Journal of Clinical Periodontology
Official Journal of The European Federation of Periodontology
Founded by the British, Dutch, French, German, Scandinavian, and Swiss Societies of Periodontology

J Clin Periodontol 2008; 35 (Suppl. 8): 22–28 doi: 10.1111/j.1600-051X.2008.01258.x

Journal of Clinical Periodontology

Advances in power driven pocket/ root instrumentation

A. Damien Walmsley[1], Simon C. Lea[1], Gabriel Landini[1] and Anthony J. Moses[2]

[1]School of Dentistry, The University of Birmingham, St. Chad's Queensway, Birmingham, UK; [2]Wolfson Centre for Magnetics, Cardiff University, Cardiff, UK

Walmsley AD, Lea SC, Landini G, Moses AJ. Advances in power driven pocket/root instrumentation. J Clin Periodontol 2008; 35 (Suppl. 8): 22–28. doi: 10.1111/j.1600-051X.2008.01258.x.

Abstract
Objectives: The primary aim was: ''Does power-driven pocket/root instrumentation offer a clinical advantage over hand instrumentation''? Secondary aim was to update knowledge base of power-driven instrumentation post Tunkel et al. (2002).
Material and Methods: A literature search of power-driven instruments (in vitro, in vivo and controlled clinical trials) was performed from April 2001 using similar criteria to Tunkel et al. (2002). Primary outcome was whether power-driven instruments offered an advantage over hand instrumentation; secondary outcomes were effect on root surface, effectiveness of new instrument designs, and role of biophysical effects such as cavitation.
Results: From a total of 41 studies, 14 studies involved comparison of power-driven devices with hand instrumentation for non-surgical therapy. These were subdivided into new designs of power instrumentation, full-mouth debridement and irrigation and patient acceptance. Use of power-driven instrumentation provides similar clinical outcomes compared with hand instrumentation. Difficulty of pooling studies continues to hinder the drawing of definitive conclusions.
Conclusion: Newer designs of powered instruments have not shown any benefit when compared with other ultrasonic devices in non-surgical periodontal therapy. New in vitro research shows there is variation in the performance of different tip designs and generators, but its clinical relevance remains unknown.

Key words: periodontal therapy/non surgical; power driven instrumentation; scaling and root planing; systematic review

Accepted for publication 20 May 2008

Deposits on tooth root surfaces may range from simple biofilms to hard tenacious calculus. Mechanical removal of these deposits from the root surface is required for establishing and maintaining periodontal health. This removal may be achieved via hand or powered instrumentation (Tunkel et al. 2002). The aim of such treatment is to disrupt the subgingival biofilm and in doing so reduce the pathogens that are present (Slots 1979, Slots & Ting 1999) to allow periodontal health to return.

Hand instruments are available in various designs, described as curettes, hoes or scalers. They all have a sharp working tip, which is used to mechanically break the bond between deposit and tooth. The process is time consuming and physically demanding, but is seen as the treatment of choice as it is believed that the clinician has direct tactile control over the hand instrumentation process compared with the use of powered devices (Meyer & Lie 1977). Power-driven instruments differ from their hand counterparts in that they are relatively blunt and rely on the acceleration of the vibrating tip to disrupt the plaque and calculus. During use, cooling water is passed over the tip to reduce frictional heating (Lea et al. 2004a) but the vibrations may also generate cavitation within the water which could assist in the cleaning process. Compared with hand scalers, power-driven instruments have the advantage of being easier to use and may take significantly less time than hand instruments (Tunkel et al. 2002). The disadvantage is that the clinician may lose tactile control although it is reported that this may only be of a transient nature, with the operator regaining sensation with time (Ryan et al. 2005). The powered instrument has the potential to damage the root surface producing indentations and unwanted scratches on the hard tissue surface although no definite conclusion has been reached on this subject (Drisko et al. 2000). The selection and use of the two methods (hand or power) is a personal decision but there seems to be a trend among clinicians to select power-

Conflict of interest and source of funding statement

The authors have declared no conflicts of interest.
The authors wish to acknowledge the support of the Engineering and Physical Sciences Research Council, UK; Grant Nos: GR/T22551 and GR/T22568. The 6th European Workshop on Periodontology was supported by unrestricted educational grant from Straumann AG.

driven scalers over hand instruments (Drisko et al. 2000, Tunkel et al. 2002) partially due to improved ergonomics. However, the use of these instruments might have potential health hazards (Trenter & Walmsley 2003).

