Journal of Clinical
Periodontology

Efficacy of subgingival calculus removal with Er:YAG laser compared to mechanical debridement: an in situ study

Jörg Eberhard[1], Heiko Ehlers[1], Wolfgang Falk[1], Yahya Açil[2], Hans-Karl Albers[1] and Søren Jepsen[3]
Departments of [1]Operative Dentistry and Periodontology and [2]Maxillofacial Surgery, University Hospital Schleswig-Holstein, Kiel, Germany and [3]Periodontology, Conservative and Preventive Dentistry, University Hospital Bonn, Germany

Eberhard J, Ehlers H, Falk W, Açil Y, Albers H-K, Jepsen S: Efficacy of subgingival calculus removal with Er:YAG laser compared to mechanical debridement: an in situ study. J. Clin Periodontol 2003; 30: 511–518. © Blackwell Munksgaard, 2003.

Abstract

Objectives: The aim of the present study was to compare the effectiveness of subgingival calculus removal from periodontally involved root surfaces with an Er:YAG laser compared to hand instrumentation in situ.

Methods: The mesial and distal surfaces of 30 single-rooted teeth with untreated periodontitis were treated either by hand instrumentation (scaling and root planing (SRP)) or by Er:YAG laser irradiation with the aim of achieving a calculus-free root surface. Subgingival plaque samples were obtained before and immediately after treatment for microbiological evaluation by culture and DNA probe analysis. The teeth were extracted and the residual calculus was measured by means of digitized planimetry. The morphology of the root surface was evaluated by scanning electron microscopy, and undecalcified sections were analyzed to determine residual calculus and the extent of cementum removal following both treatments.

Results: Following laser irradiation, $68.4 \pm 14.4\%$ of the root surface was calculus free in contrast to $93.9 \pm 3.7\%$ after SRP when both treatments were performed for the same time ($2:15 \pm 1:00$ min). If laser irradiation was allowed twice the time used for hand instrumentation, $83.3 \pm 5.7\%$ of the root surface was devoid of calculus. The effectiveness of both treatments was not related to initial probing depth. The histologic evaluation showed that after SRP 73.2% of root dentin was completely denuded from cementum, while only a minimal cementum reduction was apparent after laser irradiation. Both treatment modalities resulted in a similar reduction of periodontopathogens.

Discussion: The present investigation could demonstrate the in vivo capability of the Er:YAG laser to remove calculus from periodontally involved root surfaces, although the effectiveness did not reach that achieved by hand instrumentation. The lack of cementum removal in contrast to SRP may qualify the laser as an alternative approach during supportive periodontal therapy.

A primary goal in the treatment of periodontitis is the removal of bacterial deposits and the arrest of disease progression (American Academy of Periodontology 2001). There is considerable evidence to support scaling and root planing (SRP) as one of the most commonly used procedures for the treatment of infectious periodontal diseases (Ramfjord 1980, Badersten et al. 1981, Cercek et al. 1983, Badersten et al. 1984, Lindhe et al. 1984). As a final goal of SRP procedures, the complete removal of adherent plaque, calculus and infected root cementum is desirable (Aleo et al. 1975, Fujikawa et al. 1988), although a complete removal is rarely attained (Jones & O'Leary 1978, Breininger et al. 1987, Buchanan & Robertson 1987, Kepic et al. 1990, Sherman et al. 1990).

In search for a more efficient and less difficult instrumentation, investigators have proposed lasers as alternatives or adjuncts for SRP in periodontal therapy (Morlock et al. 1992, Neill & Mellonig 1997). The thermomechanical ablation mechanism and the high absorption of its wavelength by water may qualify the Er:YAG laser in particular as an effective tool in periodontal and also in general dental applications (Hibst & Keller 1989, Watanabe et al. 1996). The effects of Er:YAG laser irradiation on periodontally involved root surfaces have been examined and its capacity

to remove subgingival calculus and superficial layers of infected cementum has been demonstrated in vitro (Aoki et al. 1994, 2000, Keller et al. 1997). In comparison with other laser systems, the Er:YAG laser led to minor structural alterations on the root surface with no side-effects on the dental pulp (Keller & Hibst 1989, Paghdiwala et al. 1993, Wigdor et al. 1993, Israel et al. 1997, Mehl et al. 1997, Gaspirc & Skaleric 2001). The Er:YAG laser showed a high bactericidal potential and the capacity to reduce lipopolysaccharide contamination of the root surface (Ando et al. 1996, Yamaguchi et al. 1997). The clinical outcome 6 months after periodontal therapy with an Er:YAG laser was equivalent to SRP (Schwarz et al. 2001a, b).

The present in situ study was designed to compare the effectiveness of subgingival calculus removal by laser irradiation with conventional hand instrumentation.

Material and Methods
Selection of teeth

Twelve patients (age: 39–59 years) with untreated advanced chronic periodontitis contributed a total of 30 teeth. These single-rooted teeth were designated for extraction and exhibited bone loss of at least one-third of the root length, similar probing depth on the mesial and distal surfaces and radiographic evidence of subgingival calculus. Each patient was given a detailed description of the procedure and was required to sign an informed consent form prior to participation. The study was approved by the local ethic's committee.

Clinical measurements

Each subgingival tooth surface was evaluated for the presence of calculus with a CP-8 periodontal probe (Hu-Friedy, Leimen, Germany). Probing pocket depth was measured at 6 sites per tooth using a pressure-calibrated periodontal probe set at 20 g (Vivacare, Vivadent, Schaan/Lichtenstein).

Instrumentation of root surfaces

After local anesthesia of the teeth, supragingival plaque and calculus were removed. A groove was placed around the circumference of the tooth at the level of the gingival margin with a no. 2 round diamond bur in a high-speed handpiece. This groove provided a landmark for future microscopic evaluation of the subgingival root surface. The mesial or distal tooth surfaces were randomly assigned to laser or mechanical debridement. This instrumentation was performed by two experienced periodontists (S.J. and J.E.). One operator performed either laser treatment or mechanical debridement on one tooth surface, while the second treatment was performed by the other operator on the opposite tooth surface.

