Periodontal Treatment With an Er:YAG Laser Compared to Scaling and Root Planing. A Controlled Clinical Study

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Background: The aim of the present study was to compare the effectiveness of an Er:YAG laser to that of scaling and root planing for non-surgical periodontal treatment.

Methods: Twenty patients with moderate to advanced periodontal destruction were treated under local anesthesia and the quadrants were randomly allocated in a split-mouth design to either Er:YAG laser using an energy level of 160 mJ/pulse and 10 Hz or scaling and root planing (SRP) using hand instruments. Clinical assessments of plaque index (PI), gingival index (GI), bleeding on probing (BOP), probing depth (PD), gingival recession (GR), and clinical attachment level (CAL) were made prior to and at 3 and 6 months after treatment. Subgingival plaque samples were taken at each appointment and analyzed using darkfield microscopy for the presence of cocci, non-motile rods, motile rods, and spirochetes. Differences in clinical parameters and prevalence of bacterial species were analyzed using the paired *t*-test.

Results: The PI remained nearly unchanged while a significant reduction of the GI occurred in both groups after 6 months ($P \leq 0.001$, $P \leq 0.001$, respectively). The mean value of BOP decreased in the laser group from 56% at baseline to 13% after 6 months ($P \leq 0.001$) and in the SRP group from 52% at baseline to 23% after 6 months ($P \leq 0.001$). The mean value of the PD decreased in the laser group from 4.9 ± 0.7 mm at baseline to 2.9 ± 0.6 mm after 6 months ($P \leq 0.001$) and in the SRP group from 5.0 ± 0.6 mm at baseline to 3.4 ± 0.7 mm after 6 months ($P \leq 0.001$). The mean value of the CAL decreased in the laser group from 6.3 ± 1.1 mm at baseline to 4.4 ± 1.0 mm after 6 months ($P \leq 0.001$) and in the SRP group from 6.5 ± 1.0 mm at baseline to 5.5 ± 1.0 after 6 months ($P \leq 0.001$). The reduction of the BOP score and the CAL improvement was significantly higher in the laser group than in the SRP group ($P \leq 0.05$, $P \leq 0.001$, respectively). Both groups showed a significant increase of cocci and non-motile rods and a decrease in the amount of motile rods and spirochetes.

Conclusions: An Er:YAG laser may represent a suitable alternative for non-surgical periodontal treatment. *J Periodontol 2001;72: 361-367.*

KEY WORDS

Gingival index; lasers/therapeutic use; periodontal diseases/therapy; planing; scaling; comparison studies; follow-up studies.

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Since the ruby laser was introduced in 1960,[1] lasers have been used in many different areas in medicine and their use in dentistry was introduced in 1964.[2] Today various laser systems are discussed for a possible use in dentistry. The Nd:YAG (neodymium-doped: yttrium, aluminum, and garnet) and CO_2 (carbon dioxide) lasers are limited due to their thermal side effects, whereas the Er:YAG (erbium-doped: yttrium, aluminum, and garnet) laser is expected to show efficiency in medical and dental applications because of its thermomechanical ablation mechanism and the high absorption of its wavelength by water.[3-7] A primary goal in the treatment of periodontitis is the removal of bacterial deposits and halting of disease progression.[8] To achieve this goal, a complete removal of adherent plaque, calculus, and infected cementum is necessary, even though complete removal is rare.[9,10] The nature of a laser depends on its wavelength. Close attention has been paid to the clinical applicability of the Er:YAG laser with its wavelength of 2.94 μm in the near infrared spectrum. This wavelength is well absorbed by water because the peak is close to the absorption coefficient of water. Consequently an Er:YAG laser has a water absorption characteristic approximately 15 times greater than that of the CO_2 and 20,000 times greater than the Nd:YAG laser.[11,12] The application of the Er:YAG laser for caries therapy has already been established.[13,14] The Er:YAG laser also makes the removal of subgingival calculus and of superficial layers of infected cementum possible, while the effects on periodontally involved root surfaces have only been examined in vitro,[6,15-18] where the root surface was roughened at a microscopic level. This microstructured root surface showed partially a loss of cementum, but no cracks or thermal effects such as melting after Nd:YAG laser irradiation.[6,15-21] Furthermore, the Er:YAG laser seems to have a high bactericidal potential against periodontopathic and cariogenic bacteria.[22,23] Today there is considerable evidence to support scaling and root planing as one of the most commonly used procedures for the treatment of periodontal diseases.[24-26] However, such instrumentation calls for clinical skills and sometimes despite them, the anatomy of the root often precludes achieving the desired biologically compatible root surface.[10] Thus, in search of more efficient instrumentation, many investigators have proposed lasers as alternatives, especially because of their ability to detoxify root surfaces and ease of use. However, until now no published data are available concerning the clinical outcomes following treatment with an Er:YAG laser when compared to well established procedures such as scaling and root planing. Therefore the aim of the present study was to assess the clinical effectiveness of an Er:YAG laser when compared to scaling and root planing with hand instruments.

