

Effects of Erbium-Doped: Yttrium Aluminum Garnet (Er: YAG) Laser on Bacteremia due to Scaling and Root Planing

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Abstract:

Background: The aims of the present study were: [1] to evaluate whether Erbium-Doped: Yttrium, Aluminum and Garnet (Er: YAG) laser could be a prophylactic methods against transient bacteremia during scaling and root planing (SRP) [2] to confirm the efficacies of SRP with Er: YAG laser by clinical and microbiologic evaluations.

Methods: Twenty chronic periodontitis subjects were randomly treated for quadrant SRP with either conventional hand instrument ($n=10$) or Er: YAG laser ($n=10$) monotherapy. Peripheral blood samples were drawn at baseline and 6 minutes after initiation of SRP, and were cultured for the analysis of bacteremia. Clinical measurements of full mouth plaque control record (PCR), probing pocket depth (PPD), clinical attachment level (CAL) and bleeding on probing (BOP) were made at baseline and 1 month after SRP. In addition, microbiologic analyses of subgingival samples were also performed at baseline and 1 month after SRP using the polymerase chain reaction Invader method.

Results: The incidence of bacteremia during SRP was 0% (0/10) in the Er: YAG laser group and 80% (8/10) in the hand instrument group, which was significantly different ($P = 0.0003$). All isolates from blood were facultative or obligate anaerobes and more than half of the microorganisms were species of streptococci. Intragroup comparison revealed that the mean PPD and CAL significantly decreased compared to baseline in both groups ($P < 0.05$). However, the percentage of BOP positive significantly decreased only in Er: YAG laser group ($P = 0.005$). In addition, the reductions of the subgingival bacterial counts between baseline and 1 month after SRP were also comparable between the two groups.

Conclusion: The present study demonstrated that SRP with Er: YAG laser could not only be an alternative treatment for improvement of clinical and microorganisms situations but also a novel prophylactic method against transient bacteremia.

Keywords: bacteremia; Er: YAG; periodontitis

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Introduction

Periodontitis is a widespread chronic inflammatory disease caused by interaction between host immune

response and periodontal bacteria (1), and is characterized by loss of connective tissue and alveolar bone support, leading to tooth loss (2). Periodontitis is classified into two broad categories, chronic

periodontitis (CP) and aggressive periodontitis (3), with the majority of cases classified as CP. Recently, periodontitis have been receiving considerably much attention for its association with systemic diseases such as cardiovascular disease and stroke (4-7). This could be attributed by a low grade chronic local infection of periodontal tissue due to periodontopathic bacteria, which could then moderate systemic inflammatory response (8).

Transient bacteremia is a common event and occurs as a consequence of skin or mucosal injuries. In severe periodontitis patients, bacteremia is reported associated with daily activities like chewing (9), tooth brushing (9, 10) and flossing (11). Also, bacteremia has been reported in clinical trials after different dental procedures including periodontal treatment. Scaling and root planing (SRP) is one of the essential procedures for the initial periodontal treatment to remove the etiologic agents such as dental plaque, bacterial products and calculus. This procedure can also induce transient bacteremia (9, 10, 12, 13), and the problem is that in case of patients with underlying heart disease, this could be implicated in the development of infective endocarditis (IE) (14) and a variety of other distant site infection. Thus, to prevent and minimize the occurrence of bacteremia during periodontal treatment, prophylactic administrations of antibiotics have been tried, but it could not prevent it perfectly (15, 16). In addition, because repeated usage of antibiotic prophylaxis could contribute to the development of bacterial resistance, and allergic reactions, so alternative prophylactic drugs should be definitely needed.

The use of laser radiation has been expected to serve as an alternative or adjunctive treatment to conventional mechanical therapy in dentistry. The advantages of the laser therapy were like faster wound healing, improved infection control (17, 18), reduced postoperative pain and sensitivity and reduced patient anxiety (19, 20). In periodontal treatment, SRP using various kinds of laser have been tried and its effects have been investigated *in vivo* and *vitro*, and reviewed (21).

