Clinical Evaluation of Periodontal Surgical Treatment With an Er:YAG Laser: 5-Year Results

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Background: The aim of the present study was to evaluate and compare the long-term clinical outcomes of erbium-doped:yttrium, aluminum, and garnet (Er:YAG) laser–assisted periodontal flap surgery versus conventional treatment with the modified Widman flap procedure.

Methods: A total of 146 single-rooted periodontally involved teeth from 25 patients were included in this study. In each patient, left or right maxillary single-rooted teeth were assigned randomly to one of two groups: group A (Er:YAG laser) and group B (modified Widman flap surgery). Er:YAG laser was used to debride the bone pockets, scale the root surface, and trim the periodontal flap. Recession, probing depth (PD), clinical attachment level (CAL), plaque index (PI), gingival index (GI), and bleeding on probing (BOP) scores were recorded at baseline and at 3, 6, 12, 24, 36, 48, and 60 months.

Results: Both treatments resulted in decreases in PD, PI, GI, and BOP, increases in gingival recession, and gains in CAL. PD reduction in group A versus group B was statistically significant at 6, 12, 24, and 36 months ($P<0.05$). Gains in CAL were significantly greater in group A versus group B at 6, 12, 24, and 36 months. BOP scores were significantly lower in group A versus group B at 3 and 6 months ($P<0.05$). All other differences between treatment groups were not statistically significant.

Conclusions: Surgical treatment of single-rooted teeth with chronic periodontitis using the Er:YAG laser yields greater PD reduction and gains in CAL for up to 3 years compared to conventional Widman flap surgery. The short-term results obtained with both treatments can be maintained over 5 years. *J Periodontol 2007;78:1864-1871.*

KEY WORDS

Chronic periodontitis; clinical trial; laser; surgical flap.

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Periodontal therapy is directed at disease prevention, slowing or arresting disease progression, regeneration of lost periodontal tissues, and maintaining the achieved therapeutic objectives. Scaling and root planing (SRP) remains an essential part of successful periodontal therapy.[1] Debridement of the diseased root surface is performed by mechanical SRP using manual or power-driven instruments. Manual instrumentation includes the use of scalers as well as universal and area-specific curets. Power-driven instruments, such as ultrasonic or air scalers, are used frequently for root surface treatment because they facilitate the procedure and make it more efficient.

In addition to SRP, a variety of treatment techniques have used, e.g., subgingival curettage, gingivectomy, modified Widman flap, and full- or split-thickness flap procedures with or without osseous recontouring.[2-4]

The results of longitudinal clinical trials indicate that all of these techniques are effective in treating moderate to advanced periodontitis. Flap surgery in deeper pockets results in greater immediate pocket reduction and attachment gain,[5] although these differences disappear after 5 years.[6] No specific treatment technique is superior with regard to sustained reduction of probing depth and gain of clinical attachment.[7-10]

Because of the limited access to areas such as furcations, concavities, grooves,

doi: 10.1902/jop.2007.070054

and distal sites of molars, complete removal of bacterial deposits and their toxins from the root surface and within the periodontal pockets is not always possible with conventional mechanical therapy.[11] Thus, failure of SRP at such sites requires surgical intervention.

Pocket reduction or elimination per se is not required in sites that respond to non-surgical therapy and remain stable during maintenance. However, when surgery is required, shallower pockets are the main goal of the therapy, facilitating maintenance therapy and reducing the incidence of recurrence.[12-15]

Different types of lasers have been used in non-surgical periodontal treatment as an alternative or as an adjunct to mechanical SRP. The first application of a laser to dental tissue was reported by Goldman et al.[16] and Stern and Sognnaes,[17] each article describing the effects of the ruby laser on enamel and dentin. However, the current relationship of dentistry with the laser takes its origins from an article published in 1985 by Myers and Myers[18] describing the in vivo removal of dental caries using a modified ophthalmic neodymium-doped:yttrium, aluminum, and garnet (Nd:YAG) laser. The erbium-doped:YAG (Er:YAG) laser was introduced in 1974 by Zharikov et al.[19] as a solid-state laser that generates a light with a wavelength of 2,940 nm. In dentistry, the free-running pulsed Er:YAG laser has been used clinically for caries removal and cavity preparation[20-22] and soft tissue treatment.[23] The United States Food and Drug Administration approved the pulsed Er:YAG laser for hard tissue treatment, such as caries removal and cavity preparation, in 1997;[24] for soft tissue surgery and sulcular debridement in 1999; and for osseous surgery in 2004.

