Clinical Assessment of Er,Cr:YSGG Laser Application for Cavity Preparation

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ABSTRACT

In this study, an erbium, chromium:YSGG (Er,Cr:YSGG) laser emitting at a wavelength of 2.78 μm was clinically applied to remove caries and prepare cavities, and the clinical outcome was evaluated. Effective clinical application of Er,Cr:YSGG laser had been expected from previous studies. This study included 44 patients (26 females, 18 males; aged 23–58) with a total of 50 cavity preparations by the Er,Cr:YSGG laser irradiation at 3–6 W with water spray. Patient acceptance and prognosis were evaluated. Most cases (94%) were prepared without anesthesia, and no pain was felt in 34 cases (68%). No adverse reaction was observed in any of the cases, and patient acceptance for this system was favorable. All cases had a good prognosis. In 45 cases (90%), overall clinical evaluation was satisfactory. From the present study, it can be concluded that the Er,Cr:YSGG laser system is an efficient, effective, and safe device for caries removal and cavity preparation.

INTRODUCTION

Clinical applications of various lasers in dental hard tissue treatments (such as caries removal and cavity preparation for restorations) have led to increasing interest by both practitioners and researchers. Goldman et al. first demonstrated that it was possible to remove caries with the ruby laser in vitro. The effects of argon, Nd:YAG, and CO₂ lasers on caries removal were also investigated. However, these lasers caused major thermal side effects such as melting, cracking of enamel or dentin, and pulpal damage. Their efficiency for cavity preparation has not yet been proven to be clinically applicable.

Recently, effective ablation of dental hard tissues by Er:YAG laser irradiation has been introduced. Scanning electron microscopic (SEM) findings showed that cut surfaces are clean, with minimal debris and smear layer. The clinical outcome showed that there is no complication and no tooth is compromised. The erbium, chromium:YSGG (Er,Cr:YSGG) laser has been shown to be effective for cutting enamel, dentin, and bone. The Er:YAG and Er,Cr:YSGG lasers are similar in all aspects except for their wavelength. They are both capable of cutting hard tissues, and the morphological effects of Er,Cr:YSGG laser irradiation are also similar to those reported for Er:YAG laser irradiation. Before human trials of Er,Cr: YSGG laser irradiation, safety issues and pulpal effects must be evaluated in animal models and in vitro. It has been reported that temperature increases at pulp chamber by Er,Cr:YSGG laser irradiation for cavity preparation are lower compared to those of a conventional bur method. There is apparently no thermal effect on application of this laser to clinical cases, and applications to caries removal and cavity preparation have been expected in the dental clinic, though there have been no published reports to date.

In the present study, an Er,Cr:YSGG laser was clinically applied to remove caries and prepare class I–V cavities and the clinical outcome was evaluated.

MATERIALS AND METHODS

Subjects

This study included 44 patients (26 females, 18 males; aged 23–58 years), with a total of 50 preparations. Prior to the experiments, the experimental protocol and possible side effects were explained to the patients and their informed consent was obtained. Table 1 shows the tooth classification used for cavity preparation.

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Cavity preparation system

An Er,Cr:YSGG laser (Millennium; Biolase Technology Inc., San Clemente, CA) was used for cavity preparation. This laser system emitted photons at a wavelength of 2.78 μm, and pulsed with a duration of 140–200 μs and a repetition rate of 20 Hz. The output power could be varied from 0 to 6 W. The beam spot area was 0.442 mm² with the use of a 750-μm-diameter fiber at a distance of 2–3 mm.

A laser beam was used to remove caries and prepare cavities with output powers ranging from 3 to 6 W using the Er,Cr:YSGG laser with water spray according to the manufacturer’s instructions. During laser irradiation, the operators and assistants wore protective eye glasses. After cavity preparation, all cavities were filled with composite resin (Silux; 3M, St. Paul, MN).