Erbium-Doped: Yttrium, Aluminum and Garnet (Er: YAG) laser has a wavelength of 2.94 μm, and close attention has been paid to it for its clinical applicability to both soft and hard tissue due to its specific high water absorption capacity (22). Previous studies demonstrated that Er: YAG laser could remove calculus from periodontally diseased root surface without causing thermal side effects to the adjacent

tissue (23-25). Indeed, controlled clinical trial for SRP with Er: YAG laser has been performed and Er: YAG laser monotherapy showed almost equivalent clinical improvements compared to the conventional mechanical trial by hand instrument (26). In addition, under proper conditions, it has been reported that SRP with Er: YAG laser could prevent from extensive cementum removal compared to that with hand instrument (24). Moreover, human gingival fibroblasts adhesion to root surface was more effectively treated with low energy of Er: YAG laser irradiation than with hand instrument (25, 27). Besides these, one of the most striking advantages in using Er: YAG laser's in SRP is its high bactericidal potential (17). This is completely different from the conventional mechanical debridement, and could be leading to the prophylactic methods against transient bacteremia during periodontal treatment. To the best of our knowledge, there is no report investigating the efficacies of preventing bacteremia during SRP using Er: YAG laser. Therefore, the aims of the present study were: [1] to evaluate whether Er: YAG laser could be a prophylactic methods against transient bacteremia during SRP [2] to confirm the efficacies of SRP with Er: YAG laser by clinical and microbiologic evaluations.

Methods

Study Population

Twenty CP subjects were recruited from patients attending the Periodontal Clinic of Niigata University Medical & Dental Hospital, Niigata, Japan, in the study period between December 2008 and July 2011. The study protocol was approved by the regional ethical committee of the Faculty of Dentistry, Niigata University, and all subjects had signed an informed consent prior to participating in the study. All subjects selected were of Japanese descent, and systemically healthy, who possessed a minimum of 18 natural teeth, and at least three teeth with probing pocket depth (PPD) (from free gingival margin to bottom of pocket) greater than 5 mm in at least one quadrant. In addition, according to information provided on a standard questionnaire, patients who fell under any one of the following criteria were excluded: 1) congenital valve defects or any other risk situation for IE, 2) abnormal haematological profile, systemic medical conditions (diabetes mellitus, coronary heart disease) 3) pregnancy in women 4) recent medication; systemic antibiotics, anti-inflammatory

drugs or immunosuppressive drugs in the past three months before the experiment 5) previous history of periodontal surgery or periodontal therapy in the past six months 6) incompatible dentition, e.g. orthodontic bands, partial dentures or teeth unsuitable for SRP 7) heart pacemaker or any other systemic conditions that might be affected by Er: YAG laser treatment.

Study Design

The study was performed according to a case-control study to evaluate the efficacies of two methods for clinical and microbiologic findings, and preventing incidence of bacteremia during quadrant SRP. A total of twenty subjects were randomly assigned to case (Er: YAG laser group; n=10) and control (Hand instrument groups; n=10) based on the treatment protocol using random tables by one of the authors (TM), and given a code number which was used to identify the subjects throughout the study. A battery of the clinical procedure is summarized below. Periodontal examination, peripheral blood and subgingival plaque were collected (baseline). After one week, quadrant SRP was performed with either Er: YAG laser or hand instrument monotherapy. Six minutes later, the peripheral blood was taken according to our previous study (16). Clinical re-examinations and subgingival plaque sampling were done 1 month after SRP. All clinical procedures were performed by one dentist (YK) who sufficiently conducted training to avoid technical differences. During the study, subjects were requested not to take medicine or received no periodontal treatment that might affect study protocol.