In vitro studies[25] showed that the Er:YAG laser effectively removed root-bound calculus without damage to the subjacent cementum and dentin. Following Er:YAG laser–mediated scaling, root surfaces appear macroscopically smooth,[26] although scanning electron microscopic examination reveals a relatively rough surface compared to that achieved by ultrasonic scaler instrumentation.[27] Apparently the chemical structure of Er:YAG-irradiated root surfaces is not altered and the biocompatibility of diseased surfaces is reestablished, allowing fibroblast attachment.[28-31] Additionally, clinical studies[32-35] demonstrated the effectiveness of the Er:YAG laser in SRP and in reducing subgingival bacterial loads. Several in vivo human studies[32,34,36,37] showed laser treatment alone or in combination with mechanical SRP produced positive trends with respect to gains in clinical attachment level (CAL) and decreases in probing depth (PD) and bleeding on probing (BOP).

Thus, the purpose of this study was to evaluate and compare the long-term clinical outcomes of Er:YAG laser–assisted periodontal flap surgery versus conventional treatment with the modified Widman flap procedure.

MATERIALS AND METHODS

The study was designed as a single-blinded, split-mouth, randomized and controlled trial of 60-month duration. The study protocol was reviewed and approved by the National Medical Ethics Committee of the Republic of Slovenia. The study was conducted in accordance with the Helsinki Declaration of 1975, as revised in 2000, and all participants signed informed consent forms.

A total of 146 single-rooted periodontally involved teeth from 25 patients (14 females and 11 males; age: 46.3 ± 9.2 years) with advanced chronic periodontitis were involved in the study from January 2001. Inclusion criteria were residual PD ≥6 mm and good level of oral hygiene (plaque index [PI] <1) after initial therapy. Patients were excluded from participation in the study if they presented with diabetes, coronary heart disease, chronic obstructive pulmonary disease, tobacco use, or the use of antibiotics in the previous 6 months.

In each patient, left or right maxillary single-rooted teeth were assigned randomly to two groups: group A (Er:YAG laser) and group B (modified Widman flap surgery). All patients received oral hygiene instructions and SRP. At 6 weeks after SRP, a periodontist not involved with providing treatment measured and recorded the following clinical parameters: PI, gingival index (GI), PD, CAL, and gingival recession. BOP was assessed 30 seconds after obtaining the PD measurement. All clinical parameter measurements were taken at six sites per tooth using a manual periodontal probe.† Seven patients with periodontally involved (PD ≥6 mm) upper single-rooted teeth were used to calibrate the examiner. The patients were evaluated on two occasions, 24 hours apart. The reliability coefficient of the examiner was 0.93 for the PD difference of 1 mm.

A modified Widman flap was performed on each subject's left or right maxillary single-rooted teeth according to the randomized assignment and split-mouth experimental design. Group A received conventional periodontal access flap surgery and Er:YAG laser treatment, whereas group B received the same conventional treatment (modified Widman flap) but no Er:YAG laser treatment. Er:YAG laser‡ was used in group A to debride the intrabony pockets (long pulse [LP], i.e., 600 microseconds, 180 mJ/pulse at 20 Hz), scale the root surface (LP, 140 mJ/pulse at 10 Hz), and trim the periodontal flap (very long pulse, i.e., 1 millisecond, 100 mJ/pulse at 10 Hz). A normal sterile saline was used as an irrigation agent.

