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ORIGINAL ARTICLE

Efficacy of a combined Er:YAG laser and Nd:YAG laser in non-surgical treatment for severe periodontitis

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Abstract

Severe periodontitis is challenging to treat. The aim of this study was to evaluate the efficacy of a combined Er:YAG laser (ERL) and Nd:YAG laser (NDL) in non-surgical treatment for severe periodontitis. One week after supragingival scaling, 32 systemically healthy patients with stage III or IV periodontitis were randomly divided into a control group (16 subjects) and a test group (16 subjects). The control group was treated by scaling and root planning (SRP) with ultrasonic equipment and manual instruments, and the test group was treated by SRP as well as ERL and NDL. Before treatment, the following clinical parameters were recorded at baseline: debris index (DI), probing depth (PD), clinical attachment level (CAL), and percentage of bleeding on probing (BOP %). Two months after therapy, the clinical parameters were recorded again, and the results between the groups were compared. All clinical parameters were significantly improved in both groups after therapy. For moderately deep periodontal pockets (4 mm $\leq$ PD $\leq$ 6 mm), the gains in CAL were greater in the test group (1.17 $\pm$ 1.47 mm) than in the control group (0.46 $\pm$ 2.78 mm), while no significant difference was found for PD reductions after therapy between the two groups. For deep periodontal pockets (PD > 6 mm), the differences in all of the clinical parameters were similar between the test group and the control group. In this short-term study, ERL and NDL radiation exhibited potential advantages in improving the clinical attachment level compared to conventional SRP in the non-surgical treatment of severe periodontitis.

Keywords Severe periodontitis · Er: YAG laser · Nd: YAG laser · Periodontal treatment

Introduction

Periodontitis is a disease that destroys the tissues around the teeth. Severe periodontitis often poorly responds to instrument treatment due to extensive tissue destruction, and the associated inflammation is difficult to completely eliminate. The reasons for these results are that traditional instrument treatment is unable to completely remove all pathogenic microorganisms and has difficulty in accessing all infected areas, such as the bifurcation area and grooves on the root surface, concavities, and the distal sites of molars [1, 2].

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In recent years, laser radiation has been applied to oral therapy. Erbium-doped:yttrium aluminium-garnet (Er:YAG) lasers (ERLs) are capable of removing calculus by reacting with the water contained within the structural microspores and in the intrinsic components of the calculus [3, 4]. They can also promote human gingival fibroblast proliferation and increase cell attachment on the root surface in vitro [5–7]. Some studies have found that treatment with a combination of scaling and root planning (SRP) and ERL reduced the levels of proinflammatory cytokines [8, 9], such as interleukin-1 beta and tumour necrosis factor alpha. ERLs were also shown to reduce the number of microorganisms in the periodontal pockets [10, 11]. However, the results of the use of ERL in vivo studies are inconsistent. Compared with SRP, ERL alone was shown to have no advantage in improving clinical parameters [11–14]. For ERL combined with SRP, the results have also been inconsistent, and the evidence is limited. In Zhou's study [15], the effects of ERL assisted with SRP and of SRP alone were evaluated in the treatment of periodontitis. The improvements in the probing depth (PD) and clinical attachment level (CAL) in the laser group were better than those in the SRP group 3 months after therapy; however, the differences between the groups were only 0.11 mm for PD and 0.20 mm for CAL. Therefore, the adjunctive effect of an Er:YAG laser is likely to be minimal in clinical importance. A meta-analysis of the clinical effectiveness of ERL adjunct to SRP in treating periodontitis noted that ERL + SRP provided additional short-term effectiveness to that of SRP alone [16]. However, the study also revealed no significant differences at the medium-term or long-term follow-up points.