Clinical Measurements

All subjects were evaluated clinically and radiographically at first visit by one periodontist (YK). History of smoking habits as well as systemic health and intake of medication were obtained. For over a month prior to the study, all subjects received a few visits of standard oral hygiene instructions and full mouth supragingival ultra sonic scaling (Suprason P-max, Satelec, Bordeaux, France). One week before starting the study, full-mouth periodontal examinations were evaluated including the following clinical measurements: full mouth plaque control record (PCR), PPD, clinical attachment level (CAL) (from cement-enamel junction to bottom of pocket) and bleeding on probing (BOP). PPD and CAL were recorded at six

sites per tooth (mesio-buccal, buccal, disto-buccal, mesio-lingual, lingual, disto-lingual) with a calibrated manual periodontal probe (CP-12 Color-Coded Probe, Hu-Friedy, Chicago, IL). The quadrant exhibiting the most severe periodontal condition was selected as the site for SRP based on the clinical findings.

Subgingival Plaque Sampling and Quantitative Assay of Bacteria

After removing the visible supragingival plaque, selected deepest pocket site was isolated from saliva with cotton rolls and subgingival microbial sampling was carried out. Sample was collected by inserting sterile #40 paper points (Zipperer Absorbent Paper points, VDW GmbH, Munich, Germany) consecutively into the periodontal pocket as far apically as possible for 10 seconds. This was repeated four times, and two paper points were sent to BML Corporation (Saitama, Japan), and analyzed by the polymerase chain reaction (PCR)-Invader method for a quantitative analysis of total bacteria and periodontopathic bacteria including *Prevotella intermedia* (*P. intermedia*), *Porphyromonas gingivalis* (*P. gingivalis*), *Tannerella forsythia* (*T. forsythia*), *Treponema denticola* (*T. denticola*), *Fusobacterium nucleatum* (*F. nucleatum*). This method was briefly described on our previous report (16). On the other hand, the rest of two paper points were sent to GC Corporation (Tokyo, Japan) for the quantitative analysis of *Streptococcus spp.* and *lactobacillus* by real-time PCR assay with the TaqMan system based on Yoshida A et al (28). In brief, bacterial DNA was extracted from plaque samples using a commercial kit (QuickGene DNA kit S, Wako Pure Chemical Industries, Inc., Osaka, Japan) according to the manufacturer's instructions. 1.0 μ l of Template DNA was added to a 10 μ l TaqMan Fast Universal PCR Master Mix (applied Biosystem), 0.4 μ l 10 μ M forward and reverse primers, 0.4 μ l 5 μ M probe and 7.8 μ l sterilized pure water. And the reaction mixture was preheated at 95°C for 20sec, and a two-step PCR reaction was carried out for 45 cycles (95°C for 3sec, 60°C for 30 sec).

Treatments

Conventional SRP was performed by using specific manual curettes (Gracey curettes, original standard, Hu-Friedy Co., Chicago, IL) (Hand instrument groups). The laser apparatus used was Er: YAG laser (Arwin Adverl, J. Morita Mfg. Corp., Kyoto, Japan), which

employed an optical fiber delivery and contact tip system. Laser parameters was set at an energy level of 100mJ, 10pps (panel setting) with 5-7ml distilled water irrigation per minute according to the instruction given by the manufacturer. Air mixed water was released coaxially to the contact tip covering the target area during irradiation. We used the tapered tip which was called "PS600T" (J. Morita Mfg. Corp., Kyoto, Japan) made of quartz glass with 3mm length and the diameter of 600 μ m at basic and 400 μ m at top point. Two third of the divergent beam was irradiated in forward direction (transmission rate was almost 50%) and the rest of one third was just beside (transmission rate was almost 10%). We used this tip in each subjects and the treatment was performed from coronal to apical in parallel paths with an inclination of the tip of approximately 15 – 30° to the root surface, and moved in a sweeping motion at 1mm per second. Both groups were treated via monotherapy without ultrasonic scaling under local anesthesia with 2% lidocaine (+ 1:80,000 epinephrine). The instrumentation for both hand instruments and laser was performed until the operator felt the root surfaces were adequately debrided and planed. The quadrant SRP was completed within approximately 40 minutes in both groups.

Blood Sampling

Prior to each sampling, the skin overlying the vein was swabbed with ethyl alcohol and then chlorhexidine to minimize the number of potential skin contaminants. Blood sample of 10ml were drawn from the patients through an antecubital vein using strict aseptic technique using a 22-gauge butterfly and safety lock blood collection.

