (Madeitex, São José dos Campos, SP, Brazil) using clamps #207, #209, or #26 (Duflex, SSWhite, Juiz de Fora, MG, Brazil) depending on the dental morphology of each deciduous molar. After absolute isolation was achieved, the caries removal was performed with the Er:YAG laser on the deciduous molar of one hemiarch and with bur preparation (using a low-speed turbine) of the contralateral deciduous molar.

In the experimental group, the access to the carious lesion (removal of the cavosurface enamel) and the caries removal was completed with the Er:YAG laser (Fidelis Er III, Fotona, Ljubljana, Slovenia) in the MSP mode, using a pen (R02), at the noncontact mode with focal distance of 7 mm, a pulse energy of 250 mJ, a pulse frequency of 4 Hz [14], an output beam diameter of 0.9 mm, an energy density of 39 J/cm^2, and under water spray (6 mL/min). Both the patient and the operator wore protective glasses during the laser treatment. Treatment took place in a room specifically prepared for this type of treatment, in accordance with the general guidelines for safe laser application.

In the control group, the caries removal was performed using spherical carbide drills #½, #1, and #2 (KG Sorensen, Barueri, SP, Brazil), which were compatible with the cavity size, mounted in low-speed turbines (Dabi Atlante, Ribeirão Preto, SP, Brazil). When necessary, access to the carious lesion (removal of the cavosurface enamel) was performed using spherical diamond burs #1012 and #1014 (KG Sorensen, Barueri, SP, Brazil), which were also compatible with the cavity and which were mounted in high-speed turbines (Dabi Atlante, Ribeirão Preto, SP, Brazil).

Caries removal was initiated in the superficial layer of infected dentin from the surrounding walls of deciduous molars using either the Er:YAG laser or bur preparation. The affected dentin, which is hardened, dry, resistant to curettage, and susceptible to remineralization, was left in the pulpal wall [1, 3, 5]. It was checked with a probe and evaluated based on clinical criteria of consistency and texture [4]. Only the incomplete removal of the carious tissue from the surrounding walls was verified according to the clinical hardness criteria [6]. Curettes #11, #11½, and #12 (Duflex, SSWhite, Juiz de Fora, MG, Brazil), were used to supplement the total removal, whenever necessary for both groups.

Efficiency evaluation

The treatment efficiency of the control and experimental groups was evaluated according to the time required for caries removal in the deciduous molars. The infected dentin was completely removed from the surrounding walls, and the affected dentin present in the pulpal wall was preserved [6]. A precision digital timer (CD-2800, Instrutherm Measure Instruments Ltda, São Paulo, SP, Brazil) was triggered from the first pulse emitted by the laser or from the first contact of the drill with the dental surface. The timer was paused when the operator signaled that caries removal was finished. All teeth were prepared and restored by the same operator, with the presence of an auxiliary.