The noedymium-doped:yttrium–aluminium-garnet (Nd:YAG) lasers (NDLs) has strong penetrating power and can be selectively absorbed by pigments and hemoglobin. The NDL can remove the pocket-lining epithelium effectively [17] and kill pigmented bacteria such as Pg [18]. In vitro studies, NDL increased the number of cells proliferation on the root surface [19] and was shown to be superior to other lasers in its ability to congeal blood [20]. NDLs are mainly used as an adjunctive therapy to SRP; however, the clinical results of this combination are also inconsistent. Elats noted that the addition of an NDL improved the effectiveness in reducing PD in smoking patients over SRP alone [21]. In contrast, some studies found no advantage of the NDL, either in terms of clinical parameters [22, 23] or microbiological outcomes [22].

In the evidence-based clinical guidelines on the non-surgical treatment of chronic periodontitis, recommendations for the non-surgical use of lasers as SRP adjuncts are limited [24]. There is also a lack of evidence on the combined use of different kinds of lasers. In one review, the author pointed out that the combination of the debridement effect of the ERL and the photobiomodulatory effect of a deeply penetrating laser (NDL) might offer a new strategy for promoting more effective wound healing in non-surgical therapy [18]. As the ERL and NDL have exhibited positive roles in promoting tissue healing and eliminating microorganisms, we hypothesized that the combined application of the two types of lasers could improve the clinical outcomes of the non-surgical treatment of severe periodontitis. In the present study, we describe a prospective, randomized controlled trial conducted to evaluate the short-term clinical effect of the combination of an ERL and an NDL in the treatment of severe periodontitis.

Materials and methods

Study population

Thirty-two patients with generalized stage III or stage IV periodontitis [25] were recruited from the Department of Stomatology, Peking University International Hospital. All patients signed an informed consent form. This study was approved by the Ethics Committee of Peking University International Hospital and was conducted in accordance with the World Medical Association's Declaration of Helsinki, as revised in 2000. The inclusion criteria for this study were as follows: (1) generalized stage III or stage IV periodontitis, with 20 or more teeth remaining in the mouth, and (2) age between 30 and 65 years. The exclusion criteria were systemic disease that could influence the outcome of the therapy, smoking, pregnancy, breastfeeding, and the use of antibiotics within the last 6 months.

Sample size calculation

CAL gain was considered the primary outcome variable. The sample size was determined to provide 90% power to achieve a significant difference of 0.6 mm [24] between groups with a 95% confidence interval ($\alpha = 0.05$) and assuming a standard deviation of 1.59 mm based on a previous study [26]. The number of measurement sites in each group was 149. Assuming that each patient had 20 teeth with 12 sites deeper than 6 mm (for generalized stage III and stage IV patients, assuming at least 30% of teeth was involved and 2 proximal sites for each tooth), we required 12 patients for each group for a total of 24 patients at minimum. However, considering the distribution of the data and the possibility of non-parametric testing and missed follow-up, at least 30 patients were required for enrolment in this study.

Study design and treatment protocol

The study followed a single-blind, randomized design. Pockets with a probing depth $\geq$ 4 mm were included in the study and treated. One of thirty-two patients (in the control group) was lost at the 2-month follow-up. Thirty-one patients were recruited between June 2018 and January 2020. All patients were seen by a skilled oral hygienist (blinded to the group assignment) for supragingival cleaning and provision of oral hygiene instructions 1 week before root debridement. For the control group, sites with a PD $\geq$ 4 mm were then treated by subgingival SRP using ultrasonic and hand instruments. For the test group, sites with a PD $\geq$ 4 mm were treated by SRP first, followed by a combination of an ERL and an NDL. Patients were randomly assigned to the control group and test group. Two months later, the patients returned for an evaluation. The doctor who performed the evaluation was blinded to the treatment methods.

In the control group, subgingival cleaning was performed using ultrasonic instruments (P5 newtron, ACTEON, France) with an ultrasonic tip (1 s tip) and hand instruments (Gracey curettes, Hu-Friedy, Chicago, USA) (periodontal curettes nos. 5/6, 7/8, 11/12, and 13/14) under local anaesthesia if necessary.