There have been a number of key reviews in the area of powered instrumentation. In 2000 the Research, Science and Therapy Committee of the American Academy of Periodontology undertook a qualitative review of the literature (Drisko et al. 2000). It summarized that ultrasonic and sonic scalers produce similar results to hand instruments following periodontal therapy. It did recommend that more randomized clinical-controlled trials should be undertaken to determine whether there is a significant advantage in using ultrasonic scalers. A detailed systematic review of the clinical use of powered instruments compared with hand instruments (Tunkel et al. 2002) based on the informed selection of randomized-controlled trials, found that there were similar clinical outcomes compared with hand instrumentation in the efficacy in the subgingival debridement of single rooted teeth. The powered instrument was found to complete subgingival debridement quicker compared with hand scalers. A structured review has also been undertaken on the hazards associated with ultrasonic scalers (Trenter & Walmsley 2003) including aerosol production, effect on cardiac pacemakers and auditory hazards to both clinician and patient. Unlike the review by the American Academy of Periodontology it did not discuss which instrument causes most disruption of the tooth surface (Drisko et al. 2000).

Review of Available Instrumentation

Powered instruments may be categorized as either sonic or ultrasonic. Ultrasonic devices work in the frequency range of 25–42 kHz while the sonic devices typically work at frequencies between 6 and 8 kHz. The manner of oscillation production for the two classes is different. Sonic devices rely on the passage of compressed air over an eccentric rod that is driven to vibrate. Ultrasonic devices may be categorized by the method of ultrasound generation that may be either magnetostrictive or piezoelectric. The magnetostrictive devices have a nickel stack that is driven to vibrate by an electromagnetic current. In contrast, piezoelectric devices incorporate a crystal within the handle of the handpiece which will oscillate in the presence of an electromagnetic field. Both magnetostrictive and piezoelectric devices will have a scaler tip design that resembles a hand scaler which is either fixed or detachable.

There have been reports in the literature of sharpening sonic scaling tips to improve efficiency (Checchi et al. 1991). This idea led onto diamond coating the scaler tips (Yukna et al. 2007), which were shown to produce faster removal of calculus although it did lead to more root surface removal using an in vitro model to simulate the clinical situation (Kocher et al. 2001; Vastardis et al. 2005). Alterations to the probe can also lead to a decrease in efficiency. Scaler tips wear with use and this may be a problem if clinicians do not regularly update their equipment. The movement of the tips becomes variable and generally decreases as the length of the probe is reduced with wear (Lea et al. 2006). This could lead to poor clinical outcomes of treatment but further research is needed to establish whether this is the case. Another approach has been to design scaler tips with a paddle-like working end covered with spheroid convexities (Petersilka et al. 2003). This is designed to ''pound'' the calculus and dislodge it from the tooth surface. It has been claimed that the tip provides shear stresses that remove the calculus leaving the underlying root surface undamaged.

All powered scalers that are available to clinicians, have various designs of tips that may range from a traditional broad shape to a Slimline design. This movement to a thinner design of tip is related to accessibility of the furcation area of posterior teeth (Dragoo 1992).