In a first group of 15 teeth (group 1 ×), the treatment was initiated on one tooth surface using hand instruments. Teeth were scaled and root planed with Gracey curets (Hu-Friedy, Leimen, Germany) until the operator achieved a hard, smooth, calculus-free root surface as determined by tactile sensation with a dental probe. No time limits were placed on the operators for this mechanical debridement. The time for hand instrumentation was recorded and set as a time limit for the subsequent laser treatment of the opposite root surface.

An Er:YAG laser (KEY II, KaVo, Biberach, Germany) with a therapeutic wavelength of 2.94 μm and a pilot wavelength of 635 μm was selected for laser irradiation. An energy level of 160 mJ and a repetition rate of 10 to 15 Hz with water irrigation according to the instructions given by the manufacturer was used. For subgingival laser application, the handpiece P 2056 (KaVo, Biberach, Germany) attached to a fiber tip of 0.5 × 1.65 mm was used (Fig. 1). The fiber tip was moved from coronal to apical in parallel paths with an inclination of approximately 20° in relation to the root.

In a second group of 15 teeth (group 2 ×) laser treatment was allowed twice the time used for mechanical debridement of the corresponding tooth surface. The teeth were extracted immediately after the procedure with forceps and care was taken to keep the beaks above the circumferential groove. The teeth were placed under cold running tap water for about 1 min to remove blood and loosely adherent debris. The teeth were then placed in a container with 10% buffered formalin solution.

Planimetric root surface evaluation

The teeth were transferred to 1% methylene blue for 2 min to stain the connective tissue attached to the teeth.
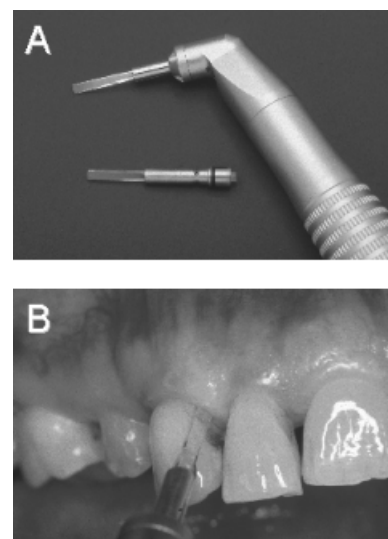

Fig. 1. (A) The laser tip (0.5 × 1.65 mm) attached to the handpiece P 2056 of the KEY II Er:YAG laser (Kavo, Biberach, Germany). (B) The laser tip inserted into a periodontal pocket.

The teeth were viewed under a microscope and the images were captured and digitized with a magnification of 2 ×. The presence of calculus on the mesial and distal root surfaces was measured using the Scion Image planimetric analysis tool (Scion Corporation, MD, USA). The surface area under investigation was determined coronally by the gingival groove (bur mark) and apically by the coronal border of the connective tissue attachment. Laterally the margins were set 1 mm apart from the line angle of the tooth. Within these boundaries the root surface area covered by residual subgingival deposits was measured (Fig. 2).

Scanning electron microscopic root surface evaluation

An impression was taken from the treated root surfaces (President, Coltene Whaledent, Altstätten, CH) and epoxy casts (Grace, Westerlo, Belgium) were made. The replicas were sputtered with gold and examined by scanning electron microscopy (XL30CP, Phillips, the Netherlands) with a magnification between 20 × and 1000 ×.

Histological root surface evaluation

Nondecalcified hard tissue sections were made according to the method of Schönfeldt and Bössmann (1980).
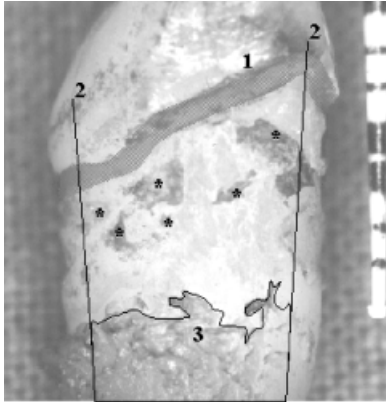
Fig. 2. Root surface after subgingival laser irradiation. Digital planimetric root surface analysis after staining with methylene blue. The area was determined by the coronal groove of the diamond bur (1), the lateral margins (2) and the coronal border of the connective tissue attachment (3). Residual deposits (∗) were located as islands on the root surface. Original magnification 2 ×.

Briefly, the formalin-fixed teeth were washed in ethanol and acetone. The specimens were embedded in methylmetacrylate (Fluka Chemie AG, Neu Ulm, Germany), cut in a mesio-distal plane, trimmed to sections of approximately 20 μm and stained with toluidine blue for 3 min. Five sections were obtained from each tooth specimen. The sections were analyzed under a Microphot-FXA (Nikon, Nippon) with a magnification of 20 × and the image analysis system Leica Q 500 MC (Leica, Cambridge, UK). The following measurements were performed: (A) the distance from the coronal groove to the coronal margin of the periodontal tissue attachment, (B) the distance covered with residual mineralized deposits, (C) the distance of the root surface covered with cementum, and (D) the distance of the root surface with exposed root dentin. Each measurement was expressed as percent of the distance A. Finally, mean values were calculated for each tooth surface.

Microbiological evaluation

Subgingival samples were obtained from 18 sites (group 2x) before and immediately after treatment by laser or by hand instruments. Prior to sampling, the selected sites were cleaned supragingivally in order to avoid contamination. At each site, 2 sterile paperpoints were inserted, kept in place for 30 s and transferred to vials containing transport medium (Cary-Blair-Transport medium, Hain Diagnostika, Nehren, Germany), and processed within less than 2 h. Samples were homogenized by vortexing for 30 s in 2 ml of pre-reduced trypticase-soy-boullion (Becton & Dickinson, Heidelberg, Germany), and 1 ml each was used for culturing and for DNA probe analysis. Aliquots of 0.1 ml of serial dilutions were plated on trypticase-soy-agar supplemented with 5 μg/ml vancomycin, 75 μg/ml bacitracin and 10% sterile horse serum (Oxoid, Wesel, Germany). Gram-negative species were selected on nonselective blood agar plates supplemented with 5 μg/ml hemine, 1 μg/ml Vitamin K_1, 1 μg/ml menadione and 5% sterile sheep blood. Plates were incubated for 3 days in air +10% CO_2 to select microaerophilic microorganisms and for 5 days to select anaerobic microorgansims (Gas Pac, Becton & Dickinson, Heidelberg, Germany). Identification of isolates was based on the Crystal system (Becton & Dickinson, Heidelberg, Germany) and the numbers of colony forming units per milliliter (CFU/ml) were calculated.