Inoculation of Blood to Culture Bottles

A fully automated microbiology growth and detection system (The BACTEC PLUS system, Nippon Becton Dickinson, Tokyo, Japan) was used for culturing of blood samples.

The collected 10 ml of blood sample was inoculated into an anaerobic culture bottle (BD BACTEC PLUS Anaerobic/F, Nippon Becton Dickinson) which could cover both anaerobic and aerobic (facultatively anaerobic) bacteria, and immediately transported to BML Corporation (Saitama, Japan), which is an integrated clinical testing laboratory. The collection, handling and transport of the blood samples for

blood culture were performed in accordance with the recommendations of manufacturer's instructions, a guideline for blood culture (29), and the methodology applied by numerous authors in studies on bacteremia following dental procedures (30-32). Bottles were incubated and continuously monitored over 6 days for the presence of microorganisms in an automated processor (BACTEC 9240, Nippon Becton Dickinson), and any bottles that signaled negative were discarded. We have ascertained that culture bottles which inoculated with *P. gingivalis* of several concentrations (10, 100, 1000 and 10000 CFU/ml) signaled positive within 6 days in the preliminary experiment. The details of the procedures have been described previously (16).

Microbiological Culture and Bacterial Identification

Bottles that signaled positive were Gram-stained and subcultured onto an appropriate plate for anaerobes, and onto each appropriate plate for aerobes and fungus to confirm that there was no skin-derived contamination. Biochemical tests for anaerobic (RapID ANA II, Remel, Lenexa, KS), aerobic (VITEK 2 system, SYSMEX bioMerieux, Tokyo, Japan) and *Streptococcus* species (API Rapid ID 32Strep, SYSMEX bioMerieux) isolates, were performed using commercially available diagnostic kits designed for bacterial identification. Tests were performed according to our previous laboratory (16).

Statistical Analyses

Statistical analyses were performed by using the standard statistical software (Stat View J-4.5 application program, SAS institute Inc., Cary, NC, USA). Significance was set at 5% ($P < 0.05$).

Intragroup comparisons of clinical parameters and subgingival organisms between baseline and re-examination were performed using the non-parametric Wilcoxon signed-ranks test. On the other hand, intergroup comparisons of clinical parameters and subgingival organisms were made by using the non-parametric Mann-Whitney *U*-test. The differences of incidence rate of bacteremia between groups were verified by χ^2 /Fisher's exact tests.

Results

Out of the 22 subjects enrolled, two did not comply

with the protocol, 20 subjects were finally included in the study. All subjects were non-smokers in the Er: YAG laser group. On the other hand, only one out of 10 subjects was current smoker in the hand instrument group.

Clinical Parameters

The clinical and demographic characteristics of the study subjects are shown in Table 1. At baseline clinical examination, there were no statistically significant differences between the two groups in any of the recorded parameters ($P > 0.05$). Intragroup comparison revealed that the mean PPD and CAL in quadrant and those in which subgingival plaque sample was obtained significantly decreased compared to baseline in both groups ($P < 0.05$). However, the percentage of BOP positive in quadrant significantly decreased after SRP only in Er: YAG laser group ($P = 0.005$). Likewise, in clinical examination after SRP, there were no statistically significant differences between the two groups in any of the recorded parameters ($P > 0.05$). The relatively low baseline PCR after oral hygiene instructions did not change throughout 1 month of the study, and yield no statistical difference between the two groups.