Evaluation criteria

The evaluation criteria in the experiments ranged from dental history and examination of the affected teeth, to laser irradiation conditions, cavity shape and depth, presence or absence of fillings, time taken to remove them, time taken for cavity preparation, and severity of induction pain that occurred then (1, no pain was felt at all; 2, slight pain was felt; 3, pain was felt, but not intolerable; 4, intolerable pain was felt), extent of discomfort felt during procedures (1, did not feel discomfort at all; 2, machine noise was a little uncomfortable; 3, machine noise was uncomfortable but not intolerable; 4, machine noise was uncomfortable and intolerable), presence or absence of pulp capping, type and method of filling, and status of cavity preparation completion (1, completed with this system alone; 2, other therapy was combined). Use or nonuse of local anesthesia was also recorded.

Prognosis observation

In principle, clinical findings at 7 and 30 days after laser preparation were examined. Examination criteria were induction pain (1, none; 2, mild; 3, moderate; 4, severe), thermal test (1, none; 2, mild; 3, moderate; 4, severe), electric test (1, negative; 2, positive), percussion (1, negative; 2, positive), loss of filling, and presence or absence of discoloration. These were examined and recorded. Photography was performed in some cases. All adverse reactions were also recorded.

Assessment during cavity preparation

Assessment during cavity preparation was determined by giving scores as follows:

- Pain during procedure: 1, felt no pain at all (10 points); 2, felt slight pain (6 points); 3, felt pain but was not intolerable (1 point); 4, felt intolerable pain (0 point)
- Induction pain: 1, none (10 points); 2, mild (3 points); 3, moderate (1 point); 4, severe (0 point)
- Thermal test: 1, none (10 points); 2, mild (3 points); 3, moderate (1 point); 4, severe (0 point)
- Electric test: presence of reaction (10 points), absence of reaction (−10 points)
- Percussion: 1, none (10 points); 2, mild (3 points); 3, moderate (1 point); 4, severe (0 point)
- Completion of cavity formation: 1, completed with this system alone (10 points); 2, completed with combination of other methods (0 point)
- Use or nonuse of local anesthesia: 1, cavity preparation finished without anesthesia (10 points); 2, cavity preparation finished with combination of local anesthesia (0 point)

A total score exceeding 32 points was considered a good result and less than 31 points considered a poor outcome.

Prognostic factors

Prognostic factors were also determined and scored as follows:

- Induction pain: 1, none (10 points); 2, mild (3 points); 3, moderate (1 point); 4, severe (0 point)
- Thermal test: 1, none (10 points); 2, mild (3 points); 3, moderate (1 point); 4, severe (0 point)
- Electric test: presence of reaction (10 points), absence of reaction (−10 points)
- Percussion: 1, none (10 points); 2, mild (3 points); 3, moderate (1 point); 4, severe (0 point)

A total score exceeding 32 points was considered good and less than 31 points considered poor.

Overall assessment of efficacy

Overall assessment of efficacy was considered (a) very good if assessment during cavity preparation and prognostic factors at both approximately 7 and 30 days after treatment, were good; (b) good if assessment during cavity preparation was good, but prognostic factor at approximately 7 or 30 days later was poor; or (c) poor if assessment during cavity preparation was good, but prognostic factors at both approximately 7 and 30 days later were poor, or if prognostic factors at both approximately 7 and 30 days later were good but assessment during cavity preparation was poor.

Safety assessment

Absence of adverse reactions such as systemic/localized allergy and shock was designated as "safe." presence of an adverse reaction requiring no treatment was designated "problematic with safety," and presence of an adverse reaction requiring treatment was designated "unsafe."

Overall clinical evaluation

Overall clinical or final evaluation of the system was determined on the basis of results of overall evaluation of efficacy and safety. Very good and safe ratings were considered very satisfactory, good and safe ratings were determined satisfactory, and very good or good ratings with safety problems were considered unsatisfactory. Of course, poor ratings were determined unsatisfactory in all cases.
Clinical Assessment of Er,Cr: YSGG Laser

RESULTS

Cavity preparations by the Er,Cr:YSGG laser irradiation were investigated in 50 teeth of 44 patients aged 23-58 years, and the results of the clinical evaluation are shown in Table 2. No adverse reactions such as systemic/localized allergy were observed in any of the cases. Regarding intraoperative pain assessment, no pain at all was felt in 34 cases (68%). However, slight pain was felt in 11 cases (22%); in two cases (4%), pain was tolerable; and in three cases (6%), pain was intolerable to the patients. Regarding intraoperative discomfort, 42 of 50 cases (84%) felt no discomfort at all, and in eight cases (16%), machined noise was slightly uncomfortable. During the assessment of cavity preparation completion, it was found that cavity preparation was completed with the laser system alone in 47/50 cases (94%). However, additional anesthesia was necessary in 3/50 cases (6%).