In the test group, the patients were treated by SRP first, followed by an Er:YAG laser (AT Fidelis Fotona, Ljubljana, Slovenia), with water irrigation to remove the residual calculus and improve biocompatibility of the root surface for approximately 60–90 s for each tooth. The Er:YAG laser was delivered into the periodontal pockets using a tip (0.6-mm diameter, 9-mm length, micro short pulse (MSP), 20 Hz, 50 mJ, 1 W). The tip was moved in a zigzag pattern within the pocket at approximately 15 degrees towards the root surface. Then, a Nd:YAG laser (AT Fidelis Fotona, Ljubljana, Slovenia) (MSP, 20 Hz, 1.5 w, 320 µm fibre tip) was used to irradiate the pocket towards the inner wall of the periodontal pocket, for approximately 3–5 s for each site; this process was repeated twice. All treatments were performed by an experienced investigator.

Clinical examination

The following parameters were recorded: (1) debris index (DI) [27], (2) percentage of bleeding on probing (BOP%), (3) PD, and (4) CAL.

The CAL and PD were assessed at six sites per tooth, including the mesio-buccal, mid-buccal, disto-buccal, mesio-lingual/palatal, mid-lingual/palatal, and disto-lingual/palatal sites, using Williams probes (KangQiao, Shanghai, China). Sites at the third molars and the disto-buccal/lingual/palatal sites of the second molars were excluded. The parameters were recorded at baseline and 2 months after the treatment. The PD values were used to group pockets into moderately deep (4–6 mm) and deep groups (> 6 mm). All measurements were performed by a skilled examiner (intra-class correlation coefficient = 0.845) blinded to the treatment.

Statistical analyses

Statistical analysis was performed using SPSS software (v19.0, IBM, Chicago, IL, USA). Descriptive statistics were calculated for measurement data, including the means and standard deviations. The distributions of the parameters were examined using the Kolmogorov–Smirnov normality test. The independent *t* test and paired *t* test were used for normally distributed data. The Wilcoxon signed-rank test and Mann–Whitney *U* test were used to compare non-normally distributed data. Chi-square tests were used to compare hierarchical data between groups. $P < 0.05$ was considered statistically significant.

Table 1 Participant demographic data

	SRP + ERL + NDL	SRP	*P* values
Sex	10 males, 6 females	6 males, 9 females	NS[a]
Age (years)	42.31 ± 11.14	42.67 ± 10.15	NS[b]

NS, not significant

[a]Chi-square test between groups

[b]Independent t test between groups

Results

Thirty-two patients were recruited at the beginning of the study. One patient was lost to follow-up after 2 months. The average ages of the patients in the two groups were 43.31 ± 11.14 years (control group) and 42.67 ± 10.15 years (test group). Table 1 shows the subject characteristics by group. Sex and age were not significantly different between the test and control groups.

Clinical parameters

The DI improved slightly for both groups after treatment; however, the difference was not significant between the values at baseline and 2 months after therapy in either group. In the test group, BOP% significantly dropped from 58.69 ± 24.46 at baseline to 9.50 ± 7.14 at the 2-month follow-up; in the control group, these values were 70.20 ± 22 0.37 and 13.33 ± 5.70, respectively. The DI and BOP% at baseline and after 2 months and the differences in these values from baseline to the 2-month follow-up were not significantly different between the test and control groups (Table 2).

For moderately deep pockets, the CAL was greater in the test group than in the SRP group at baseline. The gain of CAL at 2 months was greater in the test group (1.17 ± 1.47 mm) than in the control group (0.46 ± 2.78 mm). The PD was not significantly different between groups at either baseline or 2 months after therapy, but for both groups, it improved significantly after therapy. The reduction in PD was greater in the test group than in the control group; however, the difference was not significant (Table 3).

For deep pockets, the CAL was greater in the test group than in the SRP group at baseline, and in both groups, the PD and CAL were both improved by therapy. However, there were no significant differences between the groups in the change in the PD or the CAL (Table 4).

The CAL at baseline and 2 months in the test group and control group are shown in Fig. 1.