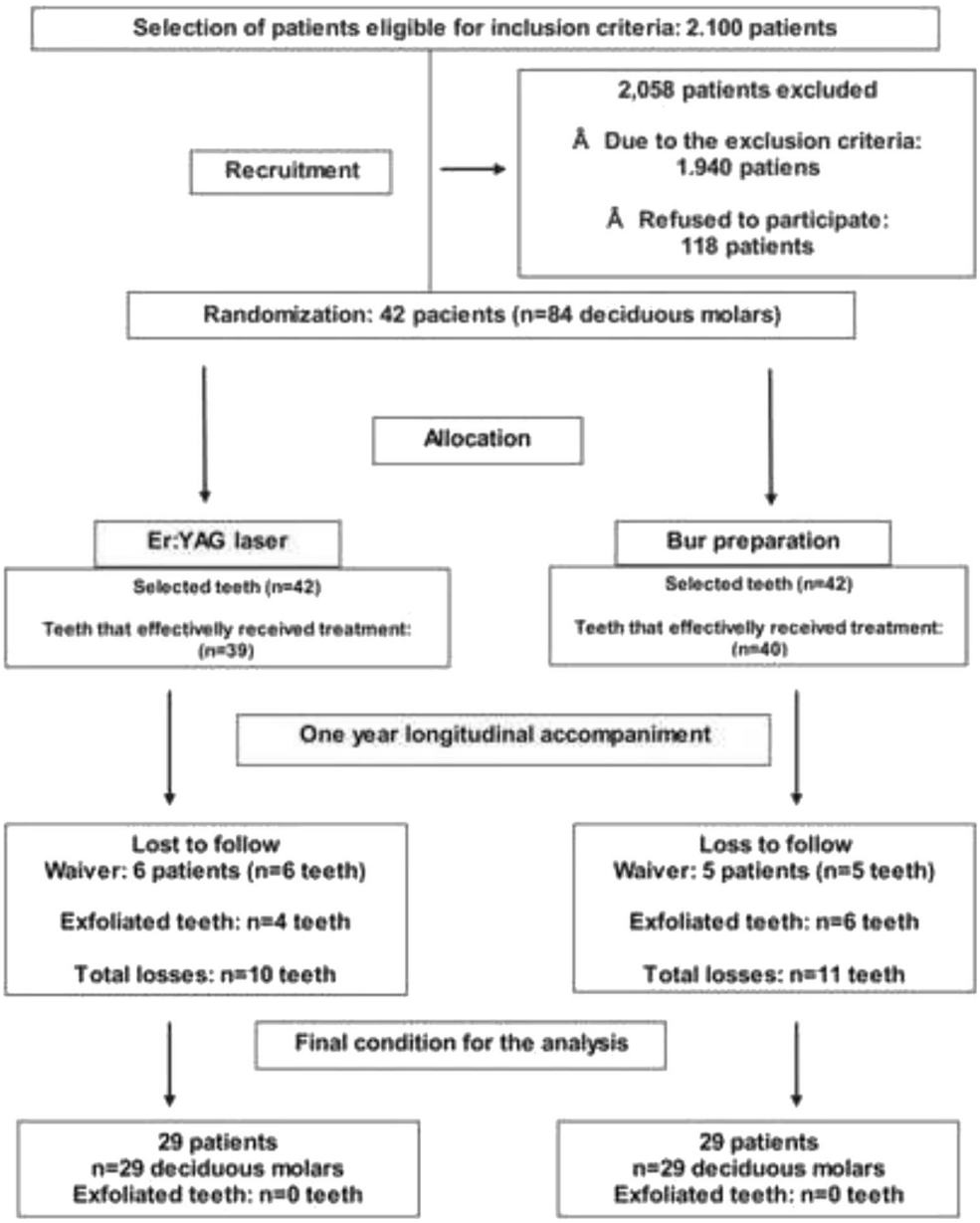

Fig. 1 CONSORT schematic explaining the recruitment, allocation, accompaniment, and analysis of the research subjects

Effectiveness evaluation

To evaluate the effectiveness of the procedures, the examiner was trained. To determine the effectiveness of the caries removal, one examiner, who was blinded to which method was employed, performed a tactile and visual examination. During the tactile and visual examination, a blunt instrument with an active tip was used to evaluate the caries removal from the surrounding walls according to the hardness clinical criteria [6] and at the pulpal wall following the clinical criteria for consistency and texture [4]. The examiner scored the tissue as either A (infected dentin) or B (affected dentin).