There are ultrasonic devices which resemble endodontic files such as those used in Endosonics. The first of these was the Periosonic® (Micro-Mega, Prodonta SA, Geneva, Switzerland) which was driven by compressed air (Rees et al. 1999, Beuchat et al. 2001) in a similar manner to a sonic scaler. This instrument was a direct copy from endodontic instrumentation and the idea was to reproduce the flushing and cleansing action of endosonic instrumentation in the root canal but within the periodontal pocket. A variation of the traditional ultrasonic oscillation the Vector system (Dürr Dental GmbH & Co. KG, Bietigheim-Bissingen, Germany) was introduced where the vibration is produced by attaching a thin metallic probe (similar to an periodontal probe) to a metal ring, which is induced to flex into ellipsoidal shapes thus producing the oscillation (Sculean et al. 2004). The instrument oscillation is powered by a piezoelectric generator. The Vector system is used in conjunction with a polishing fluid containing hydroxyapatite granules $< 10\,\mu m$ (Braun et al. 2007a, b, Kahl et al. 2007a, b).

Scaler Tip Movement

Until recently there has been limited understanding of the movement of the tips of ultrasonic scalers as the movement was at a high frequency with small displacement amplitudes (Walmsley et al. 1986). With the introduction of advanced technology of scanning laser vibrometry, it is now possible to study the vibrations of the tips at ultrasonic frequencies (Lea et al. 2002, 2004b). One of the main findings made possible through laser vibrometry is the significant variability observed in the oscillation characteristics of dental ultrasonic scalers. This might be expected between scalers whose tips are of different designs but has also been observed between instruments that are nominally the same (Lea et al. 2003a, b). This effect was particularly significant for slimmer designs of tips such as the Slimline (Dentsply International, York, PA, USA) and the P-tip (Electro Medical Systems SA, Nyon, Switzerland), both unloaded (oscillating freely in air) and when placed under loads similar to those which may be encountered clinically (Lea et al. 2003a, b, Trenter et al. 2003).

Loading will damp the vibrations of all types of scaler tips, whether driven by magnetostriction or piezoelectricity (Lea et al. 2003b). Slimmer designs of scaler tips are more susceptible to loading than the traditional tips which have larger dimensions. Increases in generator power setting, under a variety of loads, showed that slimmer tips had a highly variable change in tip vibration, whereas the wider tips were more likely to produce a linear increase in displacement amplitude with increasing power (Lea et al. 2003a, Trenter et al. 2003). Such variations of tip movement should be factored into clinical trials to allow for more meaningful comparisons.

Cavitation and Microstreaming

The ultrasonic scalers are operated with a water flow which serves several purposes including (with magnetostrictive scalers) cooling of the generator magnetic core material which drives the scaler probe oscillations. The water also provides cooling at the treatment site, where too little water can potentially lead to rapid heating due to friction between the probe and the tooth (Lea et al. 2004a). Water also clears the treatment site of material which is removed during the treatment, aiding the operator's visibility, potentially speeding up the procedure.

Another documented benefit of the flowing water is the inception of biophysical forces – namely cavitation and streaming. The potential effects of these have been shown in vitro (Walmsley et al. 1988, 1990, Khambay & Walmsley 1999). Their contribution to the clinical result remains unclear although many clinicians consider the potential benefit of such forces may, if properly harnessed, improve the efficiency of these instruments. The cavitation and the associated jet effect (generated during asymmetrical bubble collapse) may be of use in removing material from tooth surfaces (Walmsley et al. 1988) and is powerful enough to cause damage to the surface of the ultrasonic scaler (Lea et al. 2005). Acoustic microstreaming forces are characterized by low-velocity flows but generate high shear stresses close to the ultrasonic probe (Khambay & Walmsley 1999). These may be useful in disrupting the biofilm on root surfaces and for removal of loosely attached material.

Summary and Aim of Present Review

Although hard to quantify, it is likely that the majority of patients attending for a routine appointment with their dentist/clinician will be exposed to some form of powered instrument. There have been a number of different powered devices introduced into periodontology, including those powered by traditional drills which involve either a reciprocating or rotating action. This review focuses on powered oscillatory instruments/scalers. This review intends to update our knowledge of the use of power-driven instrumentation following up on publications which appeared after the reviews of Drisko et al. (2000) and Tunkel et al. (2002).