Microbiologic Evaluation in Subgingival Plaque

Table 2 shows the intragroup comparison of subgingival total and periodontopathic bacterial counts between baseline and 1 month after SRP. In the Er: YAG laser group, *P. intermedia* was significantly decreased after SRP compared to baseline ($P = 0.02$). In addition, the number of total bacteria and *P. gingivalis*,

Table 2. Intragroup comparisons of subgingival bacterial counts

		1month		
		Baseline	after SRP	P-value
Er: YAG laser group (n=10)	Total bacteria	5.1 ± 0.2	4.6 ± 0.2	0.06
	<i>P.intermedia</i>	2.4 ± 0.4	1.6 ± 0.4	0.02
	<i>P.gingivalis</i>	2.9 ± 0.6	1.6 ± 0.4	0.07
	<i>T.forsy whole</i>	3.3 ± 0.2	2.6 ± 0.3	0.10
	<i>T.denticola</i>	2.0 ± 0.5	1.2 ± 0.3	0.06
	<i>F.nucleatum</i>	3.3 ± 0.2	3.3 ± 0.2	0.74
Hand instrument group (n=10)	Total bacteria	5.0 ± 0.3	4.4 ± 0.2	0.06
	<i>P.intermedia</i>	1.1 ± 0.4	0.6 ± 0.1	0.18
	<i>P.gingivalis</i>	2.6 ± 0.6	1.2 ± 0.5	0.046
	<i>T.forsy whole</i>	2.8 ± 0.6	2.1 ± 0.4	0.24
	<i>T.denticola</i>	2.0 ± 0.6	1.5 ± 0.5	0.35
	<i>F.nucleatum</i>	3.5 ± 0.5	3.0 ± 0.4	0.67

Values represent mean ± standard error (log10/ml).

P. intermedia, *Prevotella intermedia*; *P. gingivalis*, *Porphyromonas gingivalis*; *T. forsythia*, *Tannerella forsythia*; *T.denticola*, *Treponema denticola*; *F.nucleatum*, *Fusobacterium nucleatum*.

T. forsythia and *T. denticola* were slightly decreased after SRP though there were not statistically significant ($P = 0.06$, 0.07, 0.10 and 0.06, respectively). On the other hand, in the hand instrument group, *P. gingivalis* was significantly decreased ($P = 0.046$) and the number of total bacteria was slightly decreased ($P = 0.06$) after SRP compared to baseline. The numbers of *F. nucleatum* were not significantly different before and after SRP in both two groups.

In subgingival plaque, we preliminary detected periodontopathic bacteria in three subjects in each group, but did not detect any periodontopathic microorganisms in blood cultures during SRP. Therefore, we tried to detect *Streptococcus spp.* and *lactobacillus* as well as periodontopathic bacteria in subgingival plaque in 7 out of 10 subjects in each groups. At baseline, total *Streptococcus spp.* count

Table 1. Demographic and clinical characteristics of the study population

Parameters	Er: YAG laser group (n=10)			Hand instrument group (n=10)		
	Baseline	1 month after SRP	P-value	Baseline	1 month after SRP	P-value
Age (years)	60.4 ± 3.2			57.1 ± 3.1		
Male / female	5/5			5/5		
Number of teeth present	26.4 ± 0.7			25.0 ± 0.9		
PPD (mm)	3.4 ± 0.2	2.7 ± 0.2	0.005	3.3 ± 0.3	2.5 ± 0.1	0.005
CAL (mm)	4.5 ± 0.5	3.9 ± 0.5	0.005	3.9 ± 0.3	3.4 ± 0.2	0.01
BOP (%) positive)	53.5 ± 3.5	31.6. ± 4.4	0.005	41.4 ± 6.1	29.8 ± 4.8	0.10
PPD measured sites for subgingival plaque (mm)	7.5 ± 0.4	5.2 ± 0.3	0.005	7.6 ± 0.8	5.0 ± 0.6	0.008
CAL measured sites for subgingival plaque (mm)	8.4 ± 0.6	6.7 ± 0.8	0.01	8.1 ± 0.8	6.6 ± 0.7	0.02
PCR (%)	21.2 ± 4.3	15.4 ± 3.7	0.06	23.3 ± 6.6	18.5 ± 5.2	0.21

Values represent mean ± standard error

in subgingival plaque was $10^{3.5}$ in hand instrument group and $10^{3.4}$ in Er: YAG laser group. One month after SRP, these bacterial counts were $10^{3.4}$ in both groups. Only one subject in Er: YAG laser group showed *lactobacillus* at 1.3×10^3 counts after SRP (data not shown).