MATERIALS AND METHODS

Patient Population

Twenty periodontal patients, aged between 28 to 79 years (mean age 54 years), were included in the study. They were all referred to the School of Dentistry, University of the Saarland, Homburg for periodontal therapy. The study was in accordance with the Helsinki Declaration of 1975, as revised in 1983 and all participants signed informed consent forms. Criteria for exclusion from the study were: 1) periodontal treatment within the last 12 months; 2) systemic diseases which could influence the outcome of the therapy; 3) pregnancy; or 4) systemic antibiotics within the last 6 months.

Study Design

The study was performed using a split-mouth design. A total of 34 maxillary and 21 mandibular pairs of contralateral single- and multi-rooted teeth were included (total = 660 sites). Each tooth of each contralateral pair had to exhibit gingival inflammation with a positive bleeding on probing (BOP), subgingival calculus, and a probing depth (PD) of ≥4 mm on at least one aspect of the tooth. In each contralateral pair one tooth was randomly treated with subgingival scaling and root planing using hand instruments while the other tooth was treated with an Er:YAG laser. The distribution of the 2 treatment modalities was equally divided between the right and left sides. All patients were treated by the same experienced operator.

Oral Hygiene Program

For 4 weeks before treatment all patients were enrolled in a hygiene program and received oral hygiene instructions at 2 to 4 appointments as well as professional tooth cleaning according to individual needs. A supragingival professional tooth cleaning was performed at baseline as well as 3 and 6 months after treatment.

Treatments

The mechanical subgingival instrumentation was performed using hand instruments (Gracey curets§ No. 1/2, 3/4, 7/8, 11/12, and 13/14). An Er:YAG laser‖ was selected using a handpiece at an energy level of 160 mJ/pulse and a repetition rate of 10 Hz with water irrigation according to the manufacturer's instructions. The fiber tips of 0.5 × 1.65 mm and 0.5 × 1.1 mm were chosen by the operator according to the situation. The treatment was performed from coronal to apical in parallel paths with an inclination of the fiber tip of 15 to 20° to the root surface. Both groups were treated under local anesthesia. The instrumentation for both hand instruments and laser was performed until the operator felt that the root surfaces were adequately debrided and planed. The amount of time needed in the SRP group was, on average, 9 minutes for single rooted teeth and 15 minutes for multi-rooted teeth. For the laser treatment, the averages were 5 minutes for single-rooted teeth and 10 minutes for multi-rooted teeth.

Clinical Measurements

At the baseline visit and after 3 months and 6 months after the last treatment, the following clinical parameters were measured by one calibrated periodontist who was not involved in providing treatment during the study: plaque index (PI),[27] gingival index (GI),[28] probing depth (PD), gingival recession (GR), and clinical attachment level (CAL). Bleeding on probing was assessed simultaneously to the pocket measurements, and the presence or absence of bleeding up to 30 seconds after probing was recorded. The measurements were made at 6 aspects per tooth: mesio-vestibular (mv), mid-vestibular (v), disto-vestibular (dv), mesio-lingual (ml), mid-lingual (ml) and disto-lingual (dl) using a manual periodontal probe.¶

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Microbiological Evaluation

The bacterial samples were obtained as follows: After professional supragingival tooth cleaning, a sterile paper point was introduced through the sulcus as far apically as possible. It was withdrawn after 30 seconds and then suspended in a sterile 0.9% sodium chloride solution. Within 15 minutes the samples were evaluated using darkfield microscopy by classifying cocci, spirochetes, motile and non-motile rods from 100 to 150 bacteria from fields selected at random.[29]

Statistical Analysis

A software package was used for the statistical analysis.[#] The paired *t* test was used to compare the mean scores of all investigated clinical parameters from the baseline to those after 3 and 6 months for each treatment group. Comparisons between the treatment groups at baseline and after 3 and 6 months were also accomplished with the paired *t* test. The alpha error was set at 0.05. The power of the study, given 1 mm as a significant difference between groups, was calculated to be 0.99, which justified the sample size of 20 patients.