Microbiological evaluation

Immediately after caries removal by the Er:YAG laser or bur preparation, the remaining dentin was collected with sterile curettes #11, #11½, and #12 (Duflex, SSWhite, Juiz de Fora, MG, Brazil) for microbiological analyses. Thus, at least 5 mg of the remaining dentin was weighed to ±0.01 mg (Analytical Plus AP 250D, Ohaus Corp., Florham Park, NJ, USA) in sterile microcentrifuge tubes, suspended in 1 mL of 0.9 % NaCl solution and sonicated at an amplitude of 20 % for 15 s using a sonic dismembrator (CL-334 Digital Fischer Scientific Sonicator, Park Lane, Pittsburgh, USA). From this suspension, an aliquot of 50 μL of the sonicated suspension was

Fig. 2 Caries removal and restorations after bur preparation (A) or Er:YAG laser preparation (B). *A1*, active carious lesion on the occlusal surface of a deciduous molar, with cavitation reaching the dentin; *A2*, the preparation after caries removal with the bur; *A3*, the restoration before the removal of absolute isolation to check the occlusal contacts; *B1*, active carious lesion with cavitation reaching the dentin located on the occlusal surface of a deciduous molar; *B2*, the preparation after caries removal with the Er:YAG laser; *B3*, the restoration before the removal of absolute isolation to check the occlusal contacts

diluted in 0.9 % NaCl, and serial decimal dilutions were inoculated in duplicate using the drop-counting technique in the following culture media: mitis salivarius agar plus 0.2 units bacitracin per milliliter and 15 % sucrose (MSB) for the mutans streptococci group [23] and Rogosa SL agar for the lactobacillus group. The plates were incubated in 10 % CO_2 at 37 °C for 48 h. The colony-forming units (CFUs) were counted, and the results are expressed as CFU/mg remaining dentin.

Restorative treatment

Depending on the depth of the carious lesion, an indirect pulp cap was performed. For deep cavities, calcium hydroxide cement (Dycal, Dentsply Caulk, Milford, DE, USA) was used, followed by glass ionomer cement (Ketac Molar; 3 M ESPE Seefeld, Schleswig-Holstein, Germany). In medium cavities, only glass ionomer cement (Ketac Molar; 3 M ESPE, Seefeld, Schleswig-Holstein, Germany) was used.

The cavity was conditioned with 37 % phosphoric acid gel for 15 s for enamel and 7 s for dentin [24] and washed with water for 1 min. The Adper Single Bond 2 adhesive system (3 M ESPE, Saint Paul, MN, USA) was applied in two layers with a disposable applicator (KGBrush, KG Sorensen, Cotia, SP, Brazil) and light cured (Ultralux (750 mW/cm^2), Dabi Atlante, Ribeirão Preto, SP, Brazil) following the manufacturer's instructions.

To the restoration, the composite resin Filtek Z350 (3M ESPE, Saint Paul, MN, USA) was applied in small increments and light cured for 20 s, returning the anatomical shape to the teeth.

After the restoration was complete, the isolation was removed and occlusal adjustment was performed with carbon paper (AccuFilm, Parkell, Farmingdale, NY, USA) and diamond finishing burs (KG Sorensen, Cotia, SP, Brazil). The children returned after 7 days for the final polishing of the restorations with abrasive tips (Enhance, Dentsply Caulk, Milford, DE, USA) mounted in a low-speed turbine (Dabi Atlante, Ribeirão Preto, SP, Brazil).

Figure 2 shows the images of the caries removal and the resulting restoration after either bur preparation (A) or the Er:YAG laser (B).

Clinical and photographic evaluation of the restorations

The restored teeth were carefully evaluated by means of clinical and photographic analysis at two time points: 7 days after the restorative procedure (baseline) and 1 year after the restorative procedure. The clinical analysis was performed by one examiner (blind test) by means of visual and tactile examination with a blunt instrument with an active tip, according to the modified USPHS criteria [25]. These criteria require the analysis of retention, marginal discoloration, secondary caries, and marginal adaptation. The restorations were classified into three categories: *Alpha*-when the evaluated criteria did not present problems and the restoration was in perfect condition; *Bravo*-when the evaluated criteria included small failures, but the restorations were still clinically acceptable; and *Charlie*-when the evaluated criteria included relevant failures, such that the restorations needed to be replaced. The examiner indicated one of these scores for each clinical criterion investigated (Table 1).