Based on prognostic factors, laser treatment was determined “good” in all of the 50 cases, because all cases scored more than 40 points. Overall assessment of the efficacy shows that cavity preparation was “good” in 45/50 cases (90%) and “poor” in five cases (10%). Results of the overall clinical evaluation show that cavity preparation was very satisfactory in 45 cases (90%) since safety assessment was good in all of these cases among the 50 cases. On the other hand, the assessment was determined unsatisfactory in five cases (10%). Mild or moderate wedge-shaped defects (WSD) and dentin exposures of 18 teeth were observed macroscopically. Among the 50 cases of test teeth, complaints of cervical dentin hypersensitivity were recorded in 10 cases. Induction pain was reported as “severe and intolerable” in three cases, as “moderate” in two cases, and as “mild” in five cases. The time taken for cavity preparation was related to the cavity size as follows: class I, 10-15 min (n = 3); class II, 13-20 min (n = 2); class III, 1-3 min (n = 3); class IV, 2-5 min (n = 3); and class V, 30 sec to 3 min (n = 39).

Figures 1 show the cavity preparation at the maxillary left second molar having C2 caries before treatment (mirror view) and after cavity preparation by the Er,Cr:YSGG laser irradiation at 6 W and 20 Hz (mirror view). The patient did not complain of pain during the cavity preparation with this procedure. Figure 2 shows the cavity preparation at the mandibular right second molar having C2 caries before treatment and after cavity preparation by the Er,Cr:YSGG laser irradiation at 6 W and 20 Hz. The patient complained of some pain with this technique.

DISCUSSION

Effective ablation of carious enamel or dentin, and cavity preparation by means of the Er,Cr:YSGG laser system have

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TABLE 2. CLINICAL RESULTS IN THIS STUDY

<table>
<thead>
<tr>
<th>Items</th>
<th>Cases (n = 50)</th>
<th>Percentage</th>
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</thead>
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<tr>
<td>Safety assessment</td>
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<td></td>
</tr>
<tr>
<td>Safe</td>
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<tr>
<td>Problematic with safety</td>
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<td>0%</td>
</tr>
<tr>
<td>Unsafe</td>
<td>0</td>
<td>0%</td>
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<tr>
<td>Intraoperative pain</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No pain</td>
<td>34</td>
<td>68%</td>
</tr>
<tr>
<td>Slight pain</td>
<td>11</td>
<td>22%</td>
</tr>
<tr>
<td>Tolerable pain</td>
<td>2</td>
<td>4%</td>
</tr>
<tr>
<td>Intolerable pain</td>
<td>3</td>
<td>6%</td>
</tr>
<tr>
<td>Intraoperative discomfort</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No discomfort</td>
<td>42</td>
<td>84%</td>
</tr>
<tr>
<td>Uncomfortable</td>
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<tr>
<td>Necessity of anesthesia</td>
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<tr>
<td>Use laser only</td>
<td>47</td>
<td>94%</td>
</tr>
<tr>
<td>Additional anesthesia</td>
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<td>6%</td>
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<tr>
<td>Prognostic factor</td>
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<td>Overall clinical evaluation</td>
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<td>Very useful</td>
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</tr>
<tr>
<td>Unuseful</td>
<td>5</td>
<td>10%</td>
</tr>
</tbody>
</table>