Examiner Calibration

Five patients, each showing 2 pairs of contralateral teeth (single and multi-rooted) with probing depths ≥6 mm on at least one aspect of each tooth, were used to calibrate the examiner. The examiner evaluated the patients on 2 separate occasions, 48 hours apart. Calibration was accepted if measurements at baseline and at 48 hours were similar to the millimeter at ≥90% level.

Table 1.

Plaque Index (PI), Gingival Index (GI), and Bleeding on Probing (BOP): Mean Scores (± SD, n = 20 patients) at Baseline and 3 and 6 Months

Index/Treatment	Baseline (± SD)	3 Months (± SD)	*P* Value	6 Months (± SD)	*P* Value
PI					
Laser	1.0 ± 0.6	0.7 ± 0.4	*	0.7 ± 0.4	*
SRP	1.0 ± 0.6	0.5 ± 0.5	*	0.7 ± 0.5	*
P value	n.s.	n.s.		n.s.	
GI					
Laser	1.9 ± 0.6	0.5 ± 0.6	†	0.3 ± 0.6	†
SRP	1.9 ± 0.6	0.7 ± 0.8	†	0.4 ± 0.8	†
P value	n.s.	n.s.		n.s.	
BOP					
Laser	56%	17%	†	13%	†
SRP	52%	22%	†	23%	†
P value	n.s.	*		*	

Significance of differences within and between the groups at different time points by *t* test: n.s. $P \geq 0.05$; *$P \leq 0.05$; †$P \leq 0.001$.

RESULTS

Clinical Measurements

The postoperative healing was uneventful in all cases. No complications such as abscesses or infections were observed throughout the study period. Initially the plaque index was 1.0 ± 0.6 in both groups. At the 3 month examination the plaque scores were markedly reduced and remained low throughout the study. No statistically significant differences were observed between surfaces treated by the 2 methods of instrumentation (Table 1). The gingival index was significantly reduced in both groups at the 3 and 6 months examination compared to baseline ($P \leq 0.001$, respectively). No statistically significant differences between the groups could be observed at any time (Table 1). At the baseline examination 56% of the surfaces in the laser group and 52% of the surfaces in the SRP group demonstrated bleeding on probing. Subsequent to instrumentation, a marked and gradual improvement of the bleeding scores took place until 17% of the laser group and 22% of the SRP group at the 3 month examination and 13% of the laser group and 23% of the SRP group at the 6 month examination was reached ($P \leq 0.001$, respectively). A statistically significant difference could be observed at the 3 months ($P \leq 0.05$) and the 6 months ($P \leq 0.05$) examination between the 2 groups (Table 1).

Throughout the study a significant reduction of the PD and a highly significant gain of CAL took place in both treatment groups ($P \leq 0.001$). At the 3 and 6 month examination the statistical analysis showed a significant difference for the PD ($P \leq 0.05$, $P \leq 0.001$, respectively), GR ($P \leq 0.01$, $P \leq 0.001$, respectively) and CAL ($P \leq 0.01$, $P \leq 0.001$, respectively) between the 2 treatment groups (Table 2). Initially deeper pockets (≥7 mm) showed the greatest changes in the PD, GR, and CAL. Intermediate sites (4 to 6 mm) showed moderate improvements while shallow sites exhibited the least amount of changes (Figs. 1, 2, and 3).

Microbiological Evaluation

Both treatments led to a significant reduction of motile rods and spirochetes and a significant increase of cocci and non-motile rods at 3 months ($P \leq 0.001$, respectively). After 6 months increasing percentages of motile

SPSS version 9.0, SPSS Inc., Chicago, IL.

Table 2.

Probing Depth (PD), Gingival Recession (GR), and Clinical Attachment Level (CAL): Mean Scores (± SD, n = 20 patients) at Baseline and 3 and 6 Months

Index/Treatment	Baseline (± SD)	3 Months (± SD)	*P* Value	6 Months (± SD)	*P* Value
PPD					
Laser	4.9 ± 0.7	3.5 ± 0.6	*	2.9 ± 0.6	*
SRP	5.0 ± 0.6	3.8 ± 0.7	*	3.4 ± 0.7	*
P Value	n.s.	†		*	
GR					
Laser	1.4 ± 0.8	1.5 ± 0.7	n.s.	1.5 ± 0.7	n.s.
SRP	1.5 ± 0.8	1.9 ± 0.8	*	2.0 ± 0.8	*
P Value	n.s.	‡		*	
CAL					
Laser	6.3 ± 1.1	5.1 ± 1.0	*	4.4 ± 1.0	*
SRP	6.5 ± 1.0	5.6 ± 1.1	*	5.5 ± 1.0	*
P Value	n.s	‡		*	

Significance of differences within and between the groups at different time points by *t* test: $^*P \leq 0.0001$; $^\dagger P \leq 0.05$; $^\ddagger P \leq 0.01$.

rods and decreasing percentages of cocci could be evaluated in both groups. No significant differences have been observed between the 2 groups (Fig. 4).