For DNA-based identification of periopathogens DNA was extracted from 1 ml of the homogenized samples by the High Pure DNA Preparation Kit (Roche, Mannheim, Germany). The bacterial DNA was further processed as recommended by the manufacturer for the identification of specific periopathogens (Mikrodent-Kit, Hain Diagnostika, Nehren, Germany).

Statistical methods

The results of the planimetric and histological evaluation were computed as means and standard deviations (SD). The normal distribution of data was confirmed by the Kolmogorov–Smirnov test. Statistically significant differences between treatment modalities were evaluated by using the paired and unpaired samples *t*-test. The significance level was set at $p < 0.05$.

Results

Root surface treatment

The pocket depth measurements prior to root debridement for the two treatment groups were similar (Table 1). The mean time required for hand instrumentation was 2:15 min (range: 1:05–4:15 min). For the second experimental group, the mean time for hand instrumentation amounted to 2:12 min (range: 1:33–3:15 min). Accordingly, the laser treatment was performed for a mean time of 4:24 min.

Planimetric root surface evaluation

Thirty teeth were included for evaluation, providing a total of 60 treated root surfaces. After SRP $93.9 \pm 3.7\%$ and after laser treatment $68.4 \pm 14.4\%$ (mean $\pm$ SD) of the root surfaces were free of any residual mineralized deposits in group 1 ×. When laser treatment was allowed twice the time used for hand instrumentation (group 2 ×), $83.3 \pm 5.7\%$ of the root surface was devoid of calculus, in contrast to $96.3 \pm 3.5\%$ after hand instrumentation (Fig. 2). The differences between hand instrumentation and laser treatment were statistically significant for both time settings (Fig. 3). Laser instrumentation showed statistically superior effectiveness for group 2 × when compared to group 1 ×. No differences in treatment efficacy could be observed between pockets $\leqslant 5.5$ mm and pockets > 5.5 mm neither for the laser nor for hand instrumentation (Fig. 4).

Scanning electron microscopic root surface evaluation

The morphology of the root surface after hand instrumentation appeared smooth, although traces of the curet were seen (Fig. 5A). Only limited amounts of remaining calculus were present. The scanning electron microscopic investigation of the root surfaces treated with Er:YAG laser revealed a

Table 1. Time required and site characteristics of root surfaces treated by Er:YAG laser or by hand instrumentation (SRP)

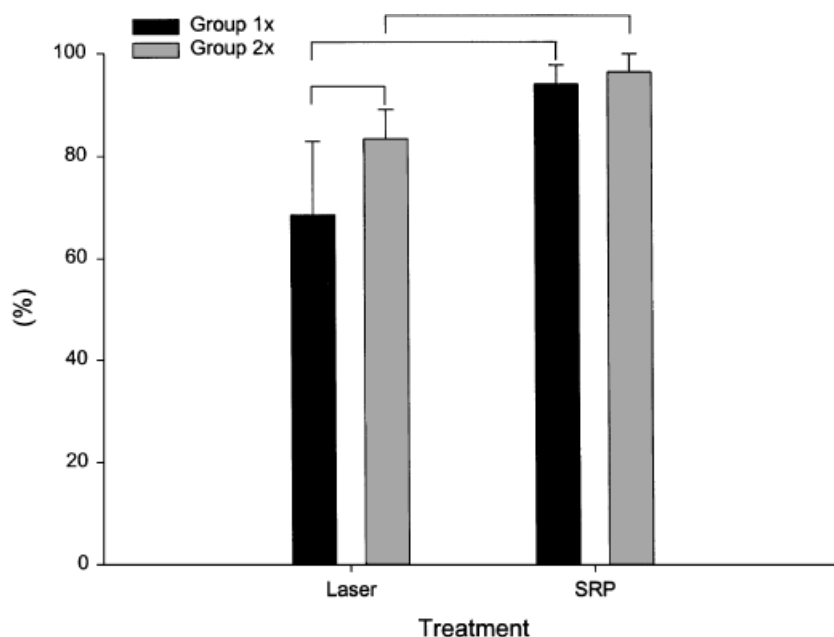| Time	N	Treatment	Time (min)		PD (mm)		Treated root surface	
			mean	SD	mean	SD	mesial	distal
1 ×	15	SRP	02:15	01:00	6.1	1.8	5	10
	15	Laser	02:15	01:00	5.6	1.1	10	5
2 ×	15	SRP	02:12	00:28	6.2	1.8	11	4
	15	Laser	04:24	00:56	6.4	1.5	4	11

Fig. 3. Results of planimetric root surface evaluation of all analyzed root surfaces ($n = 60$). The graph shows the calculus-free area (%) after laser and manual instrumentation. Brackets indicate statistical significant differences between groups (unpaired-samples *t*-test, $p < 0.05$) and treatments (paired-samples *t*-test, $p < 0.05$).

rough, acid-etched like surface, interrupted by smooth traces of cementum of about 50 μm width (Fig. 5B).

Histological root surface evaluation

The histological observation of the root surface revealed 4.3% residual deposits after manual scaling. Following laser treatment, 30.2% residual deposits were observed in group $1\times$ and 22.7% in group $2\times$. The laser-treated tooth surfaces exhibited no dentin exposition but rather a minimal reduction of cementum for both groups. In contrast, 73.2% of the dentin was denuded from the cementum after hand instrumentation (Figs. 6 and 7).

Microbiological findings

The findings for culture and DNA probe analysis of selected periopathogenic bacteria are summarized in Table 2.

There was a similar reduction of subgingival bacteria *Porphyromonas gingivalis, Prevotella intermedia, Bacteroides forsythus* and *Treponema denticola* after laser treatment and after hand instrumentation. There were no apparent differences between culture and DNA probe analysis.

