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The use of a linear oscillating device in periodontal treatment: a review

Arndt Guentsch[1] and Philip M. Preshaw[2]

[1]Department of Conservative Dentistry, University Hospital of Jena, Friedrich-Schiller University, Jena, Germany; [2]Department of Periodontology, School of Dental Sciences, University of Newcastle upon Tyne, UK

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Abstract

Background: The Vector™ system is an ultrasonic instrument that was introduced in 1999, and treatment outcomes with Vector have been compared with those achieved with the ''gold standard'' of scaling and root planing with Gracey curettes as well as conventional ultrasonic scalers. The aim of this paper is to review the existing literature regarding the Vector™ method.

Material and Methods: This review is based on a MEDLINE search of the use of Vector up to January 2008 (focused on in vitro findings, periodontal treatment, peri-implantitis therapy, clinical and microbiological data, and patient considerations). The MEDLINE search identified 128 papers, of which 18 were found to be relevant to this review. A hand search of the periodontal literature over the same period resulted in identification of a further 10 relevant papers.

Conclusion: Vector™ used for treatment of chronic periodontitis results in clinical and microbiological outcomes comparable to those achieved by manual instrumentation and conventional ultrasonic instruments. Vector™ is less efficient when removing large masses of calculus, however, and cannot be recommended for the treatment of peri-implantitis. Vector may be particularly useful in periodontal maintenance care as it is well tolerated by patients and results in less removal of cementum than other instruments.

Key words: efficacy; non-surgical periodontal treatment; SRP; ultrasonic; Vector

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Periodontal diseases are chronic inflammatory conditions that are initiated by prolonged exposure to the subgingival bacterial biofilm. The inflammatory host response to these bacteria, while protective by intent to combat the bacterial infection, also results in tissue destruction, leading to the clinical signs of disease (Genco 1996, Page 1999). Disruption and/or removal of the subgingival biofilm to reduce the bacterial challenge remains the cornerstone of periodontal therapy. Non-surgical mechanical treatment, comprising mechanical plaque control and scaling and root planing (SRP), is considered the ''gold standard'' of periodontal therapy (Cobb 1996). A great variety of instruments can be used to perform SRP, including manual, sonic, and ultrasonic instruments (Arabaci et al. 2007).

Ultrasonic instruments for removing supragingival calculus were introduced approximately 60 years ago (Cobb 2002). The inserts have been modified over time and can now be used for subgingival treatment also. The efficacy of sonic and ultrasonic instruments has been found to be comparable to that of manual instrumentation in numerous studies (Stewart et al. 1967, Torfason et al. 1979, Badersten et al. 1981, 1984, Loos et al. 1987, Dragoo 1992, Copulos et al. 1993, Kocher et al. 1997). Further benefits of sonic and ultrasonic instruments compared with hand instruments include better treatment outcomes in molar furcation areas and also that subgingival debridement can be completed much more quickly than when using hand instruments (Tunkel et al. 2002). However, potential disadvantages of sonic and ultrasonic devices include more dentinal hypersensitivity, cavitation of hypomineralized enamel, thermal alterations of pulp and/or gingival tissue, transmission of infections via aerosol, acoustic lesions, and possible effects on cardiac pacemakers (Arabaci et al. 2007).

Conflict of interest and source of funding statement

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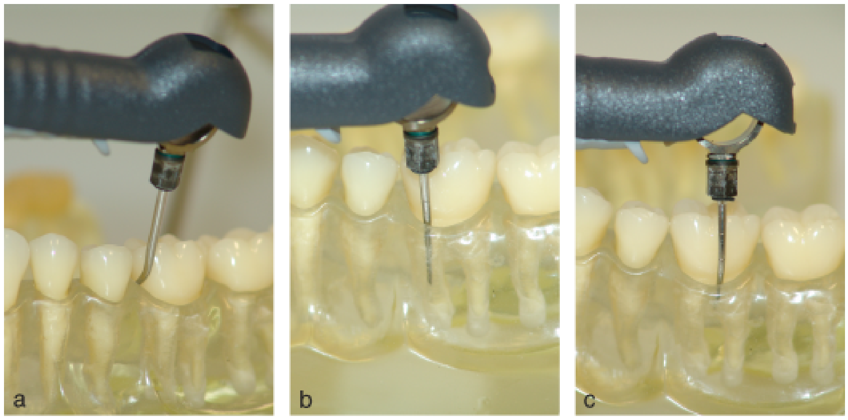

Fig. 1. The Vector™ instrument comprises a ring-shaped resonant body vibrated by an ultrasonic drive (at 25,000 Hz), which is attached to the working end at an angle of 90°. The amplitude of movement of the working tip ranges from 30–35 μm. Curettes are typical used for interproximal root surfaces (a), straight inserts for facial/buccal sites (b), and furcations inserts for affected furcation area (c).

The Vector™ instrument, which is characterized by a different working principle from conventional ultrasonics, and utilizes tips that oscillate in a linear fashion parallel to the root surface, has not yet been extensively reviewed. The aim of this paper is to review the existing literature regarding the Vector™ system.