The primary objective was to determine whether power-driven instruments offered an advantage over hand instrumentation; secondary objectives were the effect on the root surface, effectiveness of new instrument designs and the role of biophysical effects such as cavitation.

Material and Methods

Acknowledging the presence of the three substantial reviews (Drisko et al. 2000; Tunkel et al. 2002; Trenter & Walmsley 2003), a literature search of all studies that included the use of power-driven (ultrasonic instruments) was performed from April 2001 up to December 2007 using similar search criteria as in the review by Tunkel et al. (2002). Studies retrieved included in vitro, in vivo and controlled clinical trials which compared power-driven instruments with hand instruments for the treatment of chronic periodontitis.

The search was limited to English language publications. Further hand searching of the main periodontal publications; *Journal of Clinical Periodontology*, *Journal of Periodontology*, *Journal of Periodontal Research and Periodontology* 2000 was also made to check for additional literature. The results were then hand-checked to eliminate non-relevant subject areas. The articles selected were considered to be relevant to the use of the ultrasonic and sonic scalers.

Results

The search revealed 41 studies that used power-driven instrumentation. Of these, 21 were clinical studies. Closer inspection of these clinical studies showed that 14 involved comparison of power-driven devices with hand instrumentation for non-surgical therapy. These clinical studies were further subdivided into the following classes:

- New designs of power instrumentation
  - Beuchat et al. (2001) – Periosonic
  - Sculean et al. (2004) – Vector
  - Christgau et al. (2007) – Vector
  - Kahl et al. (2007a, b) – Vector
- Full-mouth debridement and irrigation
  - Del Peloso Ribeiro et al. (2006) – ultrasonic debridement with povidone–iodine
  - Leonhardt et al. (2006) – ultrasonic debridement with povidone–iodine
  - Leonhardt et al. (2007) – ultrasonic debridement with povidone–iodine
  - Rosling et al. (2001) – ultrasonic debridement with povidone–iodine
  - Koshy et al. (2005) – ultrasonic debridement
  - Wennström et al. (2005) – ultrasonic debridement
  - Tomasi et al. (2006) – ultrasonic debridement
- Patient acceptance
  - Braun et al. (2003)
  - Kocher et al. (2005)
  - Bonner et al. (2005)

Those clinical studies which investigated the new designs of power instrumentation (Vector and Periosonic) in comparison with conventional hand instrumentation did not find statistically significant differences in the clinical outcomes. In the full-mouth debridement and irrigation studies the authors concluded that there was no statistically significant differences in the clinical result achieved whether hand instrumentation or ultrasonic instruments were used. In the studies on patient acceptance it was initially claimed in a clinical trial that the Vector was more comfortable to use and had greater patient acceptance over conventional ultrasonic instrumentation (Braun et al. 2003). A randomized-controlled trial by Kocher et al. (2005) found that there was no statistically significant difference between the two types of instrumentation. It has been shown that patients experienced similar discomfort from routine supra-gingival scaling at the dentist irrespective of the procedure whether it is by manual instruments or ultrasonic scalers (Bonner et al. 2005).

Discussion

This review has found similar results to those of Tunkel et al. (2002) in that recent clinical studies do not indicate a difference between ultrasonic/sonic and manual debridement in the treatment of chronic periodontitis. In many of the studies it is not possible to compare the operating characteristics of the ultrasonic scalers as there are few details of the instrument settings and the duration of the treatment.