Discussion

The present clinical study enabled the direct comparison of laser-irradiated and conventionally treated root surfaces by computer-assisted planimetry and light microscopic evaluation for the accurate measurements of residual deposits. The manual root debridement resulted in an almost complete removal of subgingival calculus and is in agreement with other clinical studies (Eaton et al. 1985, Buchanan & Robertson 1987, Brayer et al. 1989, Sherman et al. 1990, Yukna et al. 1997). Less favorable results reported by other studies could be related to the different approaches to measure residual deposits (Rabbani et al. 1981, Caffesse et al. 1986, Breininger et al. 1987). The direct comparison of the effectiveness of hand instrumentation and laser irradiation revealed that the laser treatment was not as efficient as the conventional approach if the same time for debridement was allowed. The calculus removal by laser treatment was significantly improved by allowing twice the time that was used for hand instrumentation although it did not reach equivalent results. We did not
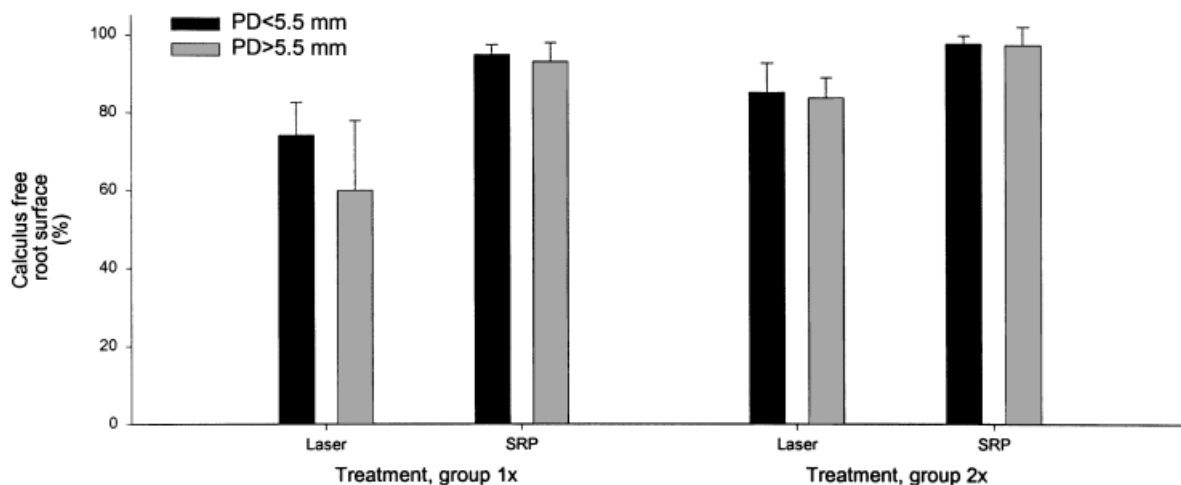

Fig. 4. Results of planimetric root surface evaluation for sites of different probing depth. There was no statistically significant difference in the effectiveness (calculus-free area (%)) of laser and hand instrumentation between pockets $\leqslant 5.5$ mm and pockets > 5.5 mm (unpaired-samples *t*-test, $p > 0.05$).
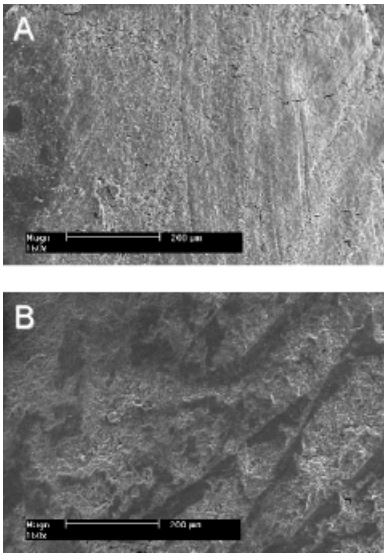
Fig. 5. The scanning electron microscopic appearance of the root surface after hand instrumentation (A) and laser irradiation (B). Magnification 150 × .

Fig. 6. Undecalcified ground section of root surfaces treated by laser irradiation (left) and hand instrumentation (right). Bur marks and apical end of instrumentation are indicated by arrows. Note the complete removal of cementum after hand instrumentation in contrast to preserved cementum layer after laser irradiation. Magnification 2 × .

find significant differences for calculus removal for shallow or deep pockets either for hand instrumentation or for laser treatment. This result is in agreement with other studies on mechanical debridement (Buchanan & Robertson 1987, Sherman et al. 1990, Yukna et al. 1997), although some investigators reported significant influence of pocket depth on the effectiveness of calculus removal (Rabbani et al. 1981, Caffesse et al. 1986, Brayer et al. 1989). Since only single-rooted, easily accessable teeth were included in the present study,

pocket depth may have had only limited influence on the outcomes.

During clinical application, the angulation of the laser tip was dictated by the anatomical situation and could not always be used with the desired 20° inclination. Consequently, the energy density of the laser light reaching the

root surface and thus its ability to remove mineralized deposits could have become reduced (Folwaczny et al. 2001). Future studies will have to evaluate whether the effectiveness could be improved by modifications of the tip to increase light transmission onto the root surface and/or by increased energy settings. However, in vitro studies clearly indicated that upregulation of the energy density was associated with the ablation of the root cementum and severe changes of the root morphology (Gaspirc & Skaleric 2001).

This is, to our knowledge, the first study that investigated the effectiveness of Er:YAG laser treatment to remove mineralized deposits from a periodontally involved root surface in a clinical situation. Although we observed considerable calculus removal by the Er:YAG laser, the clinical effectiveness was less than for hand instrumentation and more time consuming. On the other hand, our histometric analyses confirmed the extensive cementum removal caused by hand instruments and the consequent dentin exposure (Coldiron et al. 1990, Ritz et al. 1991). This gives way to dentin hypersensibility and caries lesions (Adriaens et al. 1988, Haugen & Johansen 1988, Pashley et al. 1996). In contrast, under the settings used in the present study, our histologic analyses of laser treated root surfaces did not show any exposure of dentin.

