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Healing of intrabony defects following surgical treatment with or without an Er:YAG laser

A pilot study

Anton Sculean[1], Frank Schwarz[2], Mohammad Berakdar[1], Péter Windisch[3], Nicole B. Arweiler[4] and Georg E. Romanos[5]

[1]Department of Conservative Dentistry and Periodontology, Johannes Gutenberg-University, Mainz, Germany; [2]Department of Oral Surgery, Heinrich Heine-University, Düsseldorf, Germany; [3]Department of Periodontology, Semelweis University Budapest, Hungary; [4]Department of Conservative Dentistry and Periodontology, Albert-Ludwigs-University, Freiburg, Germany; [5]Department of Oral Surgery and Implantology, University of Frankfurt, Germany

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Abstract

Aim: The aim of this controlled, parallel design clinical study was to compare the healing of intrabony periodontal defects following treatment with access flap surgery with and without debridement with an Er:YAG laser.

Methods: Twenty-three patients each of whom exhibited one deep intrabony defect were randomly treated with either access flap surgery followed by root surface and defect debridement using an Er:YAG laser (KEY3®) (160 mJ, 10 Hz) (test), or with access flap surgery followed by root surface and defect debridement using hand and ultrasonic instruments (control). The following clinical parameters were recorded at baseline and at 6 months: plaque index; gingival index; bleeding on probing; probing depth (PD); gingival recession; and clinical attachment level (CAL). The primary outcome variable was CAL. No statistically significant differences between the groups were found at baseline.

Results: No serious adverse events were observed after any of the treatments. The results have shown that in the test group the PD decreased from 7.8 ± 1.3 to 4.1 ± 1.3 mm ($p < 0.001$) and the CAL changed from 9.8 ± 2.9 to 7.2 ± 2.5 mm ($p < 0.001$). In the control group the PD decreased from 7.8 ± 0.8 to 4.6 ± 1.6 mm ($p < 0.001$) and the CAL changed from 9.2 ± 1.2 to 7.7 ± 1.6 mm ($p < 0.01$). The test group displayed a higher tendency for CAL gain, although this tendency did not prove to be statistically significant.

Conclusion: Within the limits of the present study, it can be concluded that: (i) at 6 months following treatment both therapies led to significant improvements of the investigated clinical parameters, and (ii) an Er:YAG laser may represent a suitable alternative for defect and root surface debridement in conjuction with periodontal surgery.

Key words: clinical trial; intrabony defects; lasers/therapeutic use; surgical periodontal therapy

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In recent years, the use of laser radiation has been expected to serve as an alternative or adjunctive treatment to conventional, mechanical periodontal therapy. Various advantageous characteristics, such as hemostatic effects, selective calculus ablation or bactericidal effects against periodontopathic pathogens might lead to improved treatment outcomes (Aoki et al. 1994, Ando et al. 1996, Folwaczny et al. 2002). The wavelengths of the lasers most commonly used in periodontics, which include diode lasers, the Nd:YAG laser (neodymium-doped: yttrium, aluminium and garnet), the Er:YAG laser (erbium-doped:yttrium, aluminium and garnet) and the CO_2 (carbon-dioxide) laser, range from 819 to 10.600 nm. Due to an excellent soft tissue ablation capacity, CO_2 lasers have been successfully used as an adjunctive tool to deepithelialize the mucoperiosteal flap during traditional flap surgery (Centty et al. 1997). Diode and Nd:YAG lasers were mainly used for laser-assisted subgingival curettage and disinfection of the periodontal pocket with various degrees of success (Cobb et al. 1992, Moritz et al. 1998, Liu et al. 1999). However, several studies reported on thermal side effects, such as melting, cracking or carbonization