New designs of power instrumentation

Since the review of Tunkel et al. (2002) there has been the introduction of newer designs of power instrumentation which have mainly focussed on the Vector system. Although cited as a significant progress in power-driven instruments, this device uses a similar vibration mode to traditional ultrasonic scalers. It oscillates at similar ultrasonic frequencies and the tip is set at right angles to the longitudinal oscillation of the handpiece. Ultrasonic scaler tips approach this motion as the tip curves towards a right angle to the main driver. Although one study using this device reported a reduction of the pain experienced during dental treatment (Braun et al. 2003) when compared with traditional ultrasonic scalers, details of how the clinical treatment was standardized were not clear and therefore difficult to replicate. In contrast, the RCT by Kocher et al. (2005) found no differences in the discomfort that patients experienced whether the Vector or traditional ultrasonic instruments were used.

Clinical studies have shown comparable clinical results between the Vector device and hand instrumentation (Sculean et al. 2004, Kahl et al. 2007a, b). However, in deep pockets root planing rendered a better resolution of inflammation, although there was more hypersensitivity.

A series of articles have compared the Vector system with hand scaling of teeth both in vitro and in vivo (Braun et al. 2003, 2005a, b, 2006). The clinical studies follow a similar pattern in that they have used four variables (1) hand instrumentation with Gracey curettes, (2) a traditional ultrasonic system (US) (3) Vector with hydroxyl apatite (VHA) polishing fluid and (4) Vector with a silicon carbide (VSC) containing abrasive fluid. The settings of the Vector were at 30 μm which corresponds to setting 7 on the instrument dial. One operator was used throughout the studies who was trained to deliver the lateral forces to the root surfaces which ranged from 4.76 N with the hand instrument to 0.83 N for the US. As the mode of oscillation and how it may be affected by loading has not been visualized it is difficult to draw any firm conclusions. The Vector system produced smooth surfaces (which may be due to factors such as damping). The removal of calculus was similar both with the HA system and the US. It was also reported that the Vector was slower in removing calculus than the hand and US.

Other groups have looked at the Vector system against traditional piezoelectric ultrasonic devices. Extracted teeth instrumented with a Vector HA were compared with both traditional ultrasonic scaling (piezoelectric generator) and Gracey curettes (Kishida et al. 2004). The loads used were different to the previous studies 0.39 N for the US and 4.9 N for the hand. It was quoted that, at medium power setting, profilometry of the root revealed that the Vector produced a smoother surface but was the slowest in removing calculus.

Full-mouth debridement and irrigation

Full-mouth debridement and irrigation is a frequent treatment approach for chronic periodontitis. Such a technique allows treatment to be undertaken in a shorter time period (Koshy et al. 2005, Wennström et al. 2005), although the eventual clinical results are similar (Tomasi et al. 2006).

In order to optimize the full-mouth debridement, studies have used chemotherapeutic agents as the coolant or irrigant. Povidone–iodine is water-soluble and is a combination of polyvinylpyrrolidone and iodine (PVP–I). The interest in this antimicrobial agent arises due to its properties of having a broad spectrum bactericidal activity, thereby showing much potential in periodontology (Hoang et al. 2003). Povidone–iodine as the cooling liquid in ultrasonic scalers has been shown to improve the effectiveness of non-surgical therapy (Rosling et al. 2001). A randomized clinical trial compared the use of ultrasonic scalers with either distilled water or 10% PVP–I as the cooling liquid in the treatment of lower or upper molars (Del Peloso Ribeiro et al. 2006). The article provides few details of how the scalers were used such as duration of use, time involved and approach to treating the defects. However, their conclusion was that there were no additional benefits over conventional ultrasonic scaling. The use of PVP–I has been compared against other treatments: (1) ultrasonic scaling + subgingival irrigation with 0.5% PVP–I for 5 min./tooth, (2) ultrasonic scaling + subgingival irrigation with saline solution for 5 min./tooth, (3) subgingival irrigation with saline solution for 5 min./tooth, and (4) subgingival irrigation with 0.5% PVP–I. Each tooth in the assigned quadrant received 5 min. treatment time (Leonhardt et al. 2006). No difference was found between the four treatments, although it was accepted in the trial that their concentration was lower than that used by others (0.5% *versus* 10%). Further work evaluated the reduction in putative periodontal bacteria (Leonhardt et al. 2007). It was found that the ultrasonic non-surgical treatment reduced the number of positive individuals but the results varied for the different bacterial species.