DISCUSSION

The results of the present study indicate that non-surgical periodontal treatment with either an Er:YAG laser or with scaling and root planing using hand instruments may lead to significant improvements in all investigated parameters at 6 months following treatment. However, at the 3 and 6 months evaluation, the laser group showed a significantly higher reduction of BOP ($P \leq 0.05$, $P \leq 0.05$, respectively) and CAL gain ($P \leq 0.01$, $P \leq 0.001$, respectively) compared to the SRP group. The calculated power (0.99) of the study and the strict inclusion criteria were the reasons for considering a sample size of 20 patients as sufficient. The results have also demonstrated that most of the clinical and microbial changes occurred during the first 3 months after treatment in both groups. In particular, the mean GR increased significantly after 3 months and was maintained close to that level for the following 3 months of the study. All other investigated parameters such as PI, GI, BOP, mean PD, and mean CAL showed a marked improvement 3 months post-treatment with even further improvements up to 6 months. The most obvious changes in the bacterial distribution occurred in the first 3 months and remained stable for another 3 months, with the exception of the motile rods and the spirochetes with slightly increasing percentages of the total count. These findings are consistent with results from previous studies which have shown that the bacterial recolonization occurs after 3 months.[30,31]

In a clinical study evaluating the clinical assessments of an Er:YAG laser for soft tissue surgery and scaling, a total of 38 patients with moderate to advanced periodontitis were treated.[32] Each subject was evaluated on the day of laser application and after 1, 2, 3, and 4 weeks. The mean PD was reduced from 5.6 ± 2.0 mm to 2.6 ± 0.9 mm. These results were statistically and clinically significant compared to baseline. No further details concerning the development of GR and CAL were given. The obtained mean PD reduction was higher than that from the present study. This discrepancy might be explained by differences in the initial PD. Clinical studies have demonstrated that the reduction of PD and the improvement of the CAL after both non-surgical and surgical periodontal treatment

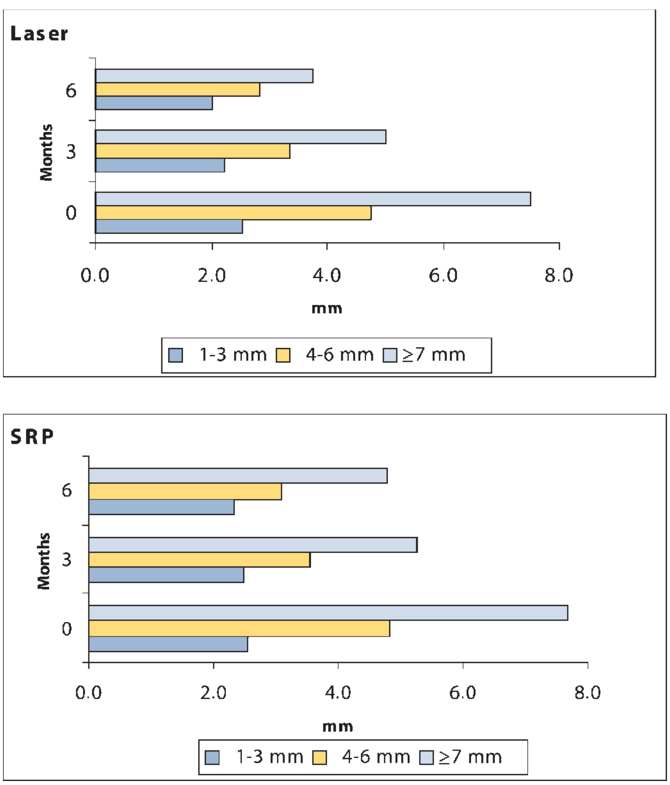

Figure 1.
Plot of mean probing depth at baseline, and 3 and 6 months at sites with initial probing depths of 1 to 3, 4 to 6 and ≥7 mm (n = 20 patients).