Intergroup comparisons of subgingival bacterial counts were then evaluated, and at baseline, total and each periodontal subgingival bacterial counts were comparable between Er: YAG laser group and hand instrument group ($P > 0.05$, Table 2). In addition, Figure 1 shows the reductions of subgingival bacterial counts between baseline and 1 month after SRP, which were as follows (laser group vs hand group, mean \pm standard error, log₁₀/ml): total bacteria (0.5 ± 0.2 VS 0.6 ± 0.3); *P. intermedia* (0.8 ± 0.3 VS 0.5 ± 0.3), *P. gingivalis* (1.4 ± 0.6 VS 1.4 ± 0.6); *T. forsythia* (0.7 ± 0.3 VS 0.6 ± 0.6); *T. denticola* (0.6 ± 0.3 VS 0.4 ± 0.4); *F. nucleatum* (0.0 ± 0.3 VS 0.1 ± 0.4). There were no significant differences in these reductions between the two groups ($P > 0.05$, Figure 1).

Incidence of Bacteremia

The incidence of bacteremia at baseline and during SRP in the groups is shown in Table 3. No bacterial growth was detected at baseline in any of the groups. The incidence of bacteremia during SRP was 0% (0/10) in the Er: YAG laser group and 80% (8/10) in the hand instrument group, which was significantly different ($P = 0.0003$).

Table 3. Incidence of bacteremia in patients with periodontitis at baseline and during scaling and root planing

	Baseline		During SRP	
	Positive	Negative	Positive	Negative
Er: YAG laser group (n=10)	0	10	0	10
Hand instrument group (n=10)	0	10	8	2
total	0	20	8	12

Incidence of bacteremia during SRP between the two groups was significantly different ($P = 0.0003$, χ^2 /Fisher's exact tests).

Identification of Microorganisms Isolated from Blood

Table 4 shows the microorganisms identified in blood cultures during SRP and their frequency. All isolates were facultative or obligate anaerobes. Three subjects of the hand instrument group exhibited

Table 4. Frequency of microorganisms in blood cultures during scaling and root planing

Microorganisms	Er: YAG laser group (n=10)	Hand instrument group (n=10)
<i>α-streptococcus</i>	0	4 (40)
<i>γ-streptococcus</i>	0	1 (10)
<i>Streptococcus mutans</i>	0	1 (10)
<i>Lactobacillus sp</i>	0	1 (10)
<i>Rothia spp</i>	0	1 (10)
<i>Fusobacterium sp</i>	0	3 (30)
<i>Peptostreptococcus micros</i>	0	1 (10)