A MEDLINE search of the English literature was carried out for the period 1999–2008 using the following search terms: ''Vector'' and ''periodontitis'', ''periodont*'', ''periodontal'', or ''peri-implantitis''. One hundred and twenty-eight retrieved abstracts/titles were analysed by two independent reviewers (A.G., P.M.P.), who selected 18 studies with potentially useful data regarding Vector (to include in vitro studies, clinical studies, microbiological findings, and patient perceptions and pain analyses). Manual searches of the periodontal literature were also performed, including English and German journals, yielding 14 additional potentially useful papers. After critical appraisal, four of these 14 were excluded (as they pertained to meeting abstracts or were duplicates of other identified studies). Thus, a total of 28 studies, which focussed on the Vector™ system in periodontal treatment were included in this review. The heterogeneity of these studies (which had very variable study designs and methods of data presentation) rendered a meta-analysis impossible. The majority of the reviewed papers were commercially sponsored, which is not surprising, given the cost of conducting clinical trials.

The Working Principle

The most commonly used ultrasonic scalers are either piezoelectric or magnetostrictive, with frequencies in the range of 25,000–42,000 Hz and an amplitude range of 10–100 μm. While the tip movement of piezoelectric scalers is primarily linear in direction, the tip movement of magnetostrictive scalers (such as the Cavitron system) is elliptical (Oda et al. 2004).

In 1999, Dürr (Bietigheim-Bissingen, Germany) developed a new generation of ultrasonic instruments named Vector™. This instrument comprises a ring-shaped resonant body vibrated by an ultrasonic drive (at 25,000 Hz), which is attached to the working end at an angle of 90° (Fig. 1). This configuration eliminates ellipsoid vibrations of the instrument tip, which therefore moves in a plane parallel to the tooth surface, in contrast to the laterally directed vibrations typical of conventional ultrasonic scalers (Hahn 2000). The amplitude of movement of the working tip ranges from 30–35 μm, which is considerably less than that observed in conventional ultrasonic scalers (which typically have an amplitude of 10–100 μm).

In order to cool the working tip during function, a coolant is supplied as part of the Vector™ system. A refillable water container (120 ml) is provided in the base station. The mobile base station also contains the fluid bags (200 ml) that can be added during treatment. The coolant is applied to the working tip by intermittent pulsation at a flow rate of 6 ml/min. A polish fluid, which includes hydroxyl apatite particles of $<10\,\mu$m is added to the liquid film for root planing. The suspension is not sprayed in an aerosol by the instrument, but is held hydrodynamically on the instrument tip (Fig. 2). In addition to the polish fluid, an abrasive fluid of approximately 50 μm particle size can be used for minimally invasive preparation of tooth cavities (not reviewed in this paper).

The working tips result in minimally invasive instrumentation (by virtue of their non-elliptical vibration pattern and small amplitude of vibration) and are comparable in dimensions to a manual probe or periodontal curette (Guentsch et al. 2006b). Both metal and carbon fibre inserts are available with the Vector™ system. Straight inserts are typically used for facial/buccal sites and curved inserts for the interproximal tooth surfaces. Furcations inserts are also included in the instrument set (Fig. 3).

Fig. 2. The Vector™ system in action. Important for function and transmission of power is the coolant suspension around the tip. The hydrodynamic fixation of the suspension along the insert avoids an aerosol.

Efficacy of the Vector™- system

Root surface instrumentation is necessary to effectively remove plaque and calculus deposits and disrupt the subgingival biofilm, but should not result in removal of excessive quantities of tooth

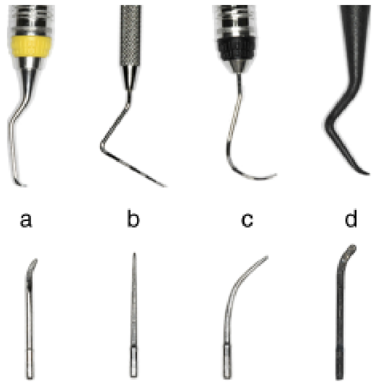

Fig. 3. The Vector™ tips (bottom line) are comparable with curettes (a), periodontal probe (b), Nabers probe for furcations (c), or plastic curettes (d).

material (cementum, dentine) from the tooth surface (Claffey et al. 2004), as this may lead to hypersensitivity (Fogel & Pashley 1993, Fukazama & Nishimura 1994).

Removal of calculus

Studies of teeth scheduled for extraction have typically demonstrated that, after subgingival instrumentation, complete removal of subgingival calculus is not predictably achieved with any instrument (Egelberg 1999). Such a study was conducted in vitro using extracted teeth to investigate calculus removal by the Vector™ system in comparison with Gracey curettes or a conventional piezoelectric ultrasonic instrument (Braun et al. 2005). The endpoint of the experiments was defined as complete visible calculus removal. Every 10 s, standardized photographs were taken and analysed. Based on the remaining calculus at intervals of 10 s, the amount of removed calculus per second was calculated. The effectiveness of calculus removal using the Vector™ system was found to depend on the precise insert tip used and the abrasiveness of the lubricating fluid. The Vector™ metal curette used in conjunction with the abrasive (50 μm) lubricating fluid achieved similar levels of calculus removal ($0.209 \pm 0.062\,mm^2/s$) to the conventional piezoelectric instrument ($0.199 \pm 0.065\,mm^2/s$). The Vector™ metal curette used with polish fluid (<10 μm particles) resulted in $0.122 \pm 0.031\,mm^2/s$ calculus removal. The lowest effectiveness of calculus removal was recorded when the Vector™ system was used with the probe insert and the polish fluid ($0.036 \pm 0.019\,mm^2/s$). Interestingly, the greatest rate of removal of calculus was observed when using hand instruments ($0.340 \pm 0.071\,mm^2/s$).