when CO_2 and Nd:YAG lasers were used directly on root surfaces (Tewfik et al. 1994, Wilder-Smith et al. 1995, Tucker et al. 1996, Israel et al. 1997). In case of the CO_2 laser these negative effects could be avoided when irradiation was performed in a pulsed mode with a defocused beam (Barone et al. 2002). So far, there is limited information about the effects of diode laser radiation on the surface properties of root surfaces. The results from recent studies showed that this laser may also cause damage to periodontal hard tissues if irradiation parameters are not adequate (Kreisler et al. 2002, Schwarz et al. 2003c). Furthermore, neither CO_2 nor Nd:YAG nor diode lasers were effective in removing calculus from the root surface (Tucker et al. 1996, Moritz et al. 1998, Liu et al. 1999). Since, according to the cause-related concept of periodontal therapy, the main objective of treatment is to remove all calcified deposits from the root surface (O'Leary 1986), these types of lasers should only be used as an adjunct to mechanical periodontal treatment. In contrast, the ability of the Er:YAG laser to effectively ablate dental calculus without producing major thermal side-effects to adjacent tissue has been demonstrated in numerous studies (Aoki et al. 1994, Israel et al. 1997, Folwaczny et al. 2000, Schwarz et al. 2003c). The absence of thermal damages was most likely caused by the optical characteristics of its wavelength of 2940 nm that peaks close to the absorption coefficient of water. Furthermore, several studies have demonstrated antimicrobial effects against periodontopathic bacteria and the ability to remove lipopolysaccharides from root surfaces by Er:YAG laser radiation (Ando et al. 1996, Yamaguchi et al. 1997, Folwaczny et al. 2002). Controlled clinical trials (Schwarz et al. 2001, 2003a d) and case report studies (Watanabe et al. 1996, Schwarz et al. 2000) have indicated that non-surgical periodontal treatment with an Er:YAG laser may lead to significant clinical improvements as evidenced by probing depth (PD) reduction and gain of clinical attachment. These improvements were comparable with those obtained following treatment with hand instruments. Furthermore, the obtained clinical results were maintained for a period of up to 2 years (Schwarz et al. 2003d). Preliminary clinical results have also indicated that this minimally invasive device may allow instrumentation of very deep and narrow pockets without leading to major trauma of the hard and soft tissues; that is, removal of tooth substance and increase in gingival recession (GR) (Schwarz et al. 2001). However, histological and SEM examination showed that the Er:YAG laser ablated not only the calculus, but also a certain amount of the superficial portion of the underlying cementum (Aoki et al. 1994, Israel et al. 1997, Folwaczny et al. 2000, Schwarz et al. 2003c). The root surface was left with an acid-etched appearance microscopically. These alterations may require traditional root planing instrumentation to achieve the desired smoothness and detoxification. However, the combined treatment Er:YAG laser and scaling and root planing using hand instruments did not seem to additionally improve the outcome of the therapy compared with laser treatment alone, suggesting from a clinical point of view that the Er:YAG laser may serve as an alternative treatment modality to conventional, mechanical periodontal therapy (Schwarz et al. 2003a). Preliminary clinical results have demonstrated that treatment of deep intrabony periodontal defects with the combination of an Er:YAG laser and the application of an enamel matrix protein derivative (EMD) may lead to a clinically important and statistically significant gain of clinical attachment (Schwarz et al. 2003b). Based on these findings, the Er:YAG laser may also be used in conjunction with conventional periodontal flap surgery. To the best of our knowledge until now no investigations from controlled clinical studies are available evaluating clinically the healing following periodontal surgery and defect debridement with an Er:YAG laser. Therefore, the aim of the present prospective, controlled, clinical trial was to evaluate clinically the healing of intrabony defects following access flap surgery with and without defect and root surface debridement with an Er:YAG laser.