Standardized photographs of the restored teeth were taken by an experienced professional with a digital camera (Canon EOS Rebel T2i 18.0 Megapixels, Canon, Tokyo, Japan), with a macrolens of 100 mm and a circular flash (Canon Macro Ring Lite MR-14EX, Canon, Tokyo, Japan). The photographic quality was fixed in JPEG FINE to be 12.0 megapixels. The

Table 1 Modified USPHS criteria employed during the evaluation of restorations

Category	Score	Criteria
Retention	Alpha	Without loss of restorative material
	Charlie	With loss of restorative material
Marginal discoloration	Alpha	Without marginal discoloration
	Bravo	Slight marginal discoloration, without axial penetration
	Charlie	Marginal discoloration with axial penetration
Secondary caries	Alpha	No recurrence of caries
	Charlie	With recurrence of caries
Marginal adaptation	Alpha	Perfectly adapted, without visible edges
	Bravo	Visible edge, but clinically acceptable
	Charlie	Marginal leakage, clinical failure

camera was handled in the manual mode ISO 200, F-22, with a speed of 100 and RGB color space. Each photo was evaluated for acceptability and quality, and if it was not acceptable, the photograph was retaken. The same examiner who performed the clinical analyses verified the photographs from the restored teeth in a flat panel display and could compare the data obtained from the clinical analyses with the photographs to reach an accurate result.

Statistical analysis

The experimental data on the efficiency and effectiveness were statistically evaluated by a *t* test (parametric), with a significance level of 5 %. The Mann-Whitney test, with a significance level of 5 %, was employed for the microbiological analysis of the remaining dentin after caries removal. The Kruskal-Wallis test ($p \leq 0.05$) was used on the values from the evaluation after 7 days and after 1 year to assess the following parameters for the laser - and bur - prepared specimens: retention, marginal discoloration, secondary caries, and marginal adaptation. Statistical analysis was performed using SPSS software for Windows, version 12.0 (SPSS Inc., Chicago, IL, USA).

Results

The results showed that the efficiency (in seconds) of the Er:YAG laser for caries removal in deciduous molars was statistically lower ($p=0.019$) than that for bur preparation, as shown in Table 2.

Table 2 Efficiency of caries removal after Er:YAG laser/bur preparation (in seconds)

Methods	Number	Mean	Std. error mean
Er:YAG laser	29	110.24	9.83
Bur preparation	29	54.96	5.64

t Test, $p=0.019$

The results showed that the effectiveness of the caries removal, as measured from the pulpal wall of deciduous molars, was similar between the two groups ($p=0.05$).

For caries removal in the surrounding walls, the results showed that the bur preparation method was more effective ($p=0.0001$). Necrotic tissue was observed in 11 samples after Er:YAG laser irradiation.

The counts of *mutans streptococci* and *lactobacilli* in the remaining dentin collected after preparation did not differ ($p<0.05$) between the two treatments (Table 3).

The clinical and photographic analysis of the restorations were performed at two time points: 7 days after the restorative procedure (baseline) and 1 year after the treatment; the results demonstrated that there were no statistically significant differences between the restorations placed after caries removal with the Er:YAG laser or the bur, as evaluated according to USPHS criteria. These criteria included retention, marginal discoloration, secondary caries, and marginal adaptation ($p \leq 0.05$) (Chart 1).

Discussion

The null hypothesis was rejected for the response variable efficiency. The results from this study demonstrated that the efficiency of the Er:YAG laser for caries removal in deciduous teeth is lower than conventional bur preparation.

These results may be due to the decreased tactile sensitivity with the Er:YAG laser, making the preparation more difficult, especially for posterior teeth, as treatment must be interrupted in order for the operator to continually verify the presence of remaining infected dentin with curettes. For conventional bur preparation, the operator knows when to stop treatment based on haptic feedback.