These results were subsequently confirmed in a further investigation of 40 extracted teeth examined before and after instrumentation with three-dimensional laser scanning (Braun et al. 2006). Again, it was identified that hand instruments removed statistically significantly more calculus ($0.048\,mm^3/s$) than a piezoelectric ultrasonic instrument ($0.016\,mm^3/s$) or the Vector™ system ($0.014\,mm^3/s$ with abrasive fluid and $0.008\,mm^3/s$ with polish fluid). In a further study, Rupf et al. examined 32 extracted human teeth following instrumentation with Vector, a piezoelectric ultrasonic system, or hand instruments. They identified significantly more residual calculus in the Vector™ group ($34 \pm 20\%$) in comparison with the piezoelectric system ($3 \pm 5\%$) and hand instruments ($3 \pm 4\%$), with no significant differences observed between the piezoelectric system and the hand instruments (Rupf et al. 2005).

In contrast to these observations, Kawashima et al. (2007a) found no differences in residual calculus after root instrumentation with the Vector™ system, a conventional ultrasonic system, or hand instruments. They used the residual calculus index (RCI) to assess residual calculus, in which RCI is defined as: 0 = no residual calculus, 1 = small patches of extraneous material probably consisted of calculus, 2 = definite patches of calculus, and 3 = considerable amounts of remaining calculus. Kishida et al. (2004) also observed similar levels of calculus removal when using Vector™ (RCI 0.75) or Gracey curettes (RCI 0.6), and also that Vector™ removed significantly more calculus from the root surfaces than a conventional ultrasonic scaler (RCI 1.8). Schwarz et al. (2006a) compared the effectiveness of subgingival instrumentation when using the Vector™ system, ER:YAG laser radiation (with different parameters), or manual instrumentation (SRP) on 27 single-rooted teeth in 12 patients in vivo. They observed the lowest level of residual subgingival calculus (RSC) in the Vector™ group (RSC area $2.4 \pm 1.8\%$). In the SRP group, $12.5 \pm 6.9\%$ of the treated root surfaces demonstrated residual calculus. The percentages of RSC areas depended on the probing depths and the extent of residual calculus was directly correlated to probing depth in the ER:YAG laser group and in the SRP group. In deep pockets, more residual calculus was observed than in shallow or moderate pockets, whether these pockets were treated with manual instruments or with the laser. Specimens treated with Vector™ exhibited comparable RSC area independent of probing depth.

To summarize, these in vitro studies present somewhat conflicting data regarding the effectiveness of the Vector™ system for calculus removal, when compared with conventional instruments (either manual, or ultrasonic). This may be as a result of the different methodologies that were employed. When considering all the studies together, it appears that overall, it is reasonable to say that effectiveness of subgingival calculus removal is similar for Vector™, manual instruments, and conventional ultrasonic instruments.

Removal of root substance

Previously, it was believed that endotoxin (i.e. lipopolysaccharide) from periodontopathic bacteria infiltrated deep into the root surfaces, and therefore that extensive cementum removal was required. This led to treatment protocols that involved extensive planing of the root to achieve a glassy hard root surface (Aleo et al. 1975). However, we now appreciate that such invasive instrumentation is not required, and more recent studies on extracted teeth have suggested that endotoxin is more superficially bound and can be removed by gentle instrumentation (Cheetham et al. 1988, Smart et al. 1990). This has led to current concepts of root surface instrumentation that advocate multiple light strokes to disrupt the biofilm and remove plaque and calculus, but without excessive removal of tooth structure. However, even lighter strokes with the instrument result in removal of some cementum, and therefore, particularly in periodontal maintenance patients, repeated instrumentation over a number of years may result in significant removal of tooth substance due to the cumulative effects of cementum removal (Zappa et al. 1991).

The Vector™ system appears to offer some advantages in this regard, as in vitro studies have demonstrated that the Vector™ system removes significantly less root substance than hand instrumentation. Thus, it has been demonstrated that the non-elliptical oscillation of the Vector™ tip results in the removal of only $2 \pm 3\,\mu$m of cementum in comparison with a conventional ultrasonic system ($24 \pm 18\,\mu$m of cementum removal) or instrumentation with hand instruments ($20 \pm 15\,\mu$m of cementum removal) (Rupf et al. 2005). There are also variations in root surface removal between the different tips available for the Vector™ system. The metal inserts remove less tooth substance ($2.7 \pm 1.4\,\mu g^2/mm^2$) than the carbon fibre inserts ($56.2 \pm 36.1\,\mu g^2/mm^2$) (Naef et al. 2004). The residual cementum left on the root surface after treatment with the Vector™ system is significantly greater ($45\,\mu$m) than that left after debridement with an ultrasonic scaler ($30\,\mu$m) or after hand instrumentation using Gracey curettes ($9\,\mu$m) (Kawashima et al. 2007a). Schwarz et al. (2006a) reported that Vector™ produces a smooth and homogeneous root surface, while SRP with manual instruments can lead to scratches, clefts, and grooves (ranging from 6.8 to $51.6\,\mu$m in depth). These studies suggest that the Vector™ inserts produce a smooth surface with minimal loss of tooth substance (Kishida et al. 2004). Schlageter et al. (1996), using an in vivo design, reported roughness values (Ra) using different instruments. In this study, Gracey curettes produced a root surface with a roughness of $1.90 \pm 0.84\,\mu$m, piezoelectric scalers $2.48 \pm 0.90\,\mu$m, and sonic scalers $2.71 \pm 1.12\,\mu$m. Naef et al. (2004) reported a surface roughness of $0.14 \pm 0.15\,\mu$m after Vector™ debridement. The attachment of fibroblasts to the root surface after instrumentation has also been studied, and following scaling with Vector™ there is better attachment and growth of fibroblasts than that observed after scaling with a conventional ultrasonic instrument, presumably as a result of the smoother root surface that is achieved (Schwarz et al. 2003, Kishida et al. 2004).

These studies conclusively indicate that the Vector™ system results in significantly less removal of dental hard tissues, thereby minimizing the risk of hypersensitivity and pulpitis. Further, the resultant root surface is smoother than that achieved with conventional instruments, which is important for reducing the likelihood of plaque accumulation.

Time required for treatment

Instrumentation time with ultrasonic instruments is usually less than that required when using manual instruments to achieve the same outcome (Arabaci et al. 2007). However, Braun et al. (2005) reported that root surface instrumentation with Vector™ to the endpoint of visible cleanliness of the root surface took significantly more time (calculated time of approximately 80 s to clean a $10\,mm^2$ deposit) than that required when using hand instruments (approximately 30 s for the same size of deposit). However, this was an in vitro study, and these findings were not replicated in a clinical trial in which Vector™ therapy was performed after complete supragingival calculus removal in patients with chronic periodontitis. The authors of this latter study reported that 10 min. were required for the treatment of a multirooted tooth with Vector™ compared with 12 min. for Gracey curettes to achieve the endpoint of tactile smoothness (Miliauskaite et al. 2005). On single-rooted teeth, the time was 6 min. in the Vector™ group and 8 min. when using hand instruments (Sculean et al. 2004).

When considering removal of gross calculus deposits, Vector™ required approximately 75 s compared with 50 s when using a conventional ultrasonic device to clean a test surface on an extracted single tooth with abundant calculus deposits and no history of previous periodontal instrumentation (Kishida et al. 2004).

Taken collectively, these studies suggest that root surface instrumentation tends to be quicker when using Vector™ compared with conventional instruments, unless gross calculus deposits are to be removed, in which case conventional ultrasonic instruments are quicker.

Periodontal Treatment with Vector™

The treatment of periodontal disease typically includes initial non-surgical therapy (comprising oral hygiene instruction and root surface instrumentation), possibly a surgical phase, and an individualized periodontal maintenance program for long-term support and maintenance. The success of the initial non-surgical therapy influences subsequent decisions about the requirement for further interventions, whether non-surgical or surgical. Whatever treatment modalities are employed, effective plaque control, oral hygiene instruction, and patient motivation are all essential pre-requisites for a successful outcome. Clinicians are required to make informed decisions about which instruments to use during periodontal therapy, and therefore studies of Vector™ used in the treatment of periodontal disease will now be reviewed. Data from these clinical studies are summarized in Table 1.

Several clinical studies have been performed to compare the effects of instrumentation with Vector™ *versus* manual instruments on clinical outcomes. One of the first reports, which compared Vector with manual instrumentation reported that the Vector™ therapy resulted in significantly reduced probing depths and bleeding on probing in patients with severe periodontitis, comparable to the results achieved with manual instrumentation (Klinger et al. 2000). Horodko et al. (2003) reported significantly greater reductions in probing depths and gains in attachment in sites treated with Vector™ when compared with manual instrumentation in a split-mouth study. Conversely, Sculean et al. 2004) observed no differences in clinical outcomes between conventional hand instruments and the Vector™ instrument, whether assessing treatment responses in single-rooted or multi-rooted teeth, and whether considering probing depths, attachment levels, or gingival recession. Miliauskaite also reported no differences in clinical outcomes between Vector therapy and manual instrumentation, but reported slightly quicker treatment when using Vector (Miliauskaite et al. 2005).

When Vector™ was compared with manual instrumentation and modified Widman-flap surgery, Vector™ resulted in less recession following treatment than either the hand instruments or the surgical techniques (Guentsch et al. 2006b). Probing depth reductions were similar in all three groups, however, and the proportion of moderate (4–5 mm) and deep ($\geqslant$6 mm) pockets reduced from 40–50% pre-treatment to approximately 10% after therapy in each treatment group. The fact that comparable results in terms of probing depth reductions were achieved with both Vector™ and manual instruments, but that Vector™ resulted in less gingival recession, suggests that Vector™ may result in less trauma to the soft tissues during therapy.

Table 1. Clinical studies comparing Vector™ with other treatment procedures

Authors	Treatment groups	Method	Duration	Clinical outcome
Klinger et al. (2000)	(1) Vector™ (2) Manual instrumentation	Clinical observation of periodontal treatment with Vector™ ($n = 12$) and manual instruments ($n = 86$)	4–6 months	Mean PD reductions were 1.46 mm in the Vector group and 2.39 mm in the manual instrumentation group. Significant reductions of PD (Vector™ from 4.65 ± 0.43 to 3.19 ± 0.56 mm; manual instruments from 5.39 ± 0.83 to 3.00 ± 0.65 mm) and BoP (Vector™ from 83.0 ± 7.8% to 23.3 ± 16.4%; manual instruments from 74.9 ± 21.3% to 18.1 ± 17.2%) were observed with both methods.
Horodko et al. (2003)	(1) Vector™ (2) Manual instrumentation	14 patients with chronic periodontitis, split-mouth design	3 months	Significant reductions in PD in both groups. Mean PD reduction in the Vector™ group (1.49 mm) was significantly greater than that observed with manual instrumentation (0.79 mm). A significant gain of AL was observed only in the Vector™ group (0.9 mm).
Sculean et al. (2004)	(1) Vector™ (2) Manual instrumentation	38 patients with chronic periodontitis, RCT	6 months	No significant differences were seen between the two groups. Mean PD of moderate pockets (4–5 mm) of single-rooted teeth in the Vector™ group was 4.5 ± 0.5 mm at baseline and 3.7 ± 1.2 mm after 6 months. Comparable results were seen in the manual instrumentation group (baseline 4.5 ± 0.3 and 3.4 ± 1.1 mm after 6 months). In deep pockets (⩾6 mm), PD reduced from 7.2 ± 1.5 to 6.6 ± 1.9 mm in the Vector™ group and from 6.6 ± 0.9 to 5.4 ± 1.8 mm in the manual group. Mean treatment time for single-rooted teeth was 6 min. with Vector™ and 8 min. with manual instruments.
Miliauskaite et al. (2005)	(1) Vector™ (2) Manual instrumentation	38 patients with chronic periodontitis, RCT	6 months	Non-surgical periodontal treatment with Vector™ or manual instrumentation resulted in comparable treatment outcomes. Mean PD of multirooted teeth with initially moderate (4–5 mm) pockets were 4.5 ± 0.5 mm at baseline and 3.7 ± 1.1 mm 6 months after therapy in the Vector™ group and 4.5 ± 0.5 mm at baseline and 3.7 ± 1.2 mm 6 months after treatment in the manual instrumentation group. In deep (⩾6 mm) pockets, PD decreased from 6.8 ± 1.2 to 5.9 ± 1.9 mm with Vector™ and from 6.6 ± 1.0 to 5.5 ± 1.8 mm with manual instruments. Treatment time, 10 min./tooth with Vector™ and 12 min. with manual instruments.
Rupf et al. (2005)	(1) Vector™ (2) Ultrasonic and CHX irrigation (3) Manual instrumentation (4) Manual instrumentation+laser disinfection	11 patients with chronic periodontitis, split-mouth design	6 months	Significant improvements were seen in clinical parameters in all groups, with no significant differences between the four treatment groups. The mean gain of attachment level was in the range of 2.4–2.9 mm. PD was reduced from baseline to day 180 post-treatment as follows: Group (1) from 5.5 ± 0.7 to 2.6 ± 0.8 mm, Group (2) from 5.3 ± 0.7 to 2.5 ± 0.6 mm, Group (3) from 5.6 ± 0.8 to 2.8 ± 0.9 mm, and Group (4) from 5.8 ± 0.7 to 2.9 ± 0.8 mm.
Guentsch et al. (2006b)	(1) Vector™ (2) Manual instrumentation (3) Modified Widman-flap (MWF)	30 patients with severe chronic periodontitis, $n = 10$ in each group, RCT	6 months	Treatment outcome with Vector™ was comparable to the results obtained following SRP with manual instruments and MWF surgery. Mean gains in attachment levels in each group were (1) 1.85 ± 0.99 mm, (2) 2.66 ± 0.74 mm, and (3) 1.66 ± 1.05 mm, and there were no significant differences between the groups for any clinical parameters. Less gingival recession was seen with

Table 1. Continued

Authors	Treatment groups	Method	Duration	Clinical outcome
				Vector™ (baseline recession 0.78 ± 0.31 mm, after therapy 0.87 ± 0.09 mm) in comparison with manual instrumentation (recession increased from 0.93 ± 0.3 to 1.12 ± 0.2 mm) and open flap surgery (recession increased from 0.86 ± 0.32 to 1.53 ± 0.15 mm).
D'Ercole et al. (2006)	(1) Vector™ (2) Manual instrumentation	18 patients with chronic periodontitis, RCT	6 months	Significant decreases of GI, PD, and BoP positive sites were seen in both groups. Greater reductions in PD were seen after 6 months in the Vector group (from 8.1 ± 1.6 to 5.4 ± 2.1 mm) compared with the manual instrumentation group (from 8.1 ± 1.2 to 6.4 ± 2.2 mm) ($p<0.05$).
Guentsch et al. (2006a)	(1) Vector™ (2) Manual instrumentation	40 patients with severe chronic periodontitis ($n = 20$ in each group), RCT	6 months	Treatment with Vector™ was comparable to manual instrumentation. PD decreases in the Vector™ group were from 5.20 ± 0.70 to 2.40 ± 0.57 mm, and in the manual instrumentation group were from 5.12 ± 0.60 to 2.33 ± 0.32 mm
Guentsch et al. (2007)	(1) Vector™ (2) Manual instrumentation	42 patients with severe chronic periodontitis (10 smokers and 11 non-smokers in each group), RCT	6 months	Significant reductions of PD and BoP were seen in both treatment groups. PD was reduced with Vector™ from 5.69 to 3.21 mm and with manual instruments from 5.25 to 2.44 mm. The difference between groups after therapy was statistically significant ($p<0.05$). Smokers who were treated with Vector™ demonstrated significantly greater PD (3.49 ± 0.99 mm) after therapy than those smokers who were treated with manual instruments (2.53 ± 0.36 mm) ($p<0.05$)
Kahl et al. (2007)	(1) Vector™ (2) Supragingival polishing (3) Manual instrumentation by hygienist (4) Manual instrumentation by dentist	20 patients with chronic periodontitis, split-mouth design	6 months	Vector™ resulted in reductions in PD and BoP that were similar to those achieved with the manual instruments. In initially deep pockets (>6 mm), PD decrease in each group over 6 months were (1) 2.5, (2) 1.5, (3) 2.6, and (4) 2.5 mm. Supragingival polishing (2) alone was less effective than the other treatment methods
Christgau et al. (2007)	(1) Vector™ (2) Manual instrumentation	20 patients with chronic periodontitis, split-mouth design	6 months	No differences were observed between manual instrumentation and Vector™. PD reductions in initially deep pockets (⩾7 mm) in the Vector™ group were 1.6 ± 0.9 mm after 6 months and 2.1 ± 1.2 mm in the manual instruments group. In deep pockets ⩾7 mm, reductions in BoP were 66.9 ± 28.6% with Vector and 88.1 ± 16.6% with manual instruments. Hypersensitivity was seen only in the SRP group

AL, attachment level; BoP, bleeding on probing; CHX, chlorhexidine; GI, gingiva index; PD, probing depth; RCT, randomized clinical trial; SRP, scaling and root planing.

Rupf et al. compared Vector™ with a conventional ultrasonic scaler and chlorhexidine irrigation, hand instrumentation alone, and hand instrumentation plus laser disinfection. In all groups, clinical and microbiological parameters were significantly improved with no significant differences between the groups (Rupf et al. 2005). Kahl et al. compared four different treatment methods (Vector™, supragingival polishing, manual instrumentation performed by hygienist, and manual instrumentation performed by a dentist) in a split-mouth design in which each procedure was performed in one quadrant. They observed no differences between Vector™ and manual instrumentation, whether performed by a dentist or hygienist (Kahl et al. 2007). However, supragingival polishing alone was inadequate for the treatment of chronic periodontitis in this study.

In a recently published study, Christgau et al. compared manual instrumentation and Vector™ in the treatment of chronic periodontitis. In 20 patients, a split-mouth design was undertaken by treating one quadrant in the upper and lower jaw either with the Vector™ system or with manual instruments. These authors observed favourable periodontal improvements in both groups, although in deep pockets, the manual instrumentation seemed to result in better reductions in signs of inflammation such as bleeding on probing (Christgau et al. 2007).

Smoking is clearly implicated as a factor that reduces the effectiveness of periodontal treatment (Kinane & Radvar 1997). Clinical trials, which compared Vector™ with other treatment methods, have predominantly been performed in non-smokers. Only one report has studied treatment outcomes using Vector in smokers, and in this study demonstrated inferior treatment responses in smokers with severe chronic periodontitis who were treated with Vector™, compared with those smokers who were treated with Gracey curettes (Guentsch et al. 2007).

Taken collectively, these studies suggest that Vector is an effective method of treatment for periodontitis and results in similar clinical improvements (with less gingival recession) to those achieved by other methods of periodontal therapy.

Microbiological findings

It is not possible to completely remove the subgingival microflora or all mineralized deposits with manual or ultrasonic instruments (Baehni et al. 1992, Dragoo 1992, Bollen & Quirynen 1996). However, reduction of the bacterial bioburden has a positive impact on periodontal status as a result of reduction of inflammation in the periodontal tissues, leading to clinical improvements such as decreases in bleeding on probing and improvements in probing depths (Badersten et al. 1981, 1984, Ali et al. 1992, Baehni et al. 1992, Bollen & Quirynen 1996, Cobb 1996, 2002, Claffey et al. 2004). Reduction of the subgingival bacterial load to a biologically acceptable level (''critical mass'') results in a ''balance'' between the remaining bacteria and the host defences and allows for resolution of inflammation and clinical improvements (WWP 1989).

The results of several different clinical studies have demonstrated that the levels of periodontopathic bacteria can be significantly reduced by both manual instrumentation and Vector™ (Rupf et al. 2005, Braun et al. 2006, D'Ercole et al. 2006, Guentsch et al. 2006a, 2007, Christgau et al. 2007). These studies are briefly summarized below and further details are given in Table 2.

Subgingival debridement with Vector™ results in significant reductions in the bacterial load. Rupf et al. treated 11 patients with four different treatment methods (Vector™, conventional ultrasonic scaler and chlorhexidine irrigation, hand instrumentation alone, and hand instrumentation plus laser disinfection) and collected subgingival plaque samples at baseline, 1 day, and 28 days after treatment. They reported that similar to manual instrumentation, Vector resulted in a significant reduction in the total number of bacteria and periodontal pathogens (Rupf et al. 2005). Braun et al. (2006) demonstrated in an in vivo study that with both treatment modalities (Vector™ and manual instruments), a similar reduction in periodontopathic microorganisms could be observed. D'Ercole et al. reported the effects of manual instrumentation and Vector™ therapy on the subgingival microflora over 6 months. They treated 18 patients with chronic periodontitis and showed that the bacterial load was significantly reduced in both groups during the examination period (D'Ercole et al. 2006). Guentsch et al. also compared Vector™ and manual instruments in the treatment of 40 patients with severe chronic periodontitis and identified a significant reduction of periodontopathic bacteria 4, 12, and 24 weeks after periodontal therapy. During the examination period, they observed a re-colonization of the tested bacteria in both groups, but the baseline values were not reached at any time point (Guentsch et al. 2006a). Similar results were reported by Christgau et al. (2007), who treated 20 patients with severe chronic periodontitis with Vector™ and manual instrumentation in a split-mouth design. They reported a significant decrease of periopathogenic bacteria after 4 weeks and 6 months, with similar results achieved by Vector™ and SRP to manual instruments.

When smokers and non-smokers with severe chronic periodontitis were studied, microbiological analysis of subgingival plaque samples revealed higher levels of *Aggregatibacter actinomycetemcomitans* and *Porphyromonas gingivalis* after treatment with Vector™ compared with manual instruments (Guentsch et al. 2007). This could explain the reduced treatment outcomes in those smokers who were treated with Vector™.