Removal of the biofilm

The biofilm is a complex hierarchy of bacteria (Costerton et al. 1995) that forms on the surface of the tooth (it does form on the root surface but also on the enamel and on tooth restorations!). The bacteria within the biofilm forms a complex living community that serves to protect itself and thrive in an aqueous environment. The purpose of any instrumentation is to disrupt this biofilm thus allowing the host to repair (Haffajee et al. 2006). After treatment, roots will still harbour plaque and calculus as well as endotoxins attached to the root cementum (O'Leary et al. 1997). Many researchers have targeted the removal of the biofilm via the use of ultrasonic scalers (Del Peloso Ribeiro et al. 2007, Leonhardt et al. 2007) but could not find it to be better than treatment with hand instruments.

The ultrasonic scaler does possess the ability to disrupt the biofilm not only from tip contact but also via the effects of cavitation and microstreaming. However, lack of understanding of how and where these phenomena do occur along the ultrasonic scaler tip at present prevents its optimal use in the clinical debridement process.

The removal of plaque biofilm and calculus is an important goal of periodontal therapy. The goal of the ultrasonic scaler is to be at least as efficient as hand instrumentation in this removal process. While the removal of calculus is deemed important, assessment of the removal process is usually by careful visual inspection or by tactile sensation with a periodontal probe. Both techniques have their difficulties. In an attempt to overcome these problems, research has been performed into developing a smart device (Meissner et al. 2006). This device features a piezoceramic crystal that picks up small differences in the oscillation of the tip as it moves over the root surface. While this device shows promise in vitro, it is yet to be trialed in clinical studies.

Improvements in cleaning root surfaces

Furcation involvements are difficult to treat and often, due to accessibility problems, there can be incomplete removal of calculus from the root surface. In the past this has been tackled by designing scaler tips which are termed ''Slimline'', i.e. they are much thinner than conventional scaler tips (Dragoo 1992). This has led to the use of specific furcation tips (Amdent, Stockholm, Sweden) and a clinical trial looked at the treatment of Class II furcations. It was found that buccal and lingual involved furcations responded better than their interproximal counterparts following the use of such instruments (Del Peloso Ribeiro et al. 2007). The furcation involvements were instrumented until a smooth, hard surface was obtained. A difference in response was reported with buccal and lingual Class II furcation involvements responding better to such non-surgical therapy. While the use of such ''slimmer'' tips continues to prove popular with clinicians, in vitro work suggests that such thin designs may be liable to variation in their movement due to their lower mass and may not, in certain contact situations, be working efficiently (Trenter et al. 2003). This may partly explain such clinical differences. A clinical study compared conventional ultrasonic scalers with Slimline tips. The primary outcome of the study was that the use of Slimline tips was associated with greater comfort although a secondary outcome was that the scaling process took longer using such instruments (Braun et al. 2007a, b). Such findings may be consistent with the susceptibility of such instruments to loading and therefore preventing them from oscillating.

Effects on root surface

One of the most common methods for the evaluation of powered instrumentation is to study their effects on tooth root surfaces in vitro. This analysis is broadly performed using one of two methodologies. The first is to apply powered instrumentation to the tooth or root surface for a known or controlled time or number of strokes (Flemmig et al. 1997, 1998a, b, Schmidlin et al. 2001, Folwaczny et al. 2004, Jepsen et al. 2004). The second is to apply the instrumentation until the surface of the tooth is deemed to be clean and smooth (Cross-Poline et al. 1995, Busslinger et al. 2001, Kawashima et al. 2007).