Post-surgical care consisted of 0.2% chlorhexidine§ rinse twice a day for 14 days. Sutures were removed at 7 days post-surgery at which time the patient initiated

† Thin Williams Probe, Hu-Friedy, Chicago, IL.
‡ Fidelis Plus II, Fotona, Ljubljana, Slovenia.
§ Curasept ADS 220, Curaden International, Kriens, Switzerland.

Table 1.

PD, Gingival Recession, and CAL Values for Both Treatment Groups at Baseline and After 3 to 60 Months

Time (months)	PD (mm)		Recession (mm)		CAL (mm)		CAL Gain (mm)	
	Control	Laser	Control	Laser	Control	Laser	Control	Laser
Baseline	5.78 ± 0.82 (N = 438)	5.63 ± 0.95 (N = 438)	0.58 ± 0.30	0.61 ± 0.25	6.36 ± 2.00	6.14 ± 1.80		
3	2.92 ± 0.70 (N = 438)	2.82 ± 0.70 (N = 438)	0.89 ± 0.45	0.81 ± 0.43	3.81 ± 1.06	3.66 ± 0.91	2.82 ± 0.46	2.85 ± 0.38
6	2.88 ± 0.51 (N = 438)	2.46 ± 0.42* (N = 438)	1.12 ± 0.50	0.95 ± 0.40*	3.90 ± 0.80	3.41 ± 0.65*	2.16 ± 0.29	2.57 ± 0.24*
12	2.67 ± 0.43 (N = 438)	2.50 ± 0.46* (N = 438)	1.15 ± 0.47	0.90 ± 0.40*	3.65 ± 0.67	3.30 ± 0.62*	2.03 ± 0.18	2.44 ± 0.35*
24	2.82 ± 0.43 (N = 438)	2.63 ± 0.36* (N = 438)	1.17 ± 0.50	0.98 ± 0.42*	3.97 ± 0.55	3.43 ± 0.50*	1.97 ± 0.26	2.29 ± 0.23*
36	2.85 ± 0.46 (N = 438)	2.70 ± 0.33* (N = 438)	1.20 ± 0.60	1.04 ± 0.50*	4.10 ± 0.73	3.63 ± 0.61*	1.91 ± 0.31	2.22 ± 0.28*
48	2.88 ± 0.40 (N = 420)	2.82 ± 0.53 (N = 432)	1.24 ± 0.60	1.12 ± 0.67	4.02 ± 0.93	3.89 ± 0.61	1.88 ± 0.21	1.90 ± 0.27
60	2.91 ± 0.55 (N = 414)	2.84 ± 0.43 (N = 426)	1.25 ± 0.45	1.2 ± 0.39	4.05 ± 0.85	3.97 ± 0.89	1.76 ± 0.33	1.72 ± 0.26

Data are mean ± SD.
N = number of measured sites.
* P <0.05 versus the control value.

toothbrushing. Follow-up appointments were scheduled at monthly intervals for 3 months and at month 6 post-surgery, and then once every 6 months during the remainder of the study. All clinical parameters were measured at each observation period, i.e., 3, 6, 12, 24, 36, 48, and 60 months post-surgery.

Statistical Analysis

For purposes of statistical analysis, the clinical outcome variables were changes in PD, gingival recession, BOP, and CAL. All statistical procedures were based on a level of significance of 5% (P <0.05) and a power of 80%. A sample size of 146 enabled detection of a difference of 0.5 mm in a sample with SD = 0.6 mm. Summary statistics were calculated for baseline as well as for 3-, 6-, 12-, 24-, 36-, 48-, and 60-month measurements. Statistical analysis was performed using a two-factor repeated measures analysis of variance followed by Tukey's honestly significant difference post hoc comparison.[‖]

RESULTS

At the baseline examination, there were no statistically significant differences between the two treatment groups in any of the recorded parameters. Both treatments produced reductions in PI, GI, BOP, and PD, increases in gingival recession, and gains in CAL. Table 1 summarizes the results of PD, gingival recession, and CAL measurements for both groups at baseline and at intervals of 3 to 60 months.