The ultrastructural evaluation of the laser-treated root surfaces revealed an irregular surface possibly due to superficial ablation of cementum as described
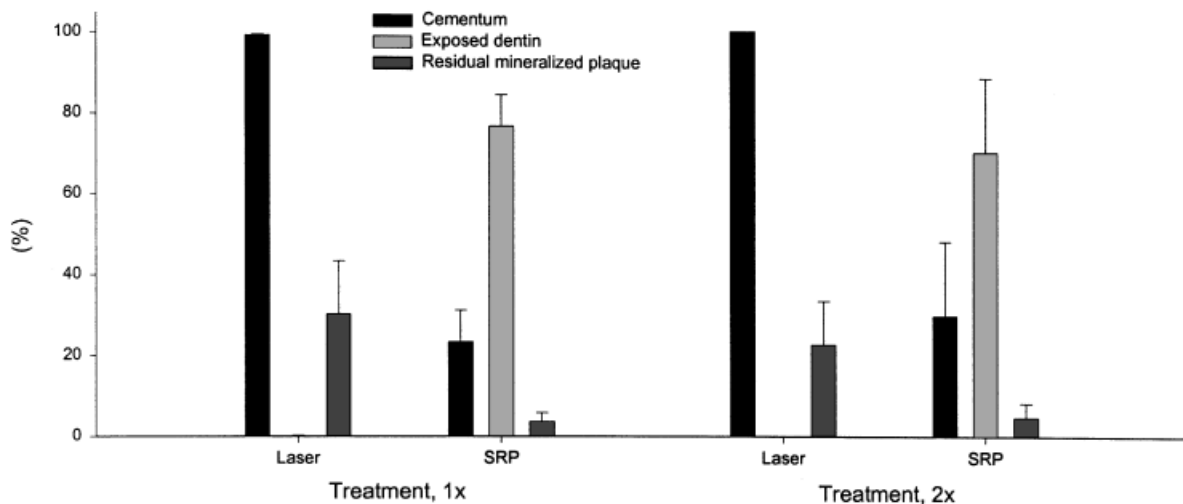

Fig. 7. Results of the histological root surface measurements for the distances of cementum, exposed dentin and residual deposits expressed as percent of the root surface instrumented by scaling or laser treatment.

Table 2. Number of CFU/ml for specific species in subgingival samples from sites before and after treatment with the Er:YAG laser or hand instruments (SRP).

Laser											SRP							
						Porphyromonas gingivalis												
									C									
0	0	5	5	6	6	6	6	6	before	6	6	6	5	5	5	5	3	0
0	0	3	3	3	3	3	4	4	after	4	4	3	3	3	3	0	0	0
									M									
0	0	5	5	5	6	6	6	6	before	6	6	6	5	5	5	5	5	0
0	0	3	3	4	4	4	4	4	after	5	5	4	4	3	3	3	3	0
						Prevotella intermedia												
									C									
0	0	3	3	3	4	4	4	5	before	5	4	4	3	3	3	0	0	0
0	0	0	0	0	3	3	3	3	after	4	4	3	3	3	3	3	0	0
									M									
0	0	0	0	0	0	3	4	5	before	6	6	4	3	3	0	0	0	0
0	0	0	0	0	0	0	0	3	after	0	0	0	0	0	0	0	0	0
						Bacteroides forsythus												
									C									
0	0	3	4	4	4	4	5	6	before	6	4	4	4	4	4	4	4	0
0	0	0	0	0	0	0	3	3	after	4	0	0	0	0	0	0	0	0
									M									
3	4	4	4	4	4	4	4	6	before	6	5	5	4	4	4	4	4	0
0	0	0	0	0	0	3	3	3	after	4	3	0	0	0	0	0	0	0
						Treponema denticola												
									M									
5	5	5	5	6	6	6	6	6	before	6	6	6	6	5	5	5	4	0
0	0	3	4	4	4	4	4	5	after	4	4	4	4	4	4	4	3	3

C = identification by selective culture methods, M = identification by DNA hybridization (Mikrodent-Kit, Hain Diagnostika, Nehren, Germany). Internal standardization enables the expression as CFU/ml.

The numbers indicate the log number of every microorganism. The data are not linked to the specific sites (Data presentation adapted from Mombelli et al. 1995, Bollen et al. 1998). The darker the shadowing of the boxes, the higher the amount of bacteria.

by other investigators (Fujii et al. 1998, Armengol et al. 1999, Aoki et al. 2000). However, the optimal surface structure of a treated root surface for most favorable periodontal wound healing is yet unknown (Pameijer et al. 1972, Adelson et al. 1980, Blomlof et al. 1987, Nyman et al. 1988, Spencer et al. 1992, Oberholzer & Rateitschak 1996, Watanabe et al. 1996). In the light of the observed minimal invasive character, the laser might be well suited to be an alternative treatment approach for the maintenance phase of periodontal therapy, when subgingival plaque removal rather than excessive root debridement is required (Axelsson et al. 1991). Therefore, future studies should address the clinical value of laser treatment during supportive periodontal care.

The present study confirmed for the first time in vivo the antibacterial capacity of the Er:YAG laser that has been shown in vitro (Ando et al. 1996, Folwaczny et al. 2002). This reduction of the bacterial load was associated with considerable amounts of residual calculus. This has to be taken into account when the results of short-term clinical studies are interpreted (Schwarz et al. 2001a, b). Favorable short-term healing as assessed by clinical parameters could be merely a reflection of a transient reduction of the bacterial load after laser treatment. Since residual subgingival deposits may favor bacterial recolonization (Leknes et al. 1994, Leknes 1997), only a long-term follow-up of patients can show whether subgingival laser irradiation can result in long-term periodontal stability as it has been shown for hand instrumentation (Lindhe et al. 1984).

In conclusion, the present study could demonstrate the capacity of an Er:YAG laser to remove calculus in a clinical situation. The effectiveness was low compared to SRP but could be improved by longer treatment periods. The effective removal of mineralized deposits by hand instruments from the root surface was accompanied by the removal of the cementum, while the laser treatment induced only minimal morphological changes to the cementum. These observations may indicate a potential usefulness of the Er:YAG laser during supportive periodontal care that has to be proven in future clinical studies. Future studies should also evaluate whether the effectiveness for calculus removal can be increased with higher energy settings and/or the combination with newly developed laser fluorescence techniques for the selective detection of subgingival calculus.