A drawback of the second method is that the operational characteristics of the ultrasonic scalers are generally poorly recorded with limited data relating to loads and contact angles used. The finishing point of the instrumentation is also fairly subjective, depending on the operator to accurately note the exact point at which the root is clean and not to over-instrument the surface. Studies which apply the instrumentation for a known length of time or a definite number of strokes are generally more controlled in terms of contact loads, contact angles, time of instrumentation, generator power setting, etc.

A limitation of these investigations, however, is that in each study, only one of each type of the available tips is investigated. Recent research (Lea et al. 2003a, b) has demonstrated that significant variability occurs between instruments of the same type and that this is particularly pronounced when the tips are placed under load. In light of this, it cannot be certain that the instruments used by each of these investigators were typical of their type. If, for example, in one of the experiments a magnetostrictive tip underperformed then the outcomes may be significantly different.

Conclusions

This review has updated the knowledge base of ultrasonic scalers post Tunkel et al. (2002)

- The use of power-driven instrumentation provides similar clinical outcomes compared with hand instrumentation. The difficulty of pooling studies continues to hinder the drawing of definitive conclusions.
- The addition of antiseptic agents to coolants or irrigants do not provide any additional clinical benefits.
- Newer designs of powered instruments have not shown any benefit when compared with other ultrasonic devices in non-surgical periodontal therapy.
- New in vitro research shows that there is variation in the performance of different tip designs and generators, but its clinical relevance remains unknown.

Acknowledgements

This paper was presented at the European Academy of Periodontology Workshop on Contemporary Periodontics held at Ittingen, Switzerland, February 2008.

References

Beuchat, M., Busslinger, A., Schmidlin, P. R., Michel, B., Lehmann, B. & Lutz, F. (2001) Clinical comparison of the effectiveness of novel sonic instruments and curettes for periodontal debridement after 2 months. *Journal of Periodontology* **28**, 1145–1150.

Bonner, B. C., Young, L., Smith, P. A., McCombes, W. & Clarkson, J. E. (2005) A randomised controlled trial to explore attitudes to routine scale and polish and compare manual versus ultrasonic scaling in the general dental service in Scotland [ISRCTN99609795]. *BMC Oral Health* **23**, 3.

Braun, A., Cichocka, A., Semaan, E., Krause, F., Jepsen, S. & Frentzen, M. (2007a) Root surfaces after ultrasonic instrumentation with a polishing fluid. *Quintessence International* **38**, e490–e496.

Braun, A., Jepsen, S. & Krause, F. (2007b) Subjective intensity of pain during ultrasonic supragingival calculus removal. *Journal of Clinical Periodontology* **34**, 668–672.

Braun, A., Krause, F., Frentzen, M. & Jepsen, S. (2005a) Efficiency of subgingival calculus removal with the Vector-system compared to ultrasonic scaling and hand instrumentation in vitro. *Journal of Periodontal Research* **40**, 48–52.

Braun, A., Krause, F., Frentzen, M. & Jepsen, S. (2005b) Removal of root substance with the Vector-system compared with conventional debridement in vitro. *Journal of Clinical Periodontology* **32**, 153–157.

Braun, A., Krause, F., Hartschen, V., Falk, W. & Jepsen, S. (2006) Efficiency of the Vector-system compared with conventional subgingival debridement in vitro and in vivo. *Journal of Clinical Periodontology* **33**, 568–574.

Braun, A., Krause, F., Nolden, R. & Frentzen, M. (2003) Subjective intensity of pain during the treatment of periodontal lesions with the Vector-system. *Journal of Periodontal Research* **38**, 135–140.

Busslinger, A., Lampe, K., Beuchat, M. & Lehmann, B. (2001) A comparative in vitro study of a magnetostrictive and a piezoelectric ultrasonic scaling instrument. *Journal of Clinical Periodontology* **28**, 642–649.

Checchi, L., Pelliccioni, G. A. & D'Achille, C. (1991) Sharpening of ultrasonic scalers. *Journal of Clinