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Periodontal healing after non-surgical therapy with a new ultrasonic device: a randomized controlled clinical trial

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Abstract

Aim: The aim of this study was to compare the clinical and microbiological healing outcomes following non-surgical periodontal therapy using the new Vector™ ultrasonic system *versus* scaling and root planing (S/RP) with Gracey curettes.

Material and Methods: The study comprised 20 chronic periodontitis patients. Using a split-mouth design, both treatment modalities were randomly applied to one quadrant of the upper and the lower jaws each. Clinical and microbiological parameters were assessed at baseline, 4 weeks, and 6 months after treatment. Furthermore, post-operative hypersensitivity was assessed. The Wilcoxon signed rank test ($\alpha = 0.05$) was used for statistical analysis.

Results: Both therapies provided statistically significant clinical and microbiological improvements of periodontal conditions after 4 weeks and 6 months. Hypersensitive teeth were found only 4 weeks after S/RP. Besides a significantly better bleeding on probing reduction in deep S/RP sites, no other clinical and microbiological parameters revealed significant differences between the sites treated with the Vector™ system or S/RP.

Conclusion: Both the Vector™ system and S/RP provided favourable periodontal healing results, although in deep pockets S/RP appeared to achieve a better resolution of inflammation.

Key words: bacteria; clinical trials; periodontal therapy; periodontitis; scaler/non-surgical periodontal therapy; sonic; ultrasonic

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Periodontitis is a destructive inflammatory disease of the tooth-supporting tissues caused by a mainly Gram-negative bacterial infection. The subgingival bacteria are organized as a biofilm adhering to the root surfaces (Darveau et al. 1997). Bacterial endotoxines and other antigenic components often induce an inflammatory host response causing loss of periodontal tissues (Page et al. 1997, Schenkein 2006). Therefore, the disruption and removal of the subgingival biofilm is the primary objective of cause-related periodontal therapy. Numerous studies have shown that plaque removal leads to the resolution of inflammation and can prevent further disease progression (Knowles et al. 1979, Lindhe & Nyman 1984, Cobb 1996, Van der Weijden & Timmerman 2002, Müller & Heinecke 2004).

Scaling and root planing (S/RP) with hand curettes is the most commonly used procedure for root surface debridement. Many studies have reported beneficial results on both clinical and microbiological healing parameters after S/RP (Morrison et al. 1980, Hill et al. 1981, Ramfjord et al. 1982, Van der Weijden & Timmerman 2002). However, even skilled operators cannot always achieve the desired biologically compatible clean root surface by non-surgical scaling and root planing due to difficult root anatomy (Sherman et al. 1990a, b). Moreover, the instrumentation of root surfaces with hand curettes is exhausting for the operator (Rylander & Lindhe 2003), can cause an unwanted loss of root substance due to overinstrumentation (Ritz et al. 1991), and consequently often induces postoperative root hypersensitivity (Chabansky et al. 1996,

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1997, Troil et al. 2002). In order to facilitate subgingival debridement and to improve clinical and microbiological results, power-driven instruments, such as sonic and ultrasonic scalers, have been proposed (AAP Position Paper 2000). Numerous studies have reported similarly favourable clinical healing outcomes following sonic, ultrasonic, and manual instrumentation (Badersten et al. 1981, 1984, Loos et al. 1987, 1989, Laurell & Pettersson 1988, Laurell 1990, Tunkel et al. 2002, Hallmon & Rees 2003, Christgau et al. 2006). However, the use of ultrasonic scalers in dentistry may bear some problems for the patients and operators (Trenter & Walmsley 2003). For example, if water cooling is not efficient, the considerable temperature increase at the ultrasonic scaler's tip may cause injury to pulpal and periodontal tissues (Nicoll & Peters 1998). Furthermore, the fine aerosol produced by ultrasonic scalers is heavily loaded with pathogenic bacteria (Holbrook et al. 1978, Trenter & Walmsley 2003). The chipping against the root surface can cause discomfort for the patients and can reduce their compliance with maintenance therapy (Hoffman et al. 2005).

Recently, a new piezoelectric ultrasonic scaling system (Vector™, Dürr, Bietigheim-Bissingen, Germany) has been introduced in order to overcome some of these problems (Hahn 2000, Petersilka & Flemmig 2004). The Vector™ ultrasonic scaling system is characterized by a resonating ring, which converts the generated horizontal oscillation (frequency: 25 kHz) into pure vertical movements with an amplitude of about 30 µm along the longitudinal axis of the instrument tip. Thus, the instrument tip moves only parallel to the root surface. The Vector™ coolant is an aqueous suspension of hydroxyapatite particles, which is applied by intermittent pulsation at a flow rate of 6 ml/min. Because of the linear ultrasonic movement of the working tip, the suspension is kept around the instrument by hydrodynamic forces and the formation of an aerosol is avoided to a large extent. The coolant establishes an indirect coupling of ultrasonic energy to the periodontal tissues (principle of lithotripsy systems; Tolley & Downey 1999). The root surface is supposed to be cleaned by hydrodynamic forces such as cavitation or acoustic microstreaming (Walmsley et al. 1988, 1990, Khambay & Walmsley 1999). While root debridement by conventional ultrasonic scalers is achieved by chipping of the instrument tip against the root surface, the indirect energy transmission by the hydroxapatite suspension of the Vector™ seems to be more gentle to the root surface (Kishida et al. 2004, Rupf et al. 2005, Braun et al. 2005a, Schwarz et al. 2006) and causes less discomfort (i.e. pain, vibrations) for the patient (Braun et al. 2003, Hoffman et al. 2005).

The rationale for this study was that there are still relatively limited data in the literature on the clinical effectiveness of the Vector™ ultrasonic system in non-surgical periodontal therapy (Klinger et al. 2000, Sculean et al. 2003, 2004, Kocher et al. 2005, Schwarz et al. 2006). Furthermore, to the best of our knowledge, there are no studies reporting the effects of the Vector™ system on the subgingival microflora. Therefore, the aim of the present prospective split-mouth study was to compare the clinical and microbiological healing outcomes after non-surgical periodontal therapy using the Vector™ ultrasonic scaling system *versus* subgingival debridement with hand curettes.

Material and Methods

Study design

This study was designed as a randomized prospective controlled clinical split-mouth study comparing the clinical and microbiological healing outcomes after non-surgical subgingival periodontal therapy with either a new ultrasonic scaler (test group) or scaling and root planing with hand instruments (S/RP) (control group). The study design was approved by the ethics committee of the University of Regensburg in accordance with the Declarations of Helsinki (1975) and Tokyo (1983). All patients received a detailed description of the proposed treatment and gave an informed and written consent.

Patient selection

The study comprised 20 patients (five females, 15 males) with a median age of 44 years. All patients were recruited from the patient pool of the Department of Operative Dentistry and Periodontology at the University of Regensburg. All patients had generalized moderate to severe chronic periodontitis, but were systemically healthy and had not received systemic antibiotics during the last 3 months. Each patient had to show at least four teeth per quadrant with a probing pocket depth (PPD) of at least 4 mm. Nine of the 20 patients (45%) were active smokers, smoking 10 cigarettes/day (median) (Table 1).

Table 1. Patients characteristics

	20 patients
Gender (*n*)	
Female	5
Male	15
Age (years)	
Median	44.0
25/75%	33.3/49.8
Mean ± SD	42.6 ± 9.1
Smoking (*n*)	
Active smokers	9
Former smokers	6
Non-smokers	5
Active smokers: cigarettes per day	
Median	10.0
25/75%	4.0/10.5
Mean ± SD	7.8 ± 3.5

n, number of patients; median, median value; 25/75%, 25/75% percentile; mean, mean value; SD, standard deviation.

Therapeutic procedures

After the first visit and before the baseline examination, each patient followed an initial pre-treatment phase consisting of oral hygiene instructions, supragingival scaling, filling of decayed teeth, extraction of hopeless teeth, and splinting of extremely mobile teeth. Two weeks after completion of this pre-treatment and control of each patient's compliance [i.e. approximal plaque index (API) and papillary bleeding index (PBI) $<25\%$], subgingival debridement of all teeth was carried out by one operator (S. B.) within 24 h to reduce the risk of reinfection of treated sites from untreated sites.

For randomized treatment allocation a randomizing table was created by our mathematician (K. A. H.) using the SPSS software (Ver. 13.0, SPSS Inc., Chicago, IL, USA). The randomization table comprised the patient numbers (1–20) and numbers for the upper and lower quadrants of the right (1) and left side (2) of each patient. The therapy methods (test or control) were randomly allocated to one of the patient's sides each. By entering the study, the patient numbers were consecutively allocated to the patients and the therapy methods were allocated to the patient's sides.

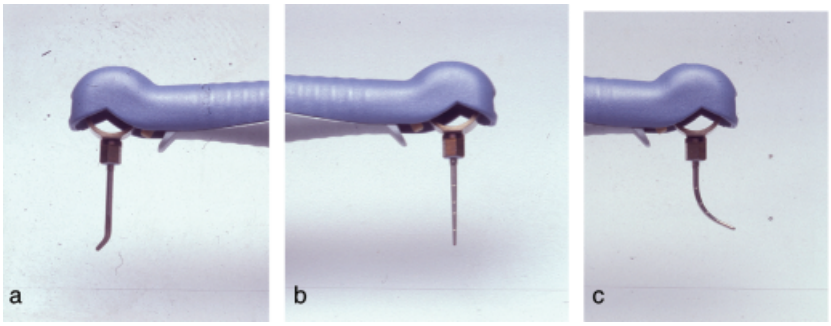

Fig. 1. (a) Vector™ metal curette, (b) Vector™ straight probe, and (c) Vector™ bent probe.

Treatment allocation was concealed to the operator until the beginning of the subgingival debridement.

Applying the split-mouth design, one quadrant of the upper and the lower jaws each were selected for treatment with either the new Vector™ ultrasonic system (Dürr, Bietigheim-Bissingen, Germany) or hand curettes (Gracey-curettes #1/2, #7/8, #11/12, #13/14, HuFriedy, Chicago, IL, USA). Subgingival debridement with the Vector™ system was carried out using the hydroxyapatite polishing fluid (median particle size: 10 μm), in combination with different working tips according to the manufacturer's instructions: the Vector™ curette for interproximal sites (Fig. 1a), the Vector™ straight probe for oral and vestibular sites (Fig. 1b), and the Vector™ bent probe for furcation defects (Fig. 1c). Local anaesthesia was provided on demand.

The time required for instrumentation of each quadrant was recorded by a stop watch. The criterion for a thorough subgingival debridement was a smooth root surface free of bacterial plaque and calculus verified by a dental explorer (CH3, HuFriedy) and × 2-magnifying lenses. Finally, all periodontal pockets were rinsed with a 0.2% chlorhexidine solution. Four weeks and 6 months after therapy, the patients were scheduled for re-evaluation and supportive periodontal therapy. At these time points, subgingival reinstrumentation was planned only in sites that showed signs of major inflammation (e.g. suppuration, swelling), which could not be left untreated until the completion of the study. After completion of the 6-month study period, all patients were set according to their individual needs on a 3- to 6-month schedule for routine supportive periodontal therapy in the Department of Operative Dentistry and Periodontology.

Clinical examinations

The following parameters were recorded at the first visit, immediately before subgingival debridement (i.e. baseline) as well as 4 weeks and 6 months after subgingival debridement: oral hygiene was assessed by the full-mouth API (Lange et al. 1977) and the full-mouth PBI (Saxer & Mühlemann 1975). The full-mouth API was calculated as the percentage of interproximal sites depicting plaque. The full-mouth PBI was calculated as the percentage of interproximal sites demonstrating bleeding after gentle probing. Furthermore, the following clinical parameters were also recorded: the PPD as the distance from the gingival margin to the bottom of the periodontal pocket and the clinical attachment level (CAL) as the distance from the CEJ or the margin of a restoration to the bottom of the periodontal pocket. Bleeding on probing (BOP; Lang et al. 1991) was calculated as the percentage of sites bleeding upon gentle probing. All parameters (PPD, CAL, and BOP) were recorded at six sites on each tooth: mesiobuccal, buccal, distobuccal, mesiooral, oral, and distooral. A pressure-calibrated probe (Brodontic 25 g, Ash, Dentsply, Weybridge, UK) with a PCP15-UNC tip (HuFriedy) provided standardized probing conditions. All clinical parameters were recorded masked by one calibrated examiner (T. M.), who had no knowledge of the treatment modality chosen for the individual tooth. Before the start of the study, the examiner was trained to adequate levels of accuracy and reproducibility in recording the clinical parameters and indices.

Assessment of the negative side effects

As a parameter for the patient's discomfort, all patients were asked about the occurrence of postoperative hypersensitivity (subjective postoperative hypersensitivity) after 4 weeks and 6 months. Furthermore, the objective postoperative hypersensitivity was assessed with air-blast pain stimuli as previously described (Tammaro & Wennström 2000). The air blast (4.1 bar, 22°C) derived from the syringe of a dental delivery unit was directed to the buccal root surface for maximum of 10 s. The syringe was held perpendicularly, 5 mm from the root surfaces. The neighbouring teeth were shielded with the gloved fingers of the dentist. The number of teeth revealing a subjective or objective pain sensation was recorded dichotomously after 4 weeks and 6 months.

Microbiological examination

At baseline, as well as 4 weeks and 6 months after subgingival debridement, subgingival bacterial samples were obtained from the deepest site of each quadrant. For this purpose, a molecular–biological testing system [(Padotest 4.5, Institute for applied Immunology (IAI), Zuchwil, Switzerland)] was used. The sample sites were isolated with cotton rolls, air dried, and supragingival plaque or calculus was removed with sterile scalers. In each site, a medium-sized sterile paper point (Johnson & Johnson, Medical Inc., Arlington, TX, USA) was inserted to the bottom of the periodontal pocket. After 20 s, the paper point was retrieved and transferred to a collection tube containing 100 μl of a stabilizing buffer sealed by an *O*-ring in the cap and mailed to the IAI. The samples were analysed by oligonucleotide probe (ssrRNA probes) technology (Dix et al. 1990) for *Actinobacillus actinomycetemcomitans*, *Tanerella forsythensis*, *Porphyromonas gingivalis*, and *Treponema denticola*. Furthermore, the total marker load (TML; number of periodontal pathogens related to the total number of bacteria in the sample) and the total bacterial load (TBL; total amount of bacteria in the sample) were determined.

Data analysis

The single patient was regarded as the evaluation unit. The primary outcome parameter was the change in BOP. The secondary outcome parameters were the changes in PPD, CAL, and microbiological findings as well as the occurrence of root hypersensitivity. Clinical and

microbiological measurements were expressed as median values (with 25 and 75 percentiles). Owing to the different healing response (Badersten et al. 1984, Van der Weijden & Timmerman 2002), the periodontal pockets were divided into three different PPD categories on the basis of the initial probing pocket depths: shallow pockets (initial PPD: 1–3 mm), moderate pockets (initial PPD: 4–6 mm), and deep pockets (initial PPD: $\geq$ 7 mm).

Taking into account the paired nature of the split-mouth design, the Wilcoxon signed rank test was used for the statistical analysis of differences between the treatment modalities and between the examination times. The significance level was set to $\alpha = 0.05$. For comparability with other studies, additionally, the mean values and standard deviations were also included in the tables. The findings concerning the occurrence of postoperative hypersensitivity were reported descriptively.

Results

While all 20 patients could be considered for the evaluation of the healing results after 4 weeks, only 19 of the 20 patients could be re-evaluated after 6 months. One patient did not show up at the 6-month examination and consequently dropped out of the study. The patients characteristics are reported in Table 1. At the 4-week and 6-month evaluation, none of the patients revealed any major periodontal inflammatory symptoms requiring re-instrumentation during the entire study period. No tooth under investigation had to be extracted during the 6-month period. A similar number of teeth was treated with the Vector™ ultrasonic scaling system or S/RP (275 *versus* 271). Both groups showed a similar distribution of the tooth types (Table 2) and of the periodontal pocket depth categories (Table 3). All patients received a local anaesthesia for subgingival debridement independent of the treatment method used.

Table 2. Distribution of tooth types

Tooth type	Test teeth (%)	Control teeth (%)
Incisors and canines	42.5	41.6
Pre-molars	26.9	28.1
Molars	30.6	30.3

Test teeth, Vector™-treated teeth ($n = 275$) of all patients; control teeth, S/RP-treated teeth ($n = 271$) of all patients.