Table 2 Clinical parameters (mean ± SD) at baseline and 2 months

Parameters		Baseline	2 months	
		Mean ± SD	Mean ± SD	Differences
DI	SRP + ERL + NDL	1.29 ± 0.50	1.16 ± 0.50	0.12 ± 0.36
	SRP	1.60 ± 0.38	1.30 ± 0.47	0.30 ± 0.67
BOP%	SRP + ERL + NDL	58.69 ± 24.46	9.50 ± 7.14 [a]	49.19 ± 20.24
	SRP	70.20 ± 22.37	13.33 ± 5.70 [a]	56.87 ± 23.85

[a] $P < 0.05$; P values represent changes from baseline to 2 months within each treatment group, paired t test

Table 3 Differences in the PD and CAL (mean ± SD) for moderately deep pockets (4 mm ≤ PD ≤ 6 mm)

Parameters		Baseline	2 months	
		Mean ± SD	Mean ± SD	Difference
PD	SRP + ERL + NDL (n = 1107)	4.76 ± 0.74	2.85 ± 0.89[b]	1.91 ± 1.03
	SRP (n = 1151)	4.81 ± 0.74	2.96 ± 0.93[b]	1.85 ± 1.00
CAL	SRP + ERL + NDL (n = 1040)	4.09 ± 2.06[a]	3.01 ± 2.13[b]	1.17 ± 1.47[a]
	SRP (n = 1109)	3.41 ± 2.88	2.95 ± 1.85[b]	0.46 ± 2.78

[a] $P < 0.05$; P values represent changes between the test and control groups at baseline and 2 months, Mann–Whitney U test

[b] $P < 0.05$; P values represent changes from baseline to 2 months within each treatment group, Wilcoxon signed-rank test, n represents the number of sites paired-compared

Table 4 Differences in the PD and CAL (mean ± SD) for deep pockets (PD > 6 mm)

Parameters		Baseline	2 months	
		Mean SD	Mean SD	Difference
PD	SRP + ERL + NDL (n = 231)	7.39 ± 0.68	3.75 ± 1.44[b]	3.61 ± 1.43
	SRP (n = 226)	7.35 ± 0.63	3.73 ± 1.41[b]	3.62 ± 1.46
CAL	SRP + ERL + NDL (n = 222)	6.64 ± 2.30[a]	4.10 ± 2.29[b]	2.63 ± 1.73
	SRP (n = 222)	5.94 ± 2.14	3.68 ± 1.97[b]	2.30 ± 2.14

[a] $P < 0.05$; P values represent changes between the test and control groups at baseline and 2 months, Mann–Whitney U test

[b] $P < 0.05$; P values represent changes from baseline within each treatment group, Wilcoxon signed-rank test, n represents the number of sites paired-compared

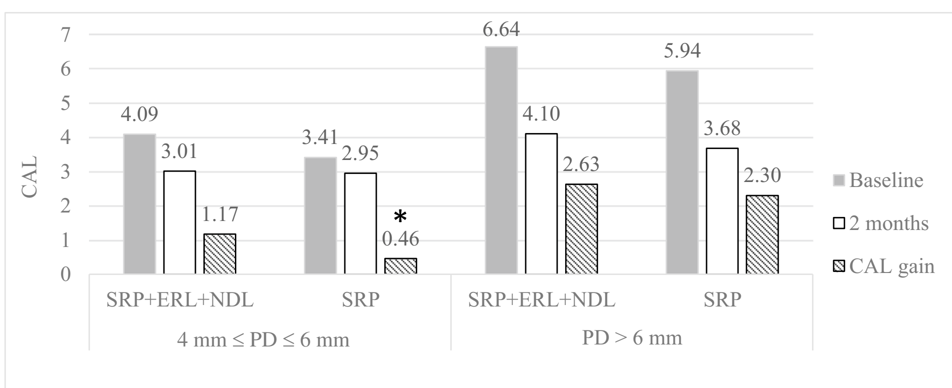

Fig. 1 Clinical attachment level (CAL) at baseline and 2-month post-therapy as well as the CAL gain from baseline to 2 months in moderately deep pockets (4 mm ≤ PD ≤ 6 mm) and deep pockets (PD > 6 mm). (*) Significant difference with the SRP + ERL + NDL group 2-month post-therapy by the Mann–Whitney U test

Discussion

This was a single-blind, randomized controlled study that enrolled thirty-two systemically healthy subjects with generalized stage III or IV periodontitis were enrolled. To the best of our knowledge, this is the first study that has focused on the treatment of severe periodontitis using an ERL and an NDL. The test group (SRP + ERL + NDL) demonstrated greater improvement in CAL than the control group for moderately deep pockets 2 months after the therapy. The combined application of the two lasers improved the clinical outcomes.