In both treatment groups, the PD decreased significantly compared to baseline (P <0.001), and this reduction was maintained throughout the study. However, the mean PD reduction at 6, 12, 24, and 36 months was significantly greater (P <0.05) for the laser-treated sites (group A) than for sites that were treated with a Widman flap only (group B).

Gingival recession increased significantly in both treatment groups compared to baseline (P <0.05). The mean gingival recession at 6, 12, 24, and 36 months was significantly lower (P <0.05) for the laser-treated sites (group A).

As a primary outcome variable, CAL decreased significantly, compared to baseline, after 3 months in both treatment groups (P <0.001). In the control group, an initial decrease in CAL after 3 months was followed by a slight increase over the remaining observation period. In the laser group, CAL decreased further after the 6- and 12-month examinations and then increased slightly between the 24- and 60-month

‖ SPSS 12.0, SPSS, Chicago, IL.

Table 2.

GI, BOP, and PI Values for Both Treatment Groups at Baseline and After 3 to 60 Months

Time (months)	GI		BOP (%)		PI	
	Control	Laser	Control	Laser	Control	Laser
Baseline	1.68 ± 0.42	1.58 ± 0.35	39.4	40.2	0.78 ± 0.20	0.71 ± 0.27
3	1.04 ± 0.53	1.12 ± 0.47	24.6	22.7*	0.82 ± 0.25	0.77 ± 0.21
6	1.33 ± 0.25	1.26 ± 0.34	19.3	14.8*	0.86 ± 0.32	0.79 ± 0.35
12	1.00 ± 0.29	1.05 ± 0.31	16.1	15.7	0.93 ± 0.31	0.86 ± 0.33
24	1.10 ± 0.44	1.00 ± 0.38	16.5	14.3	0.90 ± 0.24	0.85 ± 0.30
36	0.83 ± 0.36	0.90 ± 0.45	15.4	13.8	0.85 ± 0.22	0.81 ± 0.23
48	0.90 ± 0.46	0.92 ± 0.33	14.8	14.5	0.83 ± 0.28	0.90 ± 0.29
60	0.84 ± 0.38	0.79 ± 0.25	16.7	15.6	0.76 ± 0.21	0.80 ± 0.29

Data are mean ± SD.
* $P<0.05$ versus the control value.

examinations. CAL was lower at laser-treated sites after 6 to 36 months than at the sites that were treated with a Widman flap only ($P<0.05$).

CAL gain decreased gradually in the laser group and in the control group from months 3 to 60. After 48 months, the CAL gain in the laser group was similar to the value of the control group. The mean gain of CAL at 6, 12, 24, and 36 months was significantly greater ($P<0.05$) for the laser-treated sites (group A).

GI decreased after surgery in both treatment groups ($P<0.05$) and remained low over the entire period (Table 2). No differences were found between the two groups. Also, BOP scores for both treatment groups were reduced after the surgery. The laser group exhibited a lower BOP score at 3 and 6 months after surgery compared to the control group ($P<0.05$). The relatively low baseline values for PI in both treatment groups did not change significantly over the 60 months of the study and yielded no statistical difference between the two groups.

DISCUSSION

The present study indicated that the use of the Er:YAG laser as an adjunct to the surgical treatment of deep periodontal pockets involving single-rooted teeth can result in statistically significant reductions in PD and BOP and gains in CAL for ≥36 months post-treatment.

Results obtained in the present study with conventional modified Widman flap surgery, i.e., reduction in PD and gains in CAL, confirm those reported by other investigators. For example, Lindhe et al.[38] reported a PD reduction of 3.4 ± 0.8 mm and CAL gain of 1.5 ± 0.6 mm after open flap debridement on non-molar teeth with initial probing depth >6 mm. Similarly, Pihlstrom et al.[39] showed a significant PD reduction of 3.4 mm and CAL gain of 1.19 mm, and Isidor and Karring[40] reported PD reduction of 2.5 ± 0.4 mm and CAL gain of only 0.2 ± 0.3 mm after periodontal surgical treatment. In our study, modified Widman flap surgery resulted in immediate PD reduction and CAL gain, which is in line with the findings of Pilhstrom et al.[5] for deeper pockets (>6 mm). Nevertheless, the immediate significant post-surgical differences in PD and CAL, compared to non-surgical treatment, tend to fade after 4 to 5 years.[6] The significant differences in PD and CAL between the laser and control groups in our study decreased gradually after surgery, and the significance disappeared 3 years post-surgery; however, clinically acceptable values of PD and CAL were sustained over a 5-year period.