Table 3. Relative distribution of probing pocket depth categories per patient

Pocket depth category	Test sites (%)	Control sites (%)
Shallow pockets (1–3 mm)		
Median	55.6	56.4
25/75%	47.7/65.8	47.7/62.7
Mean ± SD	55.3 ± 15.1	54.5 ± 14.9
Moderate pockets (4–6 mm)		
Median	38.6	38.9
25/75%	33.0/48.3	30.6/47.7
Mean ± SD	38.7 ± 11.0	40.3 ± 11.5
Deep pockets ($\geq$7 mm)		
Median	5.7	5.0
25/75%	2.0/10.5	2.4/12.4
Mean ± SD	7.4 ± 6.3	6.9 ± 5.1

Test sites, Vector™-treated sites; control sites, S/RP-treated sites; 25/75%, 25/75% percentile; mean, mean value; SD, standard deviation.

Table 4. Full-mouth indices API and PBI

	API (%)	PBI (%)
First visit		
Median	96.0	25.5
25/75%	68.5/100.0	14.0/40.0
Mean ± SD	81.6 ± 28.8	27.6 ± 16.5
Baseline		
Median	12.0*	9.0*
25/75%	3.3/19.3	4.0/13.5
Mean ± SD	12.1 ± 9.9	9.3 ± 6.4
4 weeks		
Median	15.5*	7.0*
25/75%	8.5/22.5	2.0/13.0
Mean ± SD	15.9 ± 11.5	7.5 ± 6.1
6 months		
Median	14.0*	2.0*+#
25/75%	4.0/20.0	0.0/5.0
Mean ± SD	16.2 ± 15.8	3.4 ± 3.9

*Statistically significant difference compared with first visit.
+Statistically significant difference compared with baseline.
#Statistically significant difference compared with 4 weeks.
25/75%, 25/75% percentile; mean, mean value; SD, standard deviation; first visit, before supragingival cleaning; baseline, 2 weeks after supragingival cleaning; 4 weeks, 4 weeks after subgingival debridement; 6 months, 6 months after subgingival debridement; API, approximal plaque index; PBI, papillary bleeding index.

Clinical results

The clinical results are reported in Tables 4–7. Besides a significantly higher BOP value in moderately deep S/RP sites (Table 5), no other clinical parameter (BOP, PPD, CAL) revealed any statistically significant differences between the test and control groups at baseline.

Oral hygiene and gingival health

Two weeks after completion of the supragingival pre-treatment phase, all patients showed adequate compliance with good oral hygiene at baseline. The full-mouth API was 12.0% and the PBI was 9.0%. During the entire 6-month study period, all examined patients showed a good compliance with low plaque and gingival bleeding scores (Table 4).

BOP

Four weeks and 6 months after subgingival debridement, statistically significant BOP reductions compared with baseline were observed in both treatment groups and for all three pocket depth categories (Table 5). In the moderate pockets of the test group, the baseline BOP of 77% was reduced by 66% after 4 weeks and by 68% after 6 months. In the

Table 5. Bleeding on probing (BOP) (%): baseline value (BL) and changes (ΔBOP) at the various examination intervals

	Test group ($n = 20$)			Control group ($n = 20$)		
	BOP: baseline	ΔBOP: 4 weeks–BL	ΔBOP: 6 months–BL	BOP: baseline	ΔBOP: 4 weeks–BL	ΔBOP: 6 months–BL
Shallow pockets (1–3 mm)						
Median	29.8	− 29.8#	− 28.6#	30.0	− 26.5#	− 28.4#
25/75%	24.6/37.5	− 34.4/ − 21.0	− 36.7/ − 22.5	22.2/35.8	− 33.5/ − 17.7	− 36.4/ − 19.6
Mean ± SD	31.9 ± 10.7	− 28.6 ± 10.0	− 30.7 ± 10.6	30.1 ± 9.6	− 26.1 ± 8.9	− 28.3 ± 10.9
Moderate pockets (4–6 mm)						
Median	76.6*	− 66.3#	− 67.7#	81.9*	− 72.1#	− 73.1#
25/75%	63.8/88.7	− 80.3/ − 54.9	− 81.8/-59.3	75.1/90.5	− 79.0/ − 64.2	− 82.1/ − 67.7
Mean ± SD	75.8 ± 15.3	− 66.6 ± 15.3	− 69.0 ± 15.7	82.6 ± 9.4	− 71.4 ± 10.3	− 73.2 ± 13.4
Deep pockets (⩾7 mm)						
Median	100.0	− 75.0#	− 66.7#*	100.0	− 80.0#	− 100.0#*
25/75%	92.5/100.0	− 100.0/ − 66.7	− 100.0/ − 50.0	100/100	− 100.0/ − 50.0	− 100.0/ − 75.0
Mean ± SD	89.7 ± 25.8	− 73.6 ± 25.6	− 69.9 ± 28.6	98.7 ± 3.4	− 76.3 ± 22.6	− 88.1 ± 16.6

*Statistically significant difference between test and control group.
#Statistically significant change compared with baseline.
Test group, Vector™-treated teeth; control group, S/RP-treated teeth; *n*, number of patients treated in test or control group; 25/75%, 25/75% percentile; mean, mean value; SD, standard deviation.

Table 6. Probing pocket depth (PPD) (mm): baseline value (BL) and changes (ΔPPD) at the various examination intervals

	Test group ($n = 20$)			Control group ($n = 20$)		
	PPD: baseline	ΔPPD: 4 weeks–BL	ΔPPD: 6 months–BL	PPD baseline	ΔPPD 4 weeks–BL	ΔPPD 6 months–BL
Shallow pockets (1–3 mm)						
Median	2.0	0.0	0.0#	2.0	0.0	0.0
25/75%	2.0/3.0	0.0/0.0	0.0/0.0	2.0/3.0	0.0/0.0	0.0/0.0
Mean ± SD	2.4 ± 0.5	0.1 ± 0.2	0.0 ± 0.3	2.4 ± 0.5	0.0 ± 0.0	0.0 ± 0.0
Moderate pockets (4–6 mm)						
Median	5.0	− 1.0#	− 1.0#	5.0	− 1.0#	− 1.0#
25/75%	4.3/5.0	− 1.0/0.0	− 1.0/ − 1.0	5.0/5.0	− 1.0/ − 0.6	− 1.0/ − 1.0
Mean ± SD	4.8 ± 0.4	− 0.7 ± 0.5	− 1.0 ± 0.5	4.9 ± 0.5	− 0.8 ± 0.4	− 1.1 ± 0.4
Deep pockets (⩾7 mm)						
Median	7.3	− 1.0#	− 2.0#	7.0	− 2.0#	− 2.0#
25/75%	7.0/8.0	− 2.0/0.0	− 2.0/ − 1.0	7.0/8.0	− 2.5/ − 1.0	− 3.1/ − 1.4
Mean ± SD	7.4 ± 0.5	− 0.9 ± 1.0	− 1.6 ± 0.9	7.8 ± 2.0	− 1.9 ± 1.4	− 2.1 ± 1.2

*Statistically significant difference between test and control group (not found).
#Statistically significant change compared with baseline.
Test group, Vector™-treated teeth; Control group, S/RP-treated teeth; *n*, number of patients treated in test or control group; 25/75%, 25/75% percentile; Mean, mean value; SD, standard deviation.

control group, the baseline BOP of 82% was reduced by 72% and 73% after 4 weeks and 6 months, respectively. In the deep pockets, the baseline BOP was 100% in both groups. The test group revealed a BOP reduction of 75% after 4 weeks and of 67% after 6 months. In the control group, the BOP reduction was 80% and 100% after 4 weeks and 6 months, respectively. After 6 months, the control group revealed a significantly better BOP reduction than the test group in deep periodontal pockets.

In the present study, based on the BOP changes (i.e. primary outcome parameter) in deep periodontal pockets after 6 months, a sample size of 20 patients, and a two-sided significance level of $\alpha = 0.05$, the statistical power of the comparison between the test and control sites was 70.0%.

PPD

In shallow pockets, only minimal PPD changes were found after 4 weeks and 6 months. In contrast, both test and control procedures led to statistically significant PPD reductions after 4 weeks and 6 months compared with baseline in moderate and deep pockets (Table 6). In moderate pockets, a median PPD reduction of 1 mm was found after 4 weeks and 6 months in both treatment groups. In deep pockets, the test procedure caused a PPD reduction of 1 mm and 2 mm after 4 weeks and 6 months, respectively. The control procedure caused a PPD reduction of 2 mm after 4 weeks and 6 months. No significant differences were found between the test and control sites.

CAL

While shallow pockets did not reveal significant CAL changes following subgingival debridement, both test and control procedures provided statistically significant CAL gains of 1 mm in moderate pockets after 6 months (Table 7). In deep pockets, the test procedure provided CAL gains of 1 mm after 4 weeks and 0.5 mm after 6 months. Both changes were not significant compared to baseline. In contrast, the control procedure achieved CAL gains of 1 and 1.5 mm after 4 weeks and 6 months, respectively, which were significant

Table 7. Clinical attachment level (CAL) (mm): baseline value (BL) and changes (ΔCAL) at the various examination intervals

	Test group ($n = 20$)			Control group ($n = 20$)		
	CAL baseline	ΔCAL 4 weeks–BL	ΔCAL 6 months–BL	CAL baseline	ΔCAL 4 weeks–BL	ΔCAL 6 months–BL
Shallow pockets (1–3 mm)						
Median	3.0	0.0	0.0	3.0	0.0	0.0
25/75%	2.3/3.0	0.0/0.0	0.0/0.0	2.3/3.0	0.0/0.0	0.0/0.0
Mean ± SD	2.8 ± 0.5	0.1 ± 0.2	0.1 ± 0.3	2.8 ± 0.5	0.1 ± 0.2	0.2 ± 0.4
Moderate pockets (4–6 mm)						
Median	5.0	0.0[#]	− 1.0[#]	5.0	− 0.3[#]	− 1.0[#]
25/75%	4.5/5.0	− 1.0/0.0	− 1.0/0.0	5.0/5.8	− 1.0/0.0	− 1.0/ − 1.0
Mean ± SD	4.9 ± 0.7	− 0.4 ± 0.5	− 0.7 ± 0.6	5.2 ± 0.7	− 0.5 ± 0.5	− 0.8 ± 0.4
Deep pockets (⩾7 mm)						
Median	7.8	− 1.0	− 0.5	8.0	− 1.0[#]	− 1.5[#]
25/75%	7.0/8.4	− 1.0/0.0	− 2.0/0.0	7.0/9.0	− 3.0/0.0	− 3.0/0.0
Mean ± SD	7.8 ± 0.9	− 0.5 ± 1.1	− 0.8 ± 1.0	8.3 ± 2.0	− 1.5 ± 1.4	− 1.5 ± 1.4

[*]Statistically significant difference between test and control group (not found).
[#]Statistically significant change compared with baseline.
Test group, Vector™-treated teeth; control group, S/RP-treated teeth; *n*, number of patients treated in test or control group; 25/75%, 25/75% percentile; mean, mean value; SD, standard deviation.

compared to baseline. In all pocket depth categories, the differences between test and control sites did not reach the level of significance.

None of the clinical parameters revealed a statistically significant influence of the tooth type (incisors/canines, pre-molars, molars) on the effectiveness of the test or control procedure (data not shown).

Microbiological results

The microbiological results are reported in Table 8. The bacterial findings were very similar in test and control sites at baseline as well as 4 weeks and 6 months after therapy.