Materials and Methods

Study design

Twenty-three patients (17 females and six males) diagnosed of advanced chronic periodontitis were included in the study based on signed informed consent. The study was in accordance with the Helsinki Declaration of 1975, as revised in 1983. Criteria for patient selection were: (a) presence of one intrabony defect with a PD $\geqslant$ 6 mm at interproximal sites (mesiobuccal (mb), mesiolingual (ml), distobuccal (db), or distolingual (dl)) and an intrabony component of $\geqslant$ 3 mm as detected on radiographs, (b) no systemic diseases, (c) no treatment of periodontitis for the last 2 years, (d) good level of oral hygiene. As criterion for a good level of oral hygiene a mean plaque index score (PlI) $<$ 1 was chosen (Löe 1967). Two to 3 months prior to surgery each patient was given thorough oral hygiene instruction, and full mouth supra- and subgingival scaling and root planing under local anesthesia.

One week prior and at 6 months after the surgical procedure the following clinical parameters were assessed in the whole mouth by the same blinded and previously calibrated investigator (MB): PlI, gingival index (GI), bleeding on probing (BOP), pocket depth (PD), GR, clinical attachment level (CAL). The measurements were made at six sites per tooth: mb, midbuccal (b), db, ml, midlingual (l), dl. The same type of periodontal probe was used for all clinical measurements (PCP 12, Hu-Friedy, Chicago, Illinois, USA). The cemento-enamel junction (CEJ) was used as the fixed reference point. In cases where the CEJ was not clearly visible, a restoration margin was used for these measurements. During surgery and after the complete removal of granulation tissue from the defects, the following measurements were made: distance from the cemento-enamel junction to the bottom of the defect (CEJ-BD), distance from the CEJ to the most coronal extension of the alveolar bone crest (CEJ-BC). The intrabony component (INTRA) of the defects was defined as CEJ-BD–CEJ-BC. The study reports only measurements at the same deepest point of the selected defect. Prior to surgery and at 6 months after, periapical radiographs were taken using the long cone parallel technique.

Surgical procedure

All operative procedures for both test and control groups were performed under local anesthesia. Following intracrevicular incisions, full thickness mucoperiosteal flaps were raised buccally and lingually. Only after the surgical site was prepared patients were randomly selected by a toss of coin for assignment to the test or control group.

In the test group the granulation tissue from the defects and the root surfaces were debrided with an Er:YAG laser (KEY3®, KaVo, Biberach, Germany) device emitting a pulsed infrared radiation at a wavelength of 2.94 μm without any other mechanical instrumentation. Laser parameters were set at 160 mJ/pulse and 10 pulses/s (Schwarz et al. 2000, 2001, 2003a d), and pulse energy at the tip (size 0.5 × 1.65 mm) was approximately 120 mJ/pulse. The laser beam was guided onto the root surfaces under water irrigation with a specially designed periodontal handpiece and a chisel-shaped glass fiber tip (2061, KaVo, Biberach, Germany). The treatment was performed from coronal to apical in parallel paths with an inclination of the fiber tip of 15–20° (Folwaczny et al. 2001) to the root surface. In the control group all granulation tissue was removed from the defects and the roots were thoroughly scaled and planed using hand and ultrasonic instruments. No root conditioning was performed in any of the groups. In both groups the flaps were repositioned and closed with vertical or horizontal mattress sutures.

Postoperative management

The postoperative care consisted of administration of non-steroidal anti-inflammatory drugs (Ibuprofen, 3×400 mg daily for 2–3 days starting the day of surgery) and mouth rinses with a 0.2% chlorhexidine digluconate solution twice a day for 2 min over the first 4 postoperative weeks. Only after this period, tooth brushing was resumed in the operated areas. Sutures were removed 14 days after surgery. Recall appointments including supragingival tooth cleaning and reinforcement of the oral hygiene were performed every second week during the first 3 months following surgery and once per month for the remaining observation period of 6 months.

Statistical analysis

The statistical analysis was performed using a commercially available software (SPSS® for Windows 95, SPSS Inc., Chicago, IL, USA). The primary outcome variable was CAL. For these calculations only the same deepest site per tooth was included. The paired *t*-test was used to compare the data from the baseline to those at 6 months for each treatment group. Comparisons between treatment groups at baseline and those at 6 months were accomplished with the unpaired *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 0.70.