Addition of the Er:YAG laser to conventional modified Widman flap surgery resulted in greater reduction in PD and greater gain in CAL compared to modified Widman flap surgery alone. The reduction in PD and the gain in CAL were significantly greater in the laser group from month 6 to month 36. No further differences in any of the observed clinical parameters were found after 36 months.

Controlled clinical trials and case reports[23,32,36,37,41] have indicated that non-surgical and surgical periodontal treatment with an Er:YAG laser leads to significant gain in CAL. The reduction in PD and improvement in CAL in our study are comparable to those achieved by Schwarz et al.[42] who evaluated the use of the Er:YAG laser in combination with an enamel matrix protein derivative for the treatment of intrabony periodontal defects. At 6 months after therapy, the sites treated with the Er:YAG laser and enamel matrix protein derivative showed a significant reduction in mean PD from 8.6 ± 1.2 mm to 4.6 ± 0.8 mm and a change in mean CAL from 10.7 ± 1.3 mm to 7.5 ± 1.4 mm. However, no statistically significant differences in any of the investigated parameters were observed between the test and control groups; therefore, the investigators concluded that the combination of Er:YAG laser and enamel matrix protein derivative did not improve the clinical outcome of surgical therapy. As reported previously, the use of enamel matrix protein derivative itself might improve the clinical outcome of periodontal surgery.[43-48]

The biocompatibility of root surface is an important factor for new attachment formation, clinically noted as a gain in CAL following surgical therapy. In vitro, irradiation of root surfaces with the Er:YAG laser (60 mJ/pulse and an energy density of 3 J/cm^2) was reported to accelerate adhesion and growth of human gingival fibroblasts.[30] The investigators hypothesized that the laser exerts its stimulatory effect through the production of prostaglandin E_2 via elevated expression of cyclooxygenase-2, an important regulatory pathway in accelerated wound healing.[49] The laser settings used in the present study were similar to those reported by Crespi et al.[35] Their study reported significantly higher numbers of attached cells on laser-treated root surfaces (3,720 ± 316 cells/mm^2) compared to untreated control surfaces (130 ± 80 cells/mm^2) and ultrasonically treated surfaces (658 ± 140 cells/mm^2). The renewal of biocompatibility of periodontally involved root surfaces after Er:YAG laser irradiation might have enhanced new attachment and contributed to a significant gain of CAL in our study.

Obviously, decreased bacterial loads within the periodontal pockets should enhance healing. Conventional mechanical treatment fails to remove bacteria completely, usually produces a smear layer, and may result in an instrumentation-induced irregular surface topography. A smear layer may adversely affect the healing of periodontal tissues because it contains bacteria and inflammatory substances, such as debris of infected cementum and calculus.[50] Root conditioning at neutral pH removes the smear layer and exposes collagen fibers and dentinal tubules, enhancing the biocompatibility and new connective tissue attachment with cementogenesis.[51,52] In vitro studies reported bactericidal and detoxification effects of laser irradiation on root surfaces without producing a smear layer, implying that the laser-treated root surface may provide favorable conditions for the attachment of periodontal tissue. Findings from Ando et al.[53] suggested a high bactericidal potential of Er:YAG laser, even when used at a low-energy level. In this in vitro study, inhibition of bacterial growth was noted at sites irradiated with an energy density of ~0.3 J/cm^2. Survival ratios of *Porphyromonas gingivalis* colonies decreased significantly at energies of 7.1 and 10.6 J/cm^2. In addition, another in vitro study[54] reported that Er:YAG laser radiation reduced the bacterial load of *Actinobacillus actinomycetemcomitans* to 8.3% of the initial counts. Besides viable bacteria, laser radiation removed endotoxin from root surfaces in a dosage-dependent manner.[55] Clinical studies[32,36,37] using dark-field microscopy showed a significant increase in cocci and non-motile rods and a decrease in the amount of motile rods and spirochetes after laser SRP. The microbiologic effects of laser SRP with an Er:YAG laser range from complete elimination[35] to statistically insignificant reductions in the subgingival microflora.[34]