Microbiological testing detected *A. actinomyctemcomitans* in only very few sites and could not reveal significant changes following therapy. In contrast, in test sites, significant reductions compared with baseline were found for *T. forsythensis* after 4 weeks and 6 months and for *P. gingivalis* and *T. denticola* after 4 weeks. In control sites, significant reductions were revealed for *T. forsythensis* and *T. denticola* after 4 weeks and 6 months and for *P. gingivalis* after 4 weeks. In both groups, *T. forsythensis, P. gingivalis*, and *T. denticola* showed a tendency to increase between the 4-week- and 6-month examinations.

The TBL was reduced from initially $31{,}345 \times 10^3$ *versus* $30{,}320 \times 10^3$ bacteria (test *versus* control) to $13{,}850 \times 10^3$ *versus* 8785×10^3 bacteria after 4 weeks and to $14{,}920 \times 10^3$ *versus* 6900×10^3 bacteria after 6 weeks. The TML decreased from 7.2% *versus* 9.1% (test *versus* control) at baseline to 2.5% *versus* 1.8% after 4 weeks and then significantly increased again to 9.2% *versus* 8.2% after 6 months. None of the microbiological parameters revealed statistically significant differences between test and control sites.

Time of instrumentation

On the basis of the described criteria for treatment completion, the median duration needed for root instrumentation per tooth was 4.7 min. with the Vector™ system and 4.3 min. with the curettes (S/RP). This difference was not statistically significant.

Postoperative hypersensitivity

None of the patients reported subjective hypersensitivity, independent of the treatment method and the time after subgingival debridement. After 4 weeks, no tooth treated with the Vector™ system, but 6.3 teeth per patient (median) treated with S/RP showed objective postoperative hypersensitivity provoked by the air blast. 6 months after subgingival debridement, neither the test nor the control teeth revealed any objective postoperative hypersensitivity.

Discussion

The primary objective of cause-related periodontal therapy is the effective reduction of subgingival plaque and calculus and the prevention of a re-colonization of the pockets by periodontal pathogens (Braun et al. 2005b). The present study has shown that in patients with moderate to advanced chronic periodontitis, non-surgical periodontal therapy with the Vector™ ultrasonic system can result in clinical and microbiological healing results that, in general were similar to those obtained by conventional scaling and root planing with hand curettes. This was in accordance with the previous clinical studies on the Vector™ system (Klinger et al. 2000, Sculean et al. 2004, Kocher et al. 2005, Rupf et al. 2005).

The design of the present study facilitated the comparison of the two treatment modalities under very similar healing and evaluation conditions by minimizing other influence factors. The split-mouth design allowed a direct comparison of both therapeutic methods within each patient, providing a similar healing potential with similar immunological and microbiological conditions (Hujoel & Moulton 1988, Page et al. 1995, Koch & Paquette 1997). Furthermore, the test and control groups revealed very similar baseline conditions. Although its importance is still controversially discussed (Kinane 2005, Koshy et al. 2005), full-mouth debridement was carried out within 24 h to reduce the risk of re-infection of the treated sites from the remaining untreated sites (Quirynen et al. 1995, 2000). Only one operator and one blinded examiner were included for the treatment and examination of all patients, respectively, to exclude ''inter-operator'' and ''inter-examiner'' variability.

Table 8. Microbiological results: number of tested bacteria, total bacterial load, and total marker load

	Test group (n = 20)			Control group (*n* = 20)		
	baseline	4 weeks	6 months	baseline	4 weeks	6 months
Actinobacillus actinomycetemcomitans ($\times 10^3$)						
Median	0	0	0	0	0	0
25/75%	0/42	0/0	0/6	0/0	0/0	0/18
Mean ± SD	21 ± 35	9 ± 31	23 ± 49	4 ± 18	5 ± 15	12 ± 22
T. forsythensis ($\times 10^3$)						
Median	1325$^{+\#}$	55^{+}	430$^{\#}$	715$^{+\#}$	35^{+}	220$^{\#}$
25/75%	233/2640	0/358	20/1400	70/2688	0/295	0/540
Mean ± SD	2762 ± 5269	557 ± 1470	906 ± 1170	2200 ± 3361	209 ± 368	364 ± 426
Porphyromonas gingivalis ($\times 10^3$)						
Median	235^{+}	40^{+}	140	130^{+}	5$^{+\P}$	30¶
25/75%	23/1223	0/270	0/430	0/1790	0/95	0/310
Mean ± SD	1189 ± 2137	3620 ± 998	394 ± 749	1499 ± 2676	62 ± 92	332 ± 829
Treponema denticola ($\times 10^3$)						
Median	605^{+}	30^{+}	210	640$^{+\#}$	20$^{+\P}$	100$^{+\#\P}$
25/75%	135/1743	0/308	20/890	0/1540	0/125	10/420
Mean ± SD	1207 ± 1473	227 ± 381	542 ± 690	875 ± 1001	73 ± 104	270 ± 412
Total bacterial load ($\times 10^3$)						
Median	31345$^{+\#}$	13850^{+}	14920$^{+\#}$	30320$^{+\#}$	8785^{+}	6400$^{\#}$
25/75%	13,710/58,928	6950/20,360	4320/32,660	7073/58,457	5488/15,485	3060/13,800
Mean ± SD	46,034 ± 43,454	20,039 ± 26,251	19,036 ± 16,805	36,420 ± 32,262	12,372 ± 9938	11,087 ± 14,113
Total marker load (%)						
Median	7.2^{+}	2.5$^{+\P}$	9.2¶	9.1^{+}	1.8$^{+\P}$	8.2¶
25/75%	3.6/11.9	0.5/8.4	4.2/11.0	2.7/13.9	0.2/4.8	2.2/10.6
Mean ± SD	8.7 ± 6.5	4.3 ± 4.8	8.2 ± 5.3	8.9 ± 8.4	3.8 ± 5.3	7.2 ± 5.0

*Statistically significant difference between test and control group.
+Statistically significant difference between baseline and 4 weeks.
#Statistically significant difference between baseline and 6 months.
¶Statistically significant difference between 4 weeks and 6 months.
n, number of patients treated in test or control group; mean, mean value; SD, standard deviation; 25/75%, 25/75% percentile.