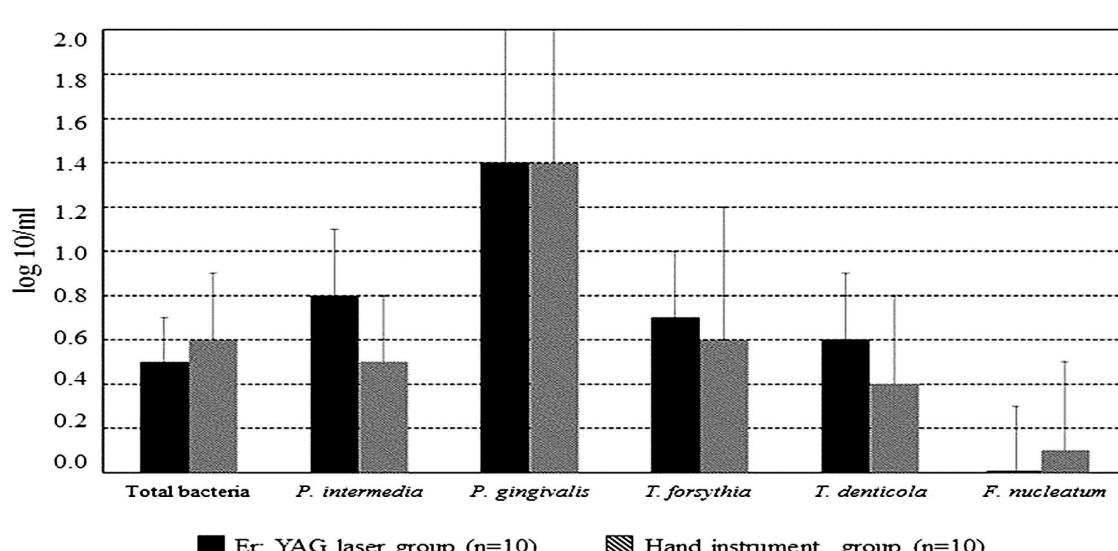


Figure 1. Intergroup comparisons of the reduction of subgingival bacterial counts between baseline and 1 month after scaling and root planing. Bars represent the mean \pm standard error (log₁₀/ml).

polymicrobial bacteremia (growth of more than one microorganism from the blood sample). From subject No.2, *Fusobacterium sp* and *Rothia spp*, from No.3, *α-streptococcus*, *γ-streptococcus* and *Streptococcus mutans*, and from No.4, *Fusobacterium sp*, and *Peptostreptococcus micros* were isolated respectively.

Discussion

In the present study, quadrant SRP was performed with either hand instrument or Er: YAG laser under local anesthesia, and it was evaluated whether Er: YAG laser could be a prophylactic methods against transient bacteremia.

First of all, we evaluated and confirmed the prevalence of transient bacteremia during SRP with the conventional mechanical hand instrument. The data in this study was almost in accordance with our previous data (16), in terms of the incident of bacteremia (previous study was 90% and present was 80%, respectively), and more than half of the microorganisms isolated from blood were species of streptococci in both studies (Table 3, 4).

Our previous study demonstrated the efficacy of AZM for the reduction of the incidence of bacteremia during SRP, though it was not 100% effective (16). However, repeated usage of antibiotic prophylaxis could contribute to the development of bacterial resistance, and allergic reactions. Thus, in the present study, we strongly focused on the Er: YAG laser's high bactericidal potential and evaluate whether Er: YAG laser could be an alternative prophylactic methods. In consequence, the incidence of bacteremia during SRP was 0% (0/10) in the Er: YAG laser group, which indicate that Er: YAG laser irradiation treatment could be a prophylactic method against transient bacteremia. We performed PCR analysis as well as microbiological culture using the blood samples according to the method described by Kinane et al (10). However, none of the target bacteria were amplified in samples of both groups, which was the same result from our previous study (16). This may indicate that the bacteria investigated in the present study were below the detectable level or some technical reasons. To the best of our knowledge, there is no report investigating the efficacies of preventing bacteremia during SRP using Er: YAG laser. Thus, present results cannot readily be compared with those of other studies, and we thought of two reasons for the prophylactic efficacies; [1] one reason was the bactericidal effect of Er: YAG laser [2]

the other was that tissue adjacent to the periodontal pocket after SRP could be less mechanically damaged in the Er: YAG laser group than that in the hand instrument group.

There is convincing evidence for the Er: YAG laser on its bactericidal effect when used as periodontal treatment. Ando Y et al. showed a high bactericidal potential and capacity to reduce lipopolysaccharide contamination of the periodontally diseased root surface (17). Moreover, Akiyama et al. recently investigated the effect and mechanism of bacterial ablation by Er: YAG laser and they concluded that the thermal evaporation of water and organic components would be the major process in the ablation of bacterial biofilms with the Er: YAG laser (33). In the present study, we clinically evaluated and compared the microbiologic findings between two different treatment modalities. In consequence, almost all bacterial species except *F. nucleatum* showed slight decreased after SRP in both groups, though significant reduction was only detected in *P. intermedia* with Er: YAG laser ($P = 0.02$) and *P. gingivalis* with hand instrument ($P = 0.046$) due to the limited small number of the bacterial counts at baseline. These findings were consistent with the study of Derdilopoulou FV et al., which demonstrated no significant differences between the hand instrument and the Er: YAG laser treatment groups in bacterial reduction after SRP (34). On the other hand, *F. nucleatum* were not significantly different before and after SRP in both two groups. *F. nucleatum* plays a central role in biofilm formation, mediating coaggregation between early and late colonizers (35). Haffajee AD et al. demonstrated that changes in microbial counts after periodontal treatment differs according to the pocket depth at baseline and bacterial species; at the sights where attachment gain and pocket depth reduction was more than 2 mm, red complex (*P. gingivalis*, *T. forsythia* and *T. denticola*) could reduce dramatically, whereas orange complex like *F. nucleatum* showed just modest decreased compared to the former (36).