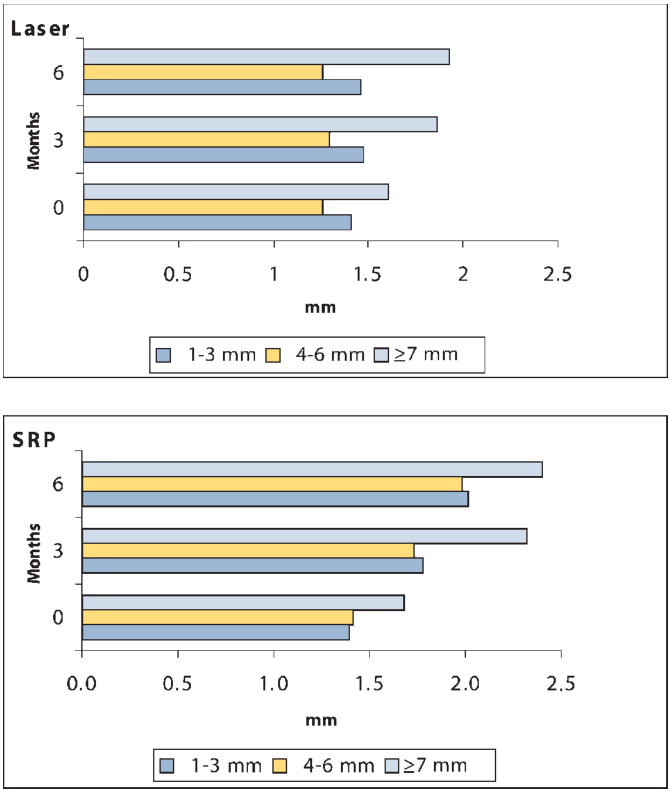

Figure 2.
Plot of mean gingiva recession at baseline, and 3 and 6 months at sites with initial probing depths of 1 to 3, 4 to 6 and ≥7 mm (n = 20 patients).

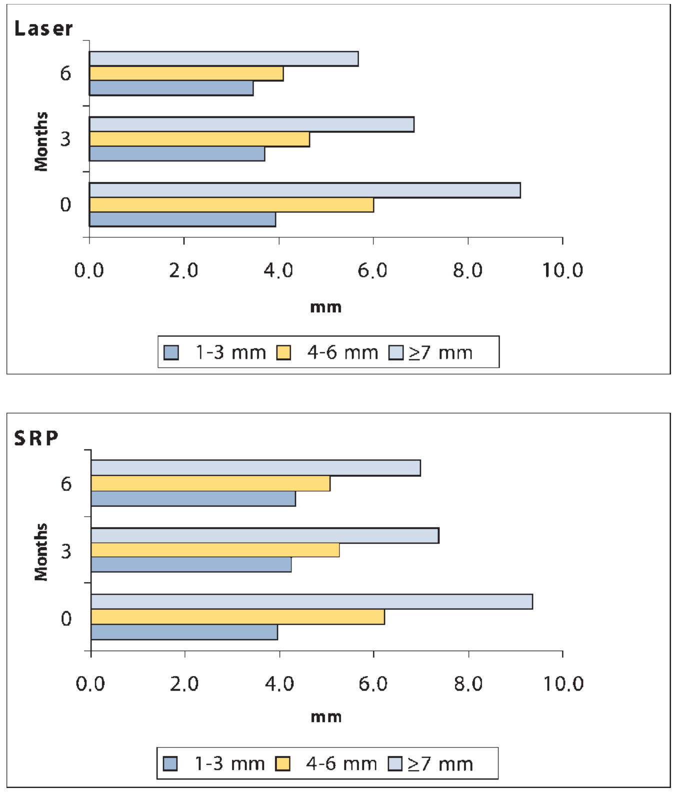

Figure 3.
Plot of mean clinical attachment level at baseline, and 3 and 6 months at sites with initial probing depths of 1 to 3, 4 to 6 and ≥7 mm (n = 20 patients).