A recent systematic review demonstrated the effectiveness of subgingival debridement, if an adequate supragingival plaque control is established (Van der Weijden & Timmerman 2002). The objective of this study was to test the effectiveness of the Vector™ system *versus* conventional S/RP for *subgingival* debridement. The influence of supragingival plaque control and patients' compliance should be kept minimal. For this reason, similar to previous studies (Laurell 1990, Brochut et al. 2005), a pre-treatment phase including supragingival cleaning and intensive oral hygiene instructions was performed 2 weeks before the baseline examination. During the 6-month study period, all investigated patients revealed a good compliance with low plaque and gingival bleeding scores.

An important clinical indication for successful subgingival debridement is a marked reduction of periodontal inflammatory symptoms like BOP. In the present study, significant BOP reductions of 66–100% were found in moderate and deep sites of both treatment groups after 4 weeks and 6 months. However, while in moderate pockets no differences were found between test and control procedures, in deep pockets ($\geqslant$7 mm) the Vector™ system caused a significantly lower BOP reduction compared with S/RP (median ΔBOP: 67% *versus* 100%). The magnitude of the BOP reductions in the present study corresponds to the data from previous studies summarized in recent systematic reviews (Tunkel et al. 2002, Van der Weijden & Timmerman 2002, Hallmon & Rees 2003). In those studies, no difference was found between S/RP and machine-driven subgingival debridement (Badersten et al. 1981, 1984, Lindhe & Nyman 1985, Laurell & Pettersson 1988, Kalkwarf et al. 1989, Copulos et al. 1993, Kocher et al. 2001b, Obeid et al. 2004). In a recent investigation (Sculean et al. 2004), a BOP reduction from 32% to 20% was found 6 months after treatment with the Vector™ system compared with a reduction from 30% to 18% after S/RP. These authors did not find a significant difference between both therapy methods. However, in contrast to the present study, they did not distinguish between different pocket depth categories when comparing the BOP values. The observed superior BOP reduction in deep S/RP sites is in line with another study (Christgau et al. 2006), which also reported a better BOP reduction in deep pockets with S/RP than with a sonic scaler. Kocher et al. (2005) compared the efficacy of the Vector™ system and a conventional ultrasonic scaler in periodontal maintenance therapy. They found a slight increase of the BOP from 25% to 28% in the Vector™ group and a decrease of the BOP from 41% to 19% in the control group for pockets, that were deeper than 4 mm.

Histologic studies have shown that successful cause-related non-surgical therapy results in the formation of a long junctional epithelium, independent of the method used (Waerhaug 1978, Aukhil et al. 1988, Sculean et al. 2003). Clinically, this is indicated by an increased tissue resistance to periodontal probing. In the present study, the Vector™ system and S/RP resulted in a significant PPD reduction of 1 mm in moderate and of 2 mm in deep periodontal pockets. After 6 months of healing, for both therapy methods the CAL gain was 1 mm in moderate pockets. However, in deep pockets the CAL gain was 1.5 mm with S/RP *versus* only 0.5 mm with the Vector™ system. Interestingly, the CAL gains in deep test sites were not statistically significant compared with baseline. Furthermore, while the differences between test and control group did not reach the level of significance, there was a clear tendency for a greater CAL gain in deep ($\geqslant$7 mm) control sites. In general, the magnitude of the PPD reductions and CAL gains found in the present study are in accordance with data summarized in different recent meta-analyses (Tunkel et al. 2002, Van der Weijden & Timmerman 2002, Hallmon & Rees 2003). Sculean et al. (2004) found PPD reductions of about 0.6–0.9 mm with the Vector™ system and of about 0.8–1.2 mm with S/RP, dependent on the initial pocket depth and the tooth type. The corresponding CAL gains were 0.5–0.7 for the Vector™ system and 0.5–0.8 for S/RP. The authors did not find significant differences between both therapeutic methods.

A major goal of periodontal therapy is to remove the subgingival biofilm as far as possible and to reduce the bacterial load below a clinically and immunologically relevant threshold, allowing the formation of a long junctional epithelium (Van der Weijden & Timmerman 2002, Wennström et al. 2005). In the present study, both treatment methods significantly reduced three of the investigated pathogens (*T. forsythensis*, *P. gingivalis*, *T. denticola*) as well as the TBL 4 weeks and 6 months after subgingival debridement, which is in line with the improvements observed in the clinical parameters (BOP, PPD, CAL). However, the significant increase of the TBL between the 4 week and 6 month examinations indicated the beginning of a re-colonization of the pockets by the pathogens. These observations confirm previous findings (Pedrazzoli et al. 1991, Ali et al. 1992, Lowenguth & Greenstein 1995, Haffajee et al. 1997, Shiloah et al. 1997, Takamatsu et al. 1999, Doungdomdacha et al. 2001, Beikler et al. 2004, Brochut et al. 2005, Christgau et al. 2006), which reported similar microbiological changes following non-surgical periodontal therapy.