There is only one report investigating the potential prophylactic efficacies of laser against bacteremia during dental treatment (37). In its study, Asaff M et al. evaluated the potential use of diode lasers (DLs) to reduce bacteremia associated with ultrasonic scaling (US) in the gingivitis. The significantly reduced bacteremia during US was shown after the application of DL (incidence of bacteremia: US alone = 68%, DL + US = 36%, respectively), though direct

clinically superior outcome was not detected. They also concluded that the mechanism of the reduced bacteremia was attributed to the reduction of the bacterial counts in gingival crevicular before US. On the other hand, DL has a wavelength of 810 nm and is poorly absorbed in water but highly absorbed in pigments and hemoglobin such as in *P. gingivalis* and *P. intermedia*. Considering the wavelength of both Diode and Er: YAG lasers, Er: YAG laser could be more effective than Diode laser in killing or detoxifying periodontopathic bacteria.

Another reason might be explained by the differences of the potential periodontal tissue damages during SRP between hand instrument and Er: YAG laser groups. As mentioned above, Er: YAG laser irradiation has the potential to devitalize and detoxified periodontal bacteria even without direct contact by means of thermal evaporation, whereas hand instruments could ablate bacteria only when it contacts the plaque biofilm directly. In this context, the mechanical damages of the capillary blood vessel adjacent to the periodontal pocket during SRP might be less in the Er: YAG laser group compared with that of the hand instrument groups. In addition, with respect to the thermal damages in periodontal tissue after Er: YAG laser irradiation, Schwarz et al. first reported the periodontal wound healing histologically / immunohistochemically in dogs and compared with the ultrasonic device (38). The results revealed that there was no severe thermal side effect after Er: YAG laser irradiation in periodontal wound healing, and both treatment procedures were effective in controlling inflammatory cell infiltrates and may support the formation of a new connective tissue attachment. Because of these two mechanisms, Er: YAG laser could then exert its prophylactic efficacies against transient bacteremia during SRP.

In terms of clinical effectiveness, both groups showed significant improvement of the mean PPD and CAL after SRP compared to baseline. In addition, only the Er: YAG laser group showed significantly improvement of the percentage of BOP after SRP ($P=0.005$). The efficacies of Er: YAG laser in removal of radicular debris (24, 39, 40) and bactericidal potential (17) have been proven *in vitro*. However, its clinical effectiveness in non-surgical periodontal therapy remains controversial. In a recent systematic review, Schwarz et al. demonstrated that Er: YAG laser monotherapy could be expected to have comparable short- and long-term clinical outcomes compared to

conventional SRP (21). In addition, Sgolastra F et al. performed the meta-analysis and did not find evidence for the superior effectiveness of Er: YAG laser use compared to conventional SRP (41). Although the present study evaluated clinical efficacies of Er: YAG laser in small sample size and only within 1 month short-term period, our data were consistent with these reports.

In conclusion, the present study demonstrated the comparable effectiveness of Er: YAG laser and conventional hand instrument in terms of clinical and microbiologic outcomes in SRP. Moreover, we provide the novel important findings that Er: YAG laser could be an adjunctive prophylactic method against transient bacteremia during SRP. This could then be leading to prevention of IE and severe systemic infection in patients with underlying heart disease and compromised host. However, it should be pointed out that the sample size of the present study was relatively small, and does not allow for definitive conclusions to be drawn. Further investigations on a larger sample size are definitely encouraged to confirm our findings and extend our observations.

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