Zusammenfassung

Effizienz der subgingivalen Zahnsteinentfernung mittels Er:YAG-Laser im Vergleich zum mechanischen Debridement: eine in situ-Studie.
Ziele: Das Ziel der vorliegenden Studie war es, *in situ* die Effektivität der subgingivalen Zahnsteinentfernung an parodontal befallenen Wurzeloberflächen durch einen Er:YAG-Laser mit der Handinstrumentierung zu vergleichen.
Methoden: Um eine zahnsteinfreie Oberfläche zu erzielen, wurden die mesialen und distalen Flächen von 30 einwurzligen Zähnen mit unbehandelter Parodontitis entweder durch Handinstrumente (SRP) oder durch Er:YAG-Laserbestrahlung bearbeitet. Für die mikrobiologische Evaluierung durch Kultivierung und DNA-Sondenanalyse wurden vor und direkt nach der Behandlung subgingivale Plaqueproben gewonnen. Die Zähne wurden gezogen und der verbliebene Zahnstein wurde mittels digitaler Planimetrie vermessen. Die Morphologie der Wurzeloberfläche wurde mit dem Rasterelektronenmikroskop evaluiert und nicht-entkalkte Schnitte untersucht, um den verbliebenen Zahnstein und das Ausmaß der Zemententfernung nach beiden Behandlungen zu beurteilen.
Ergebnisse: Wenn beide Behandlungen während der gleichen Zeit ($2:15 \pm 1:00$ Min.) durchgeführt wurden, waren nach der Laserbestrahlung $68,4 \pm 14,4$ % der Wurzeloberfläche zahnsteinfrei im Gegensatz zu $93,9 \pm 3,7$ % nach SRP. Wenn der Laserbestrahlung die doppelte Zeit, wie für die Handinstrumentierung erlaubt wurde, waren $83,3 \pm 5,7$ % der Wurzeloberfläche ohne Zahnstein. Für beide

Behandlungen stand die Effektivität in keiner Beziehung zur initialen Sondierungstiefe. Die histologische Evaluierung zeigte, dass nach SRP 73,2 % des Wurzeldentins ohne Zement waren, während nach Laserbestrahlung nur eine minimale Reduktion des Zements sichtbar war. Beide Behandlungsweisen hatte eine vergleichbare Reduktion der Parodontalpathogene zum Ergebnis.

Diskussion: Die vorliegende Untersuchung konnte zeigen, dass der Er:YAG-Laser die Fähigkeit hat *in vivo* den Zahnstein von parodontal befallenen Wurzeloberflächen zu entfernen. Die Effektivität erreichte jedoch nicht die der Handinstrumentierung. Durch die, im Gegensatz zur SRP, fehlende Zemententfernung könnte der Laser als alternative Methode in der Erhaltungstherapie geeignet sein.

Résumé

Efficacité pour l'élimination du tartre du laser Er:YAG comparé au débridement mécanique: une étude in situ

Objectifs: Le but de cette étude était de comparer l'efficacité pour l'élimination du tartre sous-gingival sur des surfaces radiculaires impliquées dans une parodontite, d'un laser Er.YAG laser comparé à une instrumentation manuelle *in situ*.

Méthodes: les surfaces mésiales et distales de 30 dents monoradiculées n'ayant pas été traitées pour parodontite furent traitées soit par instrumentation manuelle (SRP) ou par irradiation par laser Er:YAG dans le but d'obtenir une surface sans tartre. Des échantillons de plaque sous-gingivale furent prélevés avant et immédiatement après le traitement pour une évaluation microbiologique par culture et analyse avec une sonde ADN. Les dents furent extraites et le tartre résiduel fut mesuré au moyen de planimètrie digitalisée. La morphologie de la surface radiculaire fut évaluée par microscopie électronique à balayage et des coupes non décalcifiées furent analysées pour déterminer le tartre résiduel et l'étendue de l'élimination du cément à la suite des deux traitements.

Résultats: Après l'irradiation au laser, 68.4 ± 14.4 % des surfaces radiculaires n'avait plus de tartre, par opposition aux 93.9 ± 3.7 % après SRP lorsque les deux traitements étaient réalisés pendant le même temps ($2:15 \pm 1:00$ min). Si l'irradiation était maintenue pendant deux fois plus de temps que le SRP, 83.3 ± 5.7 % des surfaces radiculaires se retrouvaient dépourvues de tartre. L'efficacité des deux traitements n'était pas en relation avec les profondeurs au sondage initiales. L'évaluation histologique montrait qu'après SRP, 73.2 % de la dentine radiculaire était complètement découverte de cément, alors qu'une minime réduction cémentaire était apparente avec l'irradiation au laser. Les deux traitements résultaient en une réduction similaire des pathogènes parodontaux.

Discussion: Cette recherche pourrait démontrer la capacité *in vivo* du laser Er:YAG à éliminer le tartre des surfaces radiculaires impliquées dans une parodontite, bien que son efficacité n'atteigne pas celle obtenue avec une instrumentation manuelle. Le manque d'élimination du cément par rapport au SRP pourrait donner au laser une approche alternative pendant le traitement parodontal de soutien.

References

Adelson, L. J., Hanks, C. T., Ramfjord, S. P. & Caffesse, R. G. (1980) In vitro cytotoxicity of periodontally diseased root surfaces. *Journal of Periodontology* **51**, 700–704.

Adriaens, P. A., Edwards, C. A., De Boever, J. A. & Loesche, W. J. (1988) Ultrastructural observations on bacterial invasion in cementum and radicular dentin of periodontally diseased human teeth. *Journal of Periodontology* **59**, 493–503.

Aleo, J. J., De Renzis, F. A. & Farber, P. A. (1975) In vitro attachment of human gingival fibroblasts to root surfaces. *Journal of Periodontology* **46**, 639–645.

American Academy of Periodontology (2001) Treatment of plaque-induced gingivitis, chronic periodontitis and other clinical conditions. *Journal of Periodontology* **72**, 1790–1800.