In contrast to the data of Sculean et al. (2004), in the present study a significantly higher BOP reduction and a clear tendency towards a better CAL gain in deep pockets after S/RP indicated that the Vector™ system might be less effective in the treatment of deep pockets. In both studies, the Vector™ metal probe and metal curette inserts were used in combination with the hydroxyapatite polishing fluid for subgingival debridement according to the manufacturer's instructions. A recent in vitro study (Braun et al. 2005b) showed that the efficiency of calculus removal with the Vector™ system is significantly dependent on the selection of the inserts and irrigation fluids. Compared with Gracey curettes and a conventional ultrasonic system, the Vector™ metal probe insert was significantly less efficient in removing the calculus from the root surface. In contrast, the Vector™ metal curette insert, especially in combination with an abrasive silicon-carbide suspension, showed an efficiency similar to the conventional ultrasonic system. In the present study, the metal probe insert was used to clean the buccal and oral root surfaces, while the metal curette was used for the interproximal surfaces. While the primary objective of subgingival debridement is the disruption and removal of the bacterial biofilm, calculus remnants provide niches for retention and re-colonization of periodontal pathogens. In line with the in vitro findings of Braun et al. (2005b), possibly a less effective root surface debridement with the Vector™ system, especially in deep pockets, might explain the greater residual BOP score and the tendency towards a reduced CAL gain in

these sites compared with S/RP. A further indication for this assumption could be the tendency towards a higher bacterial load in Vector™-treated sites compared with S/RP sites after 4 weeks and 6 months. In contrast to our observations in deep pockets and the in vitro findings of Braun et al. (2005b), a recent in vivo study (Schwarz et al. 2006) reported significantly less residual subgingival calculus in sites treated by the Vector™ system compared with sites treated by S/RP.

Besides an effective pocket debridement, other aspects, like the required treatment time and unwanted side effects (postoperative hypersensitivity, pain), are also important for the clinician and the patient. Corresponding to previous study designs (Laurell & Pettersson 1988, Patterson et al. 1989, Copulos et al. 1993, Yukna et al. 1997, Sculean et al. 2004) and in contrast to the study of Wennström et al. (2005), the operator was not given a time limit, allowing an adequate and sufficient subgingival debridement of each tooth according to its individual needs. Completion of root debridement was indicated by a smooth root surface free of bacterial plaque and calculus verified by a dental explorer and magnifying lenses. Although probing of the root surface may not be a reliable method to detect all residual bacterial deposits (Sherman et al. 1990a), under clinical circumstances, this is the only possibility to verify an adequate subgingival debridement at the time of instrumentation. Within the limits of the present study design, test and control procedures required a similar treatment time per tooth (4.7 *versus* 4.3 min.). This is in contrast to previous papers (Tunkel et al. 2002, Wennström et al. 2005, Christgau et al. 2006) reporting reduced treatment times for machine-driven instruments compared with S/RP. In contrast to the present data, Sculean et al. (2004) needed less time with the Vector™ system compared with S/RP. In another study (Kocher et al. 2005), the Vector™ system initially required more time than a conventional ultrasonic scaler for subgingival debridement in maintenance patients. Also, Schwarz et al. (2006) reported a statistically significantly longer time needed for root instrumentation using the Vector™ system.

According to previous findings (Hughes et al. 1988, Cadosch et al. 2003), instruments for subgingival debridement should be effective in disrupting the biofilm and removing bacterial deposits from the root surface with minimal loss of tooth substance (Obeid & Bercy 2005, Wennström et al. 2005). In the present study, treatment with the Vector™ system did not cause considerable postoperative root hypersensitivity. This confirms in vitro (Braun et al. 2005a) and in vivo (Schwarz et al. 2006) findings that the Vector™ system in combination with the polishing fluid may facilitate gentle root debridement without extensive loss of root substance. In contrast, the present study revealed postoperative hypersensitivity 4 weeks after S/RP, which was not found anymore after 6 months. These results confirm previous findings after S/RP (Chabansky et al. 1996, 1997, Tammaro & Wennström 2000, Troil et al. 2002, Christgau et al. 2006). The observed root hypersensitivity in S/RP sites after 4 weeks has to be ascribed to an unwanted superficial loss of tooth substance (Ritz et al. 1991, Schmidlin et al. 2001, Kocher et al. 2001a, Braun et al. 2005a, Schwarz et al. 2006).

Our results, together with previous clinical (Hoffman et al. 2005, Kocher et al. 2005, Schwarz et al. 2006) and in vitro findings (Braun et al. 2005b, a), indicate that the Vector™ system may be used preferably as a gentle root debridement device for supportive periodontal therapy, as an alternative to other ultrasonic or sonic scalers. The primary objective in maintenance therapy is the removal of the bacterial biofilm rather than the removal of calculus (Kocher et al. 2005). As subgingival instrumentation is carried out repeatedly during supportive periodontal therapy, it is crucial to prevent even minimal root damage (Flemmig et al. 1997, Kocher et al. 2001a, 2005).

Conclusion

Within the limitations of this study:

1. The new Vector™ ultrasonic scaling system and S/RP provided favourable periodontal healing results.
2. In deep pockets, S/RP achieved a better resolution of inflammation and significant CAL gains.
3. S/RP resulted in initially more hypersensitive teeth, probably due to an unwanted loss of tooth substance.
4. Periodontal therapy using the Vector™ system seems to require at least a similar amount of time as hand instrumentation.

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Clinical Relevance

Scientific rationale: Owing to the completely different working mechanism of the new Vector™ ultrasonic system compared with conventional ultrasonic scalers, still relatively little knowledge exists about its effectiveness in non-surgical periodontal therapy. In this study, the influence of the Vector™ system on clinical and microbiological parameters was compared with S/RP with hand instruments.

Principal findings: The Vector™ system provided clinical and microbiological healing results similar to S/RP, although it left a higher BOP score in deep ($\geq$7 mm) periodontal pockets after 6 months. Vector™ caused less hypersensitivity than S/RP.

Practical implications: The Vector™ system may be an acceptable alternative to S/RP for gentle non-surgical subgingival debridement, especially in moderately deep pockets.