Overall, therefore, clinical studies have demonstrated that Vector™ instrumentation is capable of significantly reducing the subgingival bacterial load. Manual instrumentation and Vector™ debridement have been shown to achieve similar reductions of periopathogenic bacteria in patients with chronic periodontitis.

Maintenance therapy using Vector™

Periodontal maintenance therapy is of critical importance for preserving the clinical improvements obtained by periodontal treatment and to avoid further tissue destruction (Axelsson et al. 1991). As mentioned above, in vitro studies have demonstrated that the debridement of root surfaces with Vector™ results in significantly less cementum removal than hand instruments or conventional ultrasonic instruments (Rupf et al. 2005, Kawashima et al. 2007a). These studies suggest that Vector™ could be very useful in periodontal maintenance care for instrumenting root surfaces without resulting in extensive tissue removal over time.

A prospective study of 38 periodontal maintenance patients who had residual pockets of >4 mm demonstrated comparable results in clinical outcomes (reduction of probing depths, attachment gains, and reduction of bleeding on probing) after 6 months of maintenance care with Vector™ and conventional ultrasonic instrumentation undertaken every 3 months (Kocher et al. 2005). In a recently published study of 20 subjects with chronic periodontitis who had at least four residual pockets $\geqslant 5$ mm, Vector™ therapy with additional application of a controlled-release chlorhexidine chip resulted in better treatment outcomes than Vector™ scaling alone (Kasaj et al. 2007). Furthermore, during maintenance therapy, Vector™ has been reported to result in reduced pain and increased patient compliance (Hoffman et al. 2005), presumably because of the non-elliptical pattern of vibrations and the small amplitude of movement compared with conventional ultrasonic instruments.

Treatment of peri-implantitis

The microbiota identified in peri-implant infections is very similar to that encountered in pockets of patients

Table 2. Microbiological findings of clinical studies

Authors	Treatment groups	Method	Duration	Microbiological outcome
Rupf et al. (2005)	(1) Vector™ (2) Ultrasonic and CHX irrigation (3) Manual instrumentation (4) Manual instrumentation+laser disinfection	11 patients with chronic periodontitis, split-mouth design	6 months	Periodontal pathogens were significantly reduced ($p<0.05$) in each group as follows: (1) from 79% (baseline) to 67% (28 days post-treatment) (2) from 79% to 50% (3) from 84% to 63% (4) from 87% to 75% There were no significant differences between the groups.
Guentsch et al. (2006a)	(1) Vector™ (2) Manual instrumentation	40 patients with severe chronic periodontitis ($n=20$ in each group), RCT	6 months	Manual instrumentation (which resulted in reduction of *A.a.* 100%, *P.g.* 86%, *P.i.* 100%, *T.f.* 88%, *T.d.* 62%) suppressed the periodontopathic microflora within the first 4 weeks significantly more than that achieved by Vector™ (reduction of *A.a.* 53%, *P.g.* 20%, *P.i.* 56%, *T.f.* 37%, *T.d.* 18%) ($p<0.05$). Re-colonization occurred post-treatment in both groups, but after 6 months, bacterial levels were still significantly reduced in comparison with baseline ($p<0.05$), and there were no differences between the groups.
D'Ercole et al. (2006)	(1) Vector™ (2) Manual instrumentation	18 patients with chronic periodontitis, RCT	6 months	Reductions of total bacterial counts were seen in both groups. *C. rectus* and *P. gingivalis* were significantly reduced in the group with manual instruments. *T. forsysthensis*, *E. corrodens*, and *T. denticola* were significantly reduced in the Vector™ group after 6 months.
Christgau et al. (2007)	(1) Vector™ (2) Manual instrumentation	20 patients with chronic periodontitis, split-mouth design	6 months	Similar reductions of total bacterial load were seen in the Vector™ group (baseline, $46.0 \pm 43.5 \times 10^4$; 4 weeks, $20.0 \pm 26.3 \times 10^4$; 6 months, $19.0 \pm 16.8 \times 10^4$) and the manual instruments group (baseline, $36.4 \pm 32.3 \times 10^4$, 4 weeks, $12.4 \pm 9.9 \times 10^4$; 6 months, $11.1 \pm 14.1 \times 10^4$).
Guentsch et al. (2007)	(1) Vector™ (2) Manual instrumentation	42 patients with severe chronic periodontitis (10 smokers and 11 non-smokers in each group), RCT	6 months	*A.a.* was significantly reduced with both manual instruments (4 weeks, 93%; 6 months, 81%) and Vector™ (4 weeks, 90%; 6 months, 88%). *P.g.* was also suppressed with both manual instruments (4 weeks. 84%; 6 months, 62%), and Vector™ (4 weeks, 66%; 6 months, 69%). At every monitoring visit, higher levels of *A.a.* and *P.g.* were seen in patients who smoked.

Aggregatibacter actinomycetemcomitans (*A.a.*), *Porphyromonas gingivalis* (*P.g.*), *Prevotella intermedia* (*P.i.*), *Tannerella forsythensis* (*T.f.*), *Treponema denticola (T.d.), Campylobacter rectus (C.rectus), Eikenella corrodens (E.c.).*

with advanced periodontitis. An individualized maintenance program after implant placement is important to prevent the development of peri-implant inflammation (Lang et al. 2000).