The lack of microbial data in our study does not allow us to correlate the levels of microbiota in baseline periodontal pockets and in residual pockets after the surgery with clinical parameters at different time points of the study. However, a clinical indicator of inflammation, BOP, roughly reflects the level of periodontal pathogens in the pocket.[56,57] Adjunctive use of the Er:YAG laser with the modified Widman flap significantly decreased BOP in the laser group compared to the control group (22.7% versus 24.6% at month 6 and 14.8% versus 19.3% at month 12). We hypothesized that this reduction might be due to a bactericidal effect of the Er:YAG laser and to detoxification of lipopolysaccharide-contaminated root surfaces.

Elimination of periodontal pathogens by conventional mechanical instrumentation or laser radiation is followed by healing of periodontal tissues. Intrabony periodontal pockets in our patients were degranulated with the Er:YAG laser at 180 mJ/pulse, which is in accordance with published data about the use of the Er:YAG laser in bone remodeling and removal.[58-60] Initial histologic studies of Er:YAG laser bone removal revealed a minimal (5 to 10 μm) thermal injury zone on the remaining bone.[58] Major changes on the bone surface after Er:YAG laser irradiation included microcracking, disorganization, slight recrystallization of the original apatites, and reduction of surrounding organic matrix.[60] Fourier transform infrared spectroscopy revealed that the chemical composition of the bone surface was unchanged after Er:YAG laser ablation, and no toxic substances were produced.[61]

Recently, Mizutani et al.[62] demonstrated the modulatory role of the Er:YAG laser on new bone formation after periodontal flap surgery in an animal model. Degranulation and root debridement were performed effectively with an Er:YAG laser without major thermal damage, and it was significantly faster than with a curet. Histologically, the amount of newly formed bone was significantly greater in the laser group than in the curet group, although both groups showed similar amounts of cementum formation and connective tissue attachment.

In the present study, in addition to CAL and PD, a difference was noted in BOP scores when comparing the laser and control groups. Plaque and gingival index values (indicative of oral hygiene and gingival inflammation) showed little to no change. Differences in BOP between the laser and control groups detected 6 and 12 months after surgery disappeared after 24 months; however, the differences in CAL and PD persisted for up to 36 months. These results led us to speculate that laser radiation, along with the oral hygiene level, is responsible for the improved clinical outcome. Furthermore, even an initial effect of Er:YAG laser irradiation, expressed as a decrease in BOP score, is unlikely to maintain the long-term improvement in CAL and PD. The initial decrease in bacterial level is an important mechanism of periodontal healing; however, the significant difference in healing probably reflected the altered biocompatibility of the root surface and new bone formation after periodontal laser surgery.

Despite the large number of publications concerning the application of lasers in periodontics, there still are relatively few longitudinal clinical trials. This, in turn, has led to a persistent disagreement among clinicians regarding the appropriate application of lasers to the treatment of chronic periodontitis. Although there is no clear evidence that laser applications improve clinical outcome as a result of the action of curettage,[63] the present study demonstrated that surgical treatment of single-rooted teeth with chronic periodontitis using the Er:YAG laser yielded greater PD reduction and gains in CAL for up to 3 years compared to conventional Widman flap surgery. The study also demonstrated that the short-term results obtained with both treatments can be maintained over 5 years.

ACKNOWLEDGMENTS

This study was supported by the Slovenian Research Agency (J3-3516). Drs. Gaspirc and Skaleric report no conflicts of interest related to this study.

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Submitted January 25, 2007; accepted for publication April 12, 2007.