In the present study, an ERL and an NDL were applied following SRP in the test group, while the control group was treated by SRP alone. Two months after therapy, the DI was slightly improved relative to baseline but not to a significant degree. Furthermore, the BOP% improved significantly for both groups after therapy, indicating better inflammation control.

Although the lasers as SRP adjuncts were limited to "expert opinion against" [24], the combined application of an ERL and an NDL has not been thoroughly evaluated; indeed, to the best of our knowledge, there are only a few studies addressing this approach. In the present study, calculus and biofilms were removed by SRP, and then, an ERL was used to modify the root surface to improve cell proliferation and remove residual calcified deposits and biofilms. The NDL was used to eliminate pigmented bacteria in the epithelial cells and pockets. The combination of an ERL and NDL may thus be more effective than their application alone. We chose to evaluate the effect of SRP + ERL + NDL in treating severe periodontitis compared with SRP in patients with stage III to IV periodontitis, which has been challenging to treat historically with traditional methods. The results demonstrated that for moderately deep pockets (4 mm ≤ PD ≤ 6 mm), the improvement in CAL was greater at 2 months in the test group (1.17 ± 1.47 mm vs 0.46 ± 2.78 mm). Although the CAL was greater in the test group at baseline, this greater improvement in CAL (0.71 mm versus the SRP group) indicated the advantages of the combined application of the ERL and NDL. For deep pockets (PD > 6 mm), no difference was found for any clinical parameter between the groups. The reasons for these results may lie in the limited ability to access these pockets. It is difficult to reach deep lesions and eliminate dental plaque and calculus with SRP, which in turn limits the penetrating effect of the NDL. A similar result was found in Grzech-Leśniak's study, in which the group treated with an NDL and an ERL (the NdErNd group) had improvements in the PD reduction and CAL gain at 3 months than the SRP group (clinical attachment gain of 1.51 ± 0.21 mm vs 0.80 ± 0.12 mm) in moderately deep pockets, and there was no significant difference in deep pockets [28]. The average CAL gain was similar to that obtained in our study. In the former study, the NdErNd group was treated with an NDL first and then an ERL; NDL treatment was then repeated after 7 and 14 days, which resulted in an increased number of follow-up visits. In Saglam's study [26], which evaluated ERL + NDL therapy for the treatment of periodontitis, twenty-five systemically healthy patients with chronic periodontitis were selected. The test group was treated with ERL + NDL therapy, and the control group was treated with SRP. The results suggested that the combined laser therapy was effective only for deep pockets (PD ≥ 7 mm). The differences in PD reduction were 4.66 ± 0.93 mm vs 3.98 ± 1.45 mm, and those in CAL gain were 4.66 ± 0.93 vs 3.98 ± 1.45 mm at 3 months after therapy. These different results may be due to the different study designs, including differences in the treatment techniques and inclusion criteria used.

There are two limitations of the present study. First, we failed to perform a relatively long-term follow-up; although we initially considered both a 2-month and 6-month follow-up, the 6-month follow-up was interrupted by the novel coronavirus, and only 16 patients returned for an evaluation at this time. The high rate of patients lost to follow-up affected the data analysis; thus, this time point was not included in the results. In addition, the study design did not compare the combined application with either the ERL or NDL alone.

Conclusion

The combination of an ERL and an NDL as an adjunct to SRP can effectively improve the clinical attachment level in the short term in the treatment of severe periodontitis, and it is recommended for clinical applications.

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Declarations

Ethical approval Ethical approval was obtained from the Peking University International Hospital Ethics Committee (2018–063(BMR)).

Conflict of interest The authors declare no competing interests.

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