Results

Healing was uneventful in all cases. All patients tolerated well the surgical procedure. Minimal swelling of the soft tissues surrounding the operated areas was observed at four sites in the test group and at seven sites in the control group during the first postoperative days.

The mean values for PlI, GI and BOP at baseline and at 6 months following surgery are shown in Table 1. Between the two groups no statistically significant differences in these parameters were found at baseline. The PlI did not reveal in any of the two groups a statistically significant difference neither between baseline and 6 months nor between the groups.

At 6 months the GI and the BOP decreased significantly in both groups ($p < 0.001$). However, the difference between the two groups was not statistically significant.

The defect characteristics, as measured during surgery, are presented in Tables 2 and 3. No differences were found in terms of defect depth or configuration between the two groups.

The mean baseline PD was 7.8 ± 1.3 mm in the test group and 7.8 ± 0.8 mm in the control group (Table 4). No statistically significant difference was found. At 6 months mean PD was 4.1 ± 1.3 and 4.6 ± 1.6 mm, respectively. Thus, mean PD decreased significantly in both groups compared with the baseline data ($p < 0.001$). Again, no significant difference between the groups was found.

Mean baseline CAL was 9.8 ± 2.9 mm in the test group and 9.2 ± 1.2 mm in the control group (Table 4). This difference was not statistically significant. At 6 months mean CAL was 7.2 ± 2.5 and 7.7 ± 1.6 mm, respectively, presenting statistically significant improvement compared with baseline ($p < 0.001$). Although, in the test group a greater tendency for CAL improvement was observed, this improvement failed to prove statistically significant. In both groups, the postoperative radiographs after 6 months revealed no increases in density of the intrabony components when compared with the preoperative radiographs.

The statistical analysis did not show any gender-related differences in terms of the investigated clinical parameters. Due to the small number of smokers in each group (two in the test group and three in the control group) statistical analysis was not performed.

Table 3. Distribution and configuration of treated defects

	Test ($n = 12$)	Control ($n = 11$)
1 wall	11	9
3 wall	1	2

Table 1. Mean (± SD) plaque- and gingival-index scores and bleeding on probing at baseline and the 6 months examination

	Test ($n = 12$)	Control ($n = 11$)
plaque index scores		
baseline	1.0 ± 0.7	0.9 ± 0.5
6 months	0.9 ± 0.8	1.0 ± 0.7
gingival index scores	1.9 ± 0.7	1.8 ± 0.6
baseline	1.0 ± 0.6	0.9 ± 0.7
6 months		
bleeding scores	40%	44%
baseline	15%	18%
6 months		

Table 2. Baseline defect characteristics expressed in mm (mean ± SD) as measured at interproximal sites (mesiobuccal, mesiolingual, distobuccal, or distolingual

Treatment	PD (mm)	GR (mm)	CAL (mm)	CEJ-BD (mm)	CEJ-BC (mm)	INTRA (mm)
test ($n = 12$)	7.8 ± 1.3	2.2 ± 1.6	9.8 ± 2.9	10.6 ± 1.6	7.4 ± 1.5	3.2 ± 1.6
control ($n = 11$)	7.8 ± 0.8	1.5 ± 1.0	9.2 ± 1.2	10.2 ± 1.7	7.1 ± 1.6	3.1 ± 1.4

Table 4. Clinical parameters at baseline and 6 months for the test and control groups

Parameter	Test ($n = 12$)		p value	Control ($n = 11$)		p value
	baseline	6 months		baseline	6 months	
PD	7.8 ± 1.3	4.1 ± 1.3	<0.001	7.8 ± 0.8	4.6 ± 1.6	<0.001
GR	2.2 ± 1.6	3.1 ± 2.0	<0.01	1.5 ± 1.0	3.2 ± 1.3	<0.01
CAL	9.8 ± 2.9	7.2 ± 2.5	<0.001	9.2 ± 1.2	7.7 ± 1.6	<0.001

No significant differences between the test and control group were found.

Discussion

The results of the present study have shown that surgical treatment of intrabony defects and defect debridement with either an Er:YAG laser or hand- or ultrasonic instruments may result in significant PD reduction and CAL gain. The observation that the use of an Er:YAG laser for defect debridement and root surface conditioning did neither lead to postoperative complications nor to impaired clinical healing indicates that this type of laser may not have any detrimental effect when employed in conjunction with periodontal surgery. However, no statistically significant and clinically important differences in any of the investigated parameters were observed between both treatment modalities. In this context, it should be pointed out that the sample size of this study was relatively small, and does not allow for definitive conclusions to be drawn. These data may serve as a basis to design a clinical trial aimed at showing statistical equivalence between both treatment modalities as suggested by Gunsolley et al. (1998). On the other hand it needs to be pointed out that these are the first data from a controlled clinical study evaluating the use of an Er:YAG laser in conjunction with periodontal surgery. The mean gain of attachment 6 months postoperatively was 2.6 mm for test sites and 1.5 mm for control sites. So, the test group displayed a greater, but statistically not significant, tendency for CAL improvement compared with the control group. This difference might be explained by the fact that formation of a smear layer after both mechanical scaling and root planing and ultrasonic instrumentation has been reported to be detrimental to periodontal tissue healing as it may inhibit reattachment of cells to the root surface (Polson et al. 1984, Blomlöf & Lindskog 1995, Blomlöf et al. 1997b). In order to improve the biocompatibility of the root surface, conditioning with various substances such as ethylenediaminetetraacetic acid gel (EDTA) at neutral pH, citric- and ortho-phosphoric acids and most recently lasers have been proposed (Polson et al. 1984, Blomlöf & Lindskog 1995, Blomlöf et al. 1997a, Yamaguchi et al. 1997, Sasaki et al. 2002). The Er:YAG laser seems to have the potential to remove subgingival calculus and superficial layers of cementum without the formation of a smear layer (Schwarz et al. 2003c). These findings may be supported by the preliminary results of a recent study evaluating the combination therapy of deep intrabony periodontal defects using an Er:YAG laser and EMD. The test combination did not seem to additionally improve the clinical outcome of the therapy compared with mechanical defect and root surface debridement+EDTA+EMD.

Furthermore, the Er:YAG laser has a high bactericidal potential against periodontopathic bacteria (Ando et al. 1996, Folwaczny et al. 2002) and the capacity for a removal of bacteria-derived endotoxin from the root surface (Yamaguchi et al. 1997, Sugi et al. 1998). In this context it is important to point to the results from recent in vitro studies which have shown that the surface structure of previously diseased roots after Er:YAG laser irradiation seem to offer better conditions for the adherence of PDL fibroblasts than scaling and root planing with hand instruments (Rossa et al. 2002, Schoop et al. 2002). These observations probably explain, at least in part, the positive effect of the tested Er:YAG laser upon clinical healing when used in conjunction with periodontal surgery.

The mean gain of CAL obtained in the control group is in agreement with most of the reported results following access flap surgery in intrabony pockets (Cortellini et al. 1996, Camargo et al. 2000, Sculean et al. 2001). Slight differences in the results may be explained with baseline defect depth and configuration. It is well known that the postoperative CAL gain obtained after any type periodontal surgery is dependent upon initial defect depth (i.e. the deeper the defect the higher the CAL gain) (Ramfjord et al. 1987, Kaldahl et al. 1996, Cortellini et al. 1998).

Within the limits of the present study, it can be concluded that: (i) at 6 months following treatment both therapies led to significant improvements of the investigated clinical parameters, and (ii) an Er:YAG laser may represent a suitable alternative for defect and root surface debridement in conjuction with periodontal surgery.

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Address:
Anton Sculean
Department of Conservative Dentistry and Periodontology
Johannes Gutenberg-University
55131 Mainz,
Germany
Fax: +49 6551 7944
E-mail: anton.sculean@gmx.de