Ando, Y., Aoki, A., Watanabe, H. & Ishikawa, I. (1996) Bactericidal effect of erbium YAG laser on periodontopathic bacteria. *Lasers in Surgery and Medicine* **19**, 190–200.

Aoki, A., Ando, Y., Watanabe, H. & Ishikawa, I. (1994) In vitro studies on laser scaling of subgingival calculus with an erbium: AG laser. *Journal of Periodontology* **65**, 1097–1106.

Aoki, A., Miura, M., Akiyama, F., Nakagawa, N., Tanaka, J., Oda, S., Watanabe, H. & Ishikawa, I. (2000) In vitro evaluation of Er: AG laser scaling of subgingival calculus in comparison with ultrasonic scaling. *Journal of Periodontal Research* **35**, 266–277.

Armengol, V., Jean, A., Rohanizadeh, R. & Hamel, H. (1999) Scanning electron microscopic analysis of diseased and healthy dental hard tissues after Er:YAG laser irradiation: in vitro study. *Journal of Endodontics* **25**, 543–546.

Axelsson, P., Lindhe, J. & Nystrom, B. (1991) On the prevention of caries and periodontal disease. Results of a 15-year longitudinal study in adults. *Journal of Clinical Periodontology* **18**, 182–189.

Badersten, A., Nilveus, R. & Egelberg, J. (1981) Effect of nonsurgical periodontal therapy. I. Moderately advanced periodontitis. *Journal of Clinical Periodontology* **8**, 57–72.

Badersten, A., Nilveus, R. & Egelberg, J. (1984) Effect of nonsurgical periodontal therapy. II. Severely advanced periodontitis. *Journal of Clinical Periodontology* **11**, 63–76.

Blomlof, L., Lindskog, S., Appelgren, R., Jonsson, B., Weintraub, A. & Hammarström, L. (1987) New attachment in monkeys with experimental periodontitis with and without removal of the cementum. *Journal of Clinical Periodontology* **14**, 136–143.

Bollen, C. M., Mongardini, C., Papaioannou, W., van Steenberghe, D. & Quirynen, M. (1998) The effect of a one-stage full-mouth disinfection on different intra oral niches. *Journal of Clinical Periodontology* **25**, 56–66.

Brayer, W. K., Mellonig, J. T., Dunlap, R. M., Marinak, K. W. & Carson, R. E. (1989) Scaling and root planing effectiveness: the effect of root surface access and operator experience. *Journal of Periodontology* **60**, 67–72.

Breininger, D. R., O'Leary, T. J. & Blumenshine, R. V. (1987) Comparative effectiveness of ultrasonic and hand scaling for the removal of subgingival plaque and calculus. *Journal of Periodontology* **58**, 9–18.

Buchanan, S. A. & Robertson, P. B. (1987) Calculus removal by scaling/root planing with and without surgical access. *Journal of Periodontology* **58**, 159–163.

Caffesse, R. G., Sweeney, P. L. & Smith, B. A. (1986) Scaling and root planing with and without periodontal flap surgery. *Journal of Clinical Periodontology* **13**, 205–210.

Cercek, J. F., Kiger, R. D., Garrett, S. & Egelberg, J. (1983) Relative effects of plaque control and instrumentation on the clinical parameters of human periodontal disease. *Journal of Clinical Periodontology* **10**, 46–56.

Coldiron, N. B., Yukna, R. A., Weir, J. & Caudill, R. F. (1990) A quantitative study of cementum removal with hand curettes. *Journal of Periodontology* **61**, 293–299.

Eaton, K. A., Kieser, J. B. & Davies, R. M. (1985) The removal of root surface deposits. *Journal of Clinical Periodontology* **12**, 141–152.

Folwaczny, M., Mehl, A., Aggstaller, H. & Hickel, R. (2002) Antimicrobial effects of 2.94 µm ErYAG laser radiation on root surfaces: an in vitro study. *Journal of Clinical Periodontology* **29**, 73–78.

Folwaczny, M., Thiele, L., Mehl, A. & Hickel, R. (2001) The effect of working tip angulation on root substance removal using Er:-YAG laser radiation: an in vitro study. *Journal of Clinical Periodontology* **28**, 220–226.

Fujii, T., Baehni, P. C., Kawai, O., Kawakami, T., Matsuda, K. & Kowashi, Y. (1998) Scanning electron microscopic study of the effects of Er:YAG laser on root cementum. *Journal of Periodontology* **69**, 1283–1290.

Fujikawa, K., O'Leary, T. J. & Kafrawy, A. H. (1988) The effect of retained subgingival calculus on healing after flap surgery. *Journal of Periodontology* **59**, 170–175.

Gaspirc, B. & Skaleric, U. (2001) Morphology, chemical structure and diffusion processes of root surface after Er:YAG and Nd:YAG laser irradiation. *Journal of Clinical Periodontology* **28**, 508–516.

Haugen, E. & Johansen, J. R. (1988) Tooth hypersensitivity after periodontal treatment. A case report including SEM studies. *Journal of Clinical Periodontology* **15**, 399–401.

Hibst, R. & Keller, U. (1989) Experimental studies of the application of the Er:YAG laser

on dental hard substances: I. Measurement of the ablation rate. *Lasers in Surgery and Medicine* **9**, 338–344.

Israel, M., Cobb, C. M., Rossmann, J. A. & Spencer, P. (1997) The effects of CO_2, Nd:YAG and Er:YAG lasers with and without surface hard coolant on tooth root surfaces. An in vitro study. *Journal of Clinical Periodontology* **24**, 595–602.

Jones, W. A. & O'Leary, T. J. (1978) The effectiveness of in vivo root planing in removing bacterial endotoxin from the roots of periodontally involved teeth. *Journal of Periodontology* **49**, 337–342.

Keller, U. & Hibst, R. (1989) Experimental studies of the application of the Er:YAG laser on dental hard substances: II. Light microscopic and SEM investigations. *Lasers in Surgery and Medicine* **9**, 345–351.