is dependent on the initial PD (i.e., the greater the initial PD and CAL, the greater the PD reduction and CAL gain).[33,34] The clinical changes in the SRP group were comparable to those reported in a number of clinical studies that described the effectiveness of non-surgical periodontal therapy.[24-26,33,34] The moderate increase of gingival recession in the laser treated group may be explained by the atraumatic use of the handpiece and the fiber tips. One reason for the higher CAL gain measured in the laser group is probably due to trauma from instrumentation caused by the hand instruments in the SRP group. Results from clinical studies have indicated that trauma from instrumentation may be one reason for an increase in GR and, subsequently, a loss of clinical attachment following non-surgical periodontal treatment.[35–37] Shallow sites seem to be more susceptible than deeper sites (Fig. 3).[36,37] Furthermore, it should be pointed out that in the present study the difference between laser and hand instrumentation was much more significant in deeper pockets than in moderate or shallow pockets (Figs. 1, 2, and 3). These findings may indicate that, from a clinical point of view in shallow pockets, no differences between treatment with hand instruments or laser can be observed. On the other hand, the results in deeper pockets may point to the possible clinical application of an Er:YAG laser.

The root surface morphology after Er:YAG laser treatment has been examined in vitro in numerous studies.[6,15-18] The conclusion was that an Er:YAG laser seems to have sufficient potential for root surface modification, whereas a selective ablation of calculus was impossible. Meanwhile it is generally accepted that the surface roughness itself has no negative influence on the healing following periodontal treatment.[38,39] However, the necessity of cementum removal for accomplishing a successful periodontal therapy is still controversially discussed in the literature.[40-43] While some authors consider the removal of the "diseased" cementum an important factor for a successful periodontal therapy, others have demonstrated that similar histological and clinical results can be achieved with both, complete removal of cementum and only polishing of the root surfaces.[40-42] Furthermore, the results of a recent histological study in humans showed that even periodontal regeneration can be accomplished on a previously "diseased" cementum surface, if the bacterial deposits are mechanically or chemically removed.[43] Thus, it can be anticipated that the detoxification of the cementum surface seems to be more

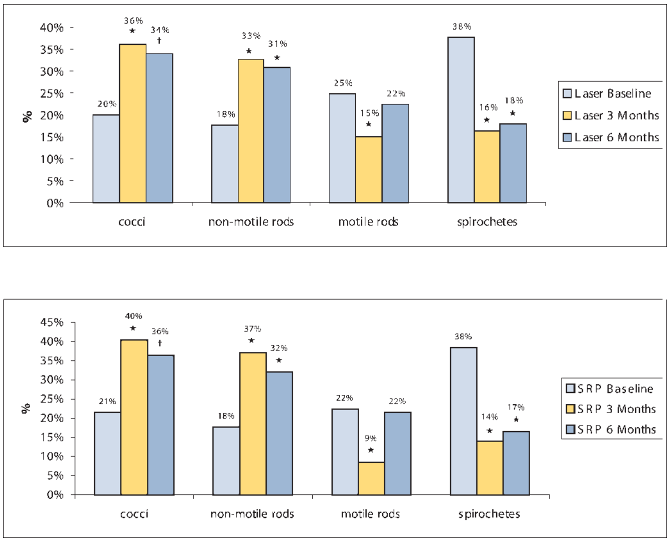

Figure 4.
Distribution of bacteria at baseline, and 3 and 6 months (laser n = 12,567; SRP n = 12,615). Significance of differences within the groups at different time points by the t *test (*P ≤0.001; †P ≤0.01).*

important for the outcome of the therapy than the removal of the entire layer of cementum. In this context it is important to point to the results of previous studies which have shown that the Er:YAG laser has also a high bactericidal potential.[22,23]

The reason for choosing darkfield microscopy in the present study was to observe certain microbiological features that are associated with the healing period, without resorting to extensive culturing techniques. It is well known that periodontally diseased pockets are associated with a high percentage of spirochetes and motile rods and a low percentage of cocci and non-motile rods, while periodontal healthy sites show inverse relations.[29,44] The findings of the present study have, furthermore, indicated that both therapies led to significant improvements on the microbiological level. In this context it should be emphasized that darkfield microscopy is not a gold standard for the microbiological evaluation of treatment. A lack of correlation between clinical parameters and the proportions of spirochetes and motile rods at individual sites was previously described by other investigators.[44] On the other hand, several studies have shown a clear association between changes in the proportions of spirochetes and motile rods and probing depth.[45,46]

It should be also mentioned that one limitation of the present study was the lack of a group treated with ultrasonic instruments. Since ultrasonic instrumentation has become nowadays an essential part of the armamentarium for non-surgical periodontal treatment, further research is needed to answer this question.

In conclusion, the results of the present study indicate that an Er:YAG laser may represent a suitable alternative for non-surgical periodontal treatment. Further studies are needed in order to evaluate the long-term results of this treatment modality.

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