A previous clinical study [14] described a longer working time when the Er:YAG laser was employed, leading to minimal discomfort [8] compared to the bur preparation in deciduous teeth. However, the technique for the total removal of

Table 3 The amount of microorganisms remaining in the cavities after caries removal with Er:YAG laser/bur preparation (mean±SD; $n=13$)

Method	Mutans streptococci (CFU/mg remaining dentine×10^3)	Lactobacilli (CFU/mg remaining dentine×10^3)
Er:YAG laser	3.6±10.8[a]	2.5±7.6a
Bur preparation	2.1±3.3[a]	4.0±7.4a

Within columns, distinct letters indicate significant differences among treatment/groups ($p<0.05$)

carious lesions and the cavities were not standardized. Similar working times were observed for the Er:YAG laser and bur preparation by DenBesten et al. [11] for a sample set containing both deciduous and permanent teeth. Other studies, using only permanent teeth, found similar results in in vitro [21] and in vivo samples [15, 16]. However, it is difficult to compare the results from the present study with those that exist in the literature because no previous study mentions as the caries removal was performed.

The null hypothesis was rejected for the response variable effectiveness. The Er:YAG laser does not curve, so it was difficult to remove all of the carious tissues from the surrounding walls. In the present study, we sought to maintain the cavosuperficial angle to perform minimally invasive dentistry [13] and preserve unsupported enamel. Thus, 11 samples still had necrotic tissue in the surrounding walls after the use of the Er:YAG laser, as determined using sharp curettes. The complete removal of carious dentin from the surrounding walls [2–4, 6] is essential to achieve a perfect hermetic seal between the restorative material and the dental substrate, aiming to reduce the supply of exogenous nutrients in the cavities [26]. Regarding effectiveness, it is difficult to compare the results between the published studies, as the effectiveness of lasers depends on complex interactions between the wavelength, pulse duration, frequency and energy and on the hardness of the dental substrate [16]. These procedures are also operator dependent, so there is no way to ensure that only infected tissue is removed, as the dentin hardness can be related to its depth [3]. The results presented in our study demonstrate that the Er:YAG laser has the same capacity to remove infected dentin from the pulpal wall as drills mounted in low-speed turbines. No statistically significant differences in the complete excavation of carious lesion were found in a study by Bohari et al. [13] in which they used 245 round bur in a high-speed air turbine hand piece compared to the Er:YAG laser in deciduous teeth. In permanent teeth, Dommisch et al. [15] verified the total removal of carious tissue by visual and tactile examination and found no statistically significant differences between the use of the Er:YAG laser and a conventional bur. In the study of Schwass et al. [27], the Er:YAG laser irradiation resulted in complete removal of demineralized tissue and some sound enamel was removed to provide access to depths of the lesion. A comparison of our results with those described in the literature is difficult because no prior studies have described how the carious dentin was completely removed from the surrounding walls and how caries removal was standardized.

The null hypothesis was accepted for the response variables of clinical and photographic restoration evaluation. The results from this study showed no statistically significant differences between the restorations placed following bur preparation and those placed following Er:YAG laser preparation in deciduous molars, as assessed by the USPHS method proposed by Cvar and Ryge [25] and careful photographic analysis of restorations after a 1- year period.

This positive result may be due to the ability of the Er:YAG laser to increase the resistance of enamel to acid demineralization and to reduce acid dissolution, thus preventing the occurrence of secondary caries [28]. The laser also produces physical changes, such as melting and recrystallization with pores, which creates a coarse surface that provides a micromechanical bond for adhesives [29]. The increase in

Chart 1 Clinical and photographic analysis of the restorations using modified USPHS criteria