The existing data regarding the use of the Vector™ system in implants implicate that it is important to distinguish between the use of maintenance therapy after implant placement (using carbon fibre tips) and the treatment of peri-implantitis.

When considering maintenance after implant therapy, it seems that Vector™ may provide a useful alternative to manual instruments for plaque and calculus removal from implant abutments. Kawashima et al. (2007b) reported in a study of 14 implant patients that Vector™ (in comparison with ultrasonics with either plastic or metal inserts) removed plaque and calculus effectively and produced smooth abutment surfaces. The surfaces of the abutments after scaling with ultrasonic metallic inserts were significantly rougher than after the usage of plastic inserts. A rough surface may increase the accumulation of peridontopathic bacteria (Ericsson et al. 1992).

In relation to peri-implantitis, Karring et al. (2005) treated 11 patients with at least two screw-type implants with peri-implantitis (defined as presence of bleeding on probing, probing depth $\geqslant 5$ mm, and at least 1.5 mm bone loss). One implant was treated with the Vector™ carbon fibre curette and the other implant was treated with a manual plastic curette (treatment was performed at baseline and after 3 months). They reported that bleeding on probing at peri-implantitis sites was better reduced with Vector™ than with the plastic curettes. However, Vector™ scaling with carbon fibre tips had no greater influence on probing depth reduction or bone levels compared with the manual plastic curettes (Karring et al. 2005). In an experimental study in dogs, it was confirmed that Vector™ treatment in peri-implant infection sites has limited effects on bone regeneration (Schwarz et al. 2006b), and this may be explained by the results of an in vitro study, which reported less attachment of human osteoblast-like cells to implant surfaces after Vector™ scaling with carbon fibre inserts compared with application of an Er:YAG laser (Schwarz et al. 2003). Schwarz et al. (2003) also reported conspicuous implant surface damage and debris following the use of carbon fibre inserts on implants.

Summarizing the existing literature, it seems that there are advantages in using Vector™ with carbon fibre tips for maintenance after implant placement, but if there is definite peri-implantitis and/or bone destruction, then other treatment options are necessary.

Patient Considerations

Patient compliance with periodontal maintenance therapy is typically poor, with non-compliance rates between 15% (Matthews et al. 2001) and 75% (König et al. 2001). The reasons for this are multifactorial, but pain and/or discomfort during maintenance visits are probably significant factors for many patients (Kerry 1995).

Braun et al. reported that Vector™ resulted in less pain compared with conventional methods of non-surgical therapy (ultrasonic instruments and hand instrumentation). These authors concluded that instrumentation techniques that cause less discomfort and pain could be of benefit in increasing patient compliance with periodontal maintenance programmes (Braun et al. 2003). Hoffman et al. (2005) found that patients who received Vector instrumentation experienced approximately half the pain reported by patients treated with conventional ultrasonic systems. The patients in this study reported that Vector was preferable to conventional ultrasonic scalers, because of less pain, vibration, noise, and volume of coolant (Hoffman et al. 2005). In contrast to this, Kocher et al. (2005) reported that patients perceived no differences in pain experience when Vector™ was compared with a conventional system.

Conclusions

The efficacy of the Vector™ system has been studied both in vitro and in vivo. Furthermore, clinical and microbiological outcomes following periodontal therapy with Vector™ have been investigated in a number of clinical trials. Studies have also reported that Vector™ can improve patient compliance because of reduced pain and discomfort during treatment. Vector™ can be used without local anaesthesia, which may improve patient acceptance.

The studies of the use of Vector™ permit the following conclusions:

- Vector™ cannot be recommended when large masses of supragingival calculus must be removed. Conventional ultrasonics should be used instead.
- In general terms, Vector™ used for the treatment of moderate–severe chronic periodontitis results in clinical improvements, which are comparable to those achieved with manual instruments or conventional ultrasonic devices. Some specific findings of these studies are:
  Vector™ results in less gingival recession post-treatment compared with surgical or other non-surgical procedures, and also less removal of cementum.
  In deep pockets ($\geqslant 7$ mm), manual instrumentation results in better outcomes than Vector™ scaling (presumably because of the complexity of the anatomy in deeper sites).
  Smoking reduces the clinical outcomes of Vector™ therapy in patients with chronic periodontitis.
- Instrumentation with Vector™ can be recommended particularly for use in periodontal maintenance therapy, because it is more pleasant for the patient and results in minimal removal of cementum.
- Vector™ can also be recommended in implant maintenance because it removes plaque and calculus effectively and produces a smooth abutment surface. However, it is important that the carbon fibre insert is used to avoid damage to the surface of the abutment.
- Recommendations for using Vector™ for treatment of peri-implantitis cannot, at present, be made because of the limitation of the existing literature.

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Address:
Arndt Guentsch
Department of Conservative Dentistry
University Hospital of Jena
Friedrich-Schiller-University
An der alten Post 4
D-07743 Jena
Germany
E-mail: Arndt.Guentsch@med.uni-jena.de

Clinical Relevance

Scientific rationale for the study: Various in vitro and in vivo studies and clinical trials were published about the Vector™ method. This suggested that there is a need for a review about the existing literature.

Principal findings: Non-surgical periodontal treatment with Vector™ results in clinical and microbiological outcomes which are comparable to manual instrumentation or conventional ultrasonic instruments. Vector™ is less efficient in removing large masses of calculus, and cannot be recommended for the treatment of peri-implantitis.

Practical implications: Vector™ seems to be a possible alternative instrument for treatment of chronic periodontitis, supportive periodontal treatment, and implant maintenance.