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FIG. 1. Photographs of class I cavity preparation at the maxillary left second molar of a 24-year-old woman before treatment view (mirror view; A) and after cavity preparation at 6 W and 20 Hz (mirror view; B). The time taken for preparation was approximately 15 min. Patient complained no pain during the cavity preparation with this procedure.
FIG. 2. Photographs of class V cavity preparation at the mandibular right second molar of a 36-year-old man before treatment view (A) and after cavity preparation at 6 W and 20 Hz (B). The time taken for preparation was approximately 50 sec. Patient complained of some pain with this technique. 

been reported, and its clinical application has been anticipated. However, to be considered clinically effective, several considerations must be taken into account. The patient acceptance and thermal side effects during cavity preparation are important factors to consider. In the present study, cavity preparations by the Er, Cr:YSGG laser irradiation were investigated and their clinical outcome was evaluated.

Test teeth

In the present clinical study, cavity preparations by the Er,Cr:YSGG laser irradiation that involved class I (three teeth), class II (two teeth), class III (three teeth), class IV (three teeth), and class V (39 teeth) were investigated. Clinical performance such as patient acceptance or any adverse reaction during cavity preparation by this laser was analyzed. In addition, patient reactions with mild to moderate hypersensitive and WSD teeth were also evaluated.

Laser systems

When lasers are used for cavity preparation, heat generation during laser irradiation often causes major thermal side effects such as carbonization, melting, cracking of the tooth structure, and pulpal damage. Clinical outcomes of the Er-YAG laser have shown that there is no such complication and no tooth is compromised. On the other hand, the laser system used in the present study, the Er,Cr:YSGG, minimizes thermal side effects by improvements in its delivery system. It uses a pulsed-beam system, fiber delivery, and a sapphire tip bathed in a mixture of air and water vapor. With this laser system, it has been reported that the use of water spray minimizes the heat generation, and therefore, the risk for thermal side effects could be easily avoided. However, further improvements of the delivery system such as development of a disposable tip could facilitate convenient maintenance of sterile conditions.

Adverse reactions

No adverse reactions such as systemic or localized allergy were noted in any of the cases. Systemic allergy is not likely since the waves are emitted at 2.78 μm (in the infrared light zone) and not within the ultraviolet or x-ray zone. Adverse reactions or thermal damages do not appear to be particular clinical problems if this device is used with care on hard-tissue ablation under water spray.

Pain during cavity preparation

Among the 50 cases, 34 cases (68%) felt no pain at all, 11 cases felt slight pain, and two cases felt tolerable pain. However, three patients (6.8%) with severe dentin hypersensitivity reported intolerable pain. These patients were given additional anesthesia during cavity preparation. A high rate of good clinical outcome was achieved with this system, which may be due to the fact that relatively moderate, not severe, caries were removed in the present study and cutting efficiency was enhanced by the addition of continuous water spray. In addition, the laser may have had a mild analgesic effect, and it seemed that cavity preparation by this laser system could be possible without the use of additional local anesthesia in the future. Reports of preparing cavities without additional local anesthesia by the Er:YAG laser system have appeared elsewhere.

Intraoperative discomfort

During cavity preparation, 42 of 50 cases (84%) were considered to be comfortable. In eight patients, machine noise was uncomfortable. However, most patients felt no discomfort since the noise was muffled by the noise of the vacuum suction.

Time required for cavity preparation

The analysis of preparation time by this laser showed that the Er,Cr:YSGG laser was able to produce shallow cavities within a few minutes. However, longer preparation time was required for class I (10-15 min) and class II (13-20 min) cavity preparations, because removal of much sound enamel was needed. Longer preparation time by the laser is inconvenient for some patients. However, cavity preparation by this laser system has some major advantages. First, the acid-etching process could be omitted; therefore, the total treatment time could be reduced. Second, a caries-preventive effect may be acquired with this laser treatment, which has been reported in some previous research. Other improvements such as a reduction of clinical time and improvement of the delivery system are re-
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required to extend the clinical benefits of this laser. Long-term clinical evaluation is also needed.

CONCLUSION

From our present study, it can be concluded that the Er,Cr:YSGG laser system is an efficient, effective and safe device for caries removal and cavity preparation in clinic. The patient acceptance rate was excellent, and there were no adverse side effects.

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REFERENCES


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