Methods	Retention			Marginal discoloration			Secondary caries			Marginal adaptation		
	A	B	C	A	B	C	A	B	C	A	B	C
Bur preparation												
Baseline	29 (100 %)	0 (0 %)	0 (0 %)	29 (100 %)	0 (0 %)	0 (0 %)	29 (100 %)	0 (0 %)	0 (0 %)	29 (100 %)	0 (0 %)	0 (0 %)
1 year	29 (100 %)	0 (0 %)	0 (0 %)	29 (100 %)	0 (0 %)	0 (0 %)	29 (100 %)	0 (0 %)	0 (0 %)	28 (96.5 %)	1 (3.5 %)	0 (0 %)
Er:YAG laser												
Baseline	29 (100 %)	0 (0 %)	0 (0 %)	29 (100 %)	0 (0 %)	0 (0 %)	29 (100 %)	0 (0 %)	0 (0 %)	29 (100 %)	0 (0 %)	0 (0 %)
1 year	29 (100 %)	0 (0 %)	0 (0 %)	28 (96.5 %)	1 (3.5 %)	0 (0 %)	29 (100 %)	0 (0 %)	0 (0 %)	27 (93 %)	1 (3.5 %)	1 (3.5 %)

the bond strength in both caries-affected and sound dentin in primary molars following Er:YAG laser preparation was verified by Koyuturk et al. [30], and no significant difference was identified between the laser and bur-prepared cavities using self-etch primers in primary canine teeth [31]. Furthermore, the Er:YAG laser's bond strength was found to be similar to that following bur preparation [32]. In the present study, no restorative material was lost in follow-up, as clinically evaluated by the USPHS criteria and photographic analysis.

This study verified that the difficulty in the complete caries removal from the surrounding walls of cavities prepared with Er:YAG lasers can be overcome with curettes. This finding suggests that curettes must always be used after the removal of carious lesions with Er:YAG lasers to allow for an enhanced sealing of the adhesive interface.

Clinical and photographic analyses are useful and necessary tools for the evaluation of the quality of restorations. Photographic analysis shows an increase in the restoration defects compared to those clinically and visually observed according to the USPHS method [33]. The results from this study are in agreement with Yazici et al. [34] who compared occlusal restorations using the USPHS method after the removal of carious lesions using either a conventional bur or an Er,Cr:YSGG laser.

The null hypothesis was accepted for the response variable microbiological evaluation. Although the methods employed for caries removal could not completely eliminate the viable microorganisms, the amount of remaining bacteria was clinically irrelevant [15]. The Er:YAG laser reduced the number of *S. mutans* and *Lactobacillus sp* to a similar level as the bur preparation. These results are likely due to the Er:YAG laser's ablation ability on moist surfaces such as infected dentin [27], which contains a greater number of microorganisms than the remaining affected dentin [7]. However, Bönecker et al. [35] observed no differences between the dentin's consistency and the level of bacterial colonization. Other changes observed in the dentin during caries removal, such as changes in the color and hardness, may not interfere with the level of bacterial viability [5, 36, 37].

The increased temperature during the ablation of the dentin can modify the cell structure [19] of gram-positive bacteria, such as *S. mutans* and *Lactobacillus sp* [38], which have resistant cell structures that hamper their elimination [39]. Due to the thermal effects, the Er:YAG laser reduces bacterial viability [18] but does not damage the remaining dental structure [20,40].

Here, the presence of *S. mutans* and *Lactobacillus sp* was analyzed, as they are associated dental caries [37]. Microbiological evaluation of carious dentin during caries removal is not feasible during routine clinical practice, and clinical parameters like hardness, moisture, and color [37] are typically used to distinguish infected and affected dentin.

Conclusion

It can be concluded from this study that bur preparation (using drills with low-speed rotations) is more efficient for caries removal in primary teeth. Both the Er:YAG laser and the bur preparation methods were effective for caries removal from the pulpal wall; however, for the surrounding walls, the bur preparation was found to be more effective. The amount of *S. mutans* and *Lactobacillus sp* found on the affected dentin in the pulpal walls was similar after caries removal by both methods. The restorations placed after the caries removal using either the bur preparation or the Er:YAG laser were clinically acceptable according to USPHS criteria and photographic assessment after a 1- year period.

Acknowledgments This study was supported by FAPESP (2011/00272-5). The author thanks CAPES for the PhD support. The funders had no role in the study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Conflict of interest The authors declare that they have no conflicts of interest.

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