Keller, U., Stock, K. & Hibst, R. (1997) Morphology of Er:YAG laser-treated root surfaces. *Proceedings of Medical Applications of Lasers in Dermatology, Ophthalmology, Dentistry, and Endoscopy* **3192**, 24–31.

Kepic, T. J., O'Leary, T. J. & Kafrawy, A. H. (1990) Total calculus removal: an attainable objective? *Journal of Periodontology* **61**, 16–20.

Leknes, K. N. (1997) The influence of anatomic and iatrogenic root surface characteristics on bacterial colonization and periodontal destruction: a review. *Journal of Periodontology* **68**, 507–516.

Leknes, K. N., Lie, T., Wikesjo, U. M., Bogle, G. C. & Selvig, K. A. (1994) Influence of tooth instrumentation roughness on subgingival microbial colonization. *Journal of Periodontology* **65**, 303–308.

Lindhe, J., Westfelt, E., Nyman, S., Socransky, S. S. & Haffajee, A. D. (1984) Long-term effect of surgical/non-surgical treatment of periodontal disease. *Journal of Clinical Periodontology* **11**, 448–458.

Mehl, A., Kremers, L., Salzmann, K. & Hickel, R. (1997) 3D volume-ablation rate and thermal side effects with the Er:YAG and Nd:YAG laser. *Dental Materials* **13**, 246–251.

Mombelli, A., Marxer, M., Gaberthul, T., Grunder, U. & Lang, N. P. (1995) The microbiota of osseointegrated implants in patients with a history of periodontal disease. *Journal of Clinical Periodontology* **22**, 124–130.

Morlock, B. J., Pippin, D. J., Cobb, C. M., Killoy, W. J. & Rapley, J. W. (1992) The effect of Nd:YAG laser exposure on root surfaces when used as an adjunct to root planing: an in vitro study. *Journal of Periodontology* **63**, 637–641.

Neill, M. E. & Mellonig, J. T. (1997) Clinical efficacy of the Nd:YAG laser for combination periodontitis therapy. *Practical Periodontics and Aesthetic Dentistry* **9**, 1–5.

Nyman, S., Westfelt, E., Sarhed, G. & Karring, T. (1988) Role of ''diseased'' root cementum in healing following treatment of periodontal disease. A clinical study. *Journal of Clinical Periodontology* **15**, 464–468.

Oberholzer, R. & Rateitschak, K. H. (1996) Root cleaning or root smoothing. An in vivo study. *Journal of Clinical Periodontology* **23**, 326–330.

Paghdiwala, A. F., Vaidyanathan, T. K. & Paghdiwala, M. F. (1993) Evaluation of erbium:YAG laser radiation of hard dental tissues: analysis of temperature changes, depth of cuts and structural effects. *Scanning Microscopy* **7**, 989–997.

Pameijer, C. H., Stallard, R. E. & Hiep, N. (1972) Surface characteristics of teeth following periodontal instrumentation: a scanning electron microscope study. *Journal of Periodontology* **43**, 628–633.

Pashley, D. H., Matthews, W. G., Zhang, Y. & Johnson, M. (1996) Fluid shifts across human dentine in vitro in response to hydrodynamic stimuli. *Archievs of Oral Biology* **41**, 1065–1072.

Rabbani, G. M., Ash, M. M., Jr & Caffesse, R. G. (1981) The effectiveness of subgingival scaling and root planing in calculus removal. *Journal of Periodontology* **52**, 119–123.

Ramfjord, S. P. (1980) Root planing and curettage. *International Dental Journal* **30**, 93–100.

Ritz, L., Hefti, A. F. & Rateitschak, K. H. (1991) An in vitro investigation on the loss of root substance in scaling with various instruments. *Journal of Clinical Periodontology* **18**, 643–647.

Schönfeldt, C. & Bössmann, K. (1980) [Embedding in methacrylate for the histologic study of decalcified and non-decalcified preparations of teeth with their surrounding periodontium]. *Deutsche Zahnärztliche Zeitschrift* **35**, 789–794.

Schwarz, F., Putz, N., Georg, T. & Reich, E. (2001a) Effect of an Er:YAG laser on periodontally involved root surfaces: an in vivo and in vitro SEM comparison. *Lasers in Surgery and Medicine* **29**, 328–335.

Schwarz, F., Sculean, A., Georg, T. & Reich, E. (2001b) Periodontal treatment with an Er:-YAG laser compared to scaling and root planing. A controlled clinical study. *Journal of Periodontology* **72**, 361–367.

Sherman, P. R., Hutchens, L. H. Jr. & Jewson, L. G. (1990) The effectiveness of subgingival scaling and root planing. II. Clinical responses related to residual calculus. *Journal of Periodontology* **61**, 9–15.

Spencer, P., Trylovich, D. J. & Cobb, C. M. (1992) Chemical characterization of lased root surfaces using Fourier transform infrared photoacoustic spectroscopy. *Journal of Periodontology* **63**, 633–636.

Watanabe, H., Ishikawa, I., Suzuki, M. & Hasegawa, K. (1996) Clinical assessments of the erbium:YAG laser for soft tissue surgery and scaling. *Journal of Clinical Laser Medicine & Surgery* **14**, 67–75.

Wigdor, H., Abt, E., Ashrafi, S. & Walsh, J. T. Jr. (1993) The effect of lasers on dental hard tissues. *Journal of the American Dental Association* **124**, 65–70.

Yamaguchi, H., Kobayashi, K., Osada, R., Sakuraba, E., Nomura, T., Arai, T. & Nakamura, J. (1997) Effects of irradiation of an erbium:YAG laser on root surfaces. *Journal of Periodontology* **68**, 1151–1155.

Yukna, R. A., Scott, J. B., Aichelmann-Reidy, M. E., LeBlanc, D. M. & Mayer, E. T. (1997) Clinical evaluation of the speed and effectiveness of subgingival calculus removal on single-rooted teeth with diamond-coated ultrasonic tips. *Journal of Periodontology* **68**, 436–442.

Address:
Søren Jepsen
Department of Conservative
  and Preventive Dentistry
University of Bonn
Welschnonnenstr. 17
D-53111 Bonn
Germany
E-mail: jepsen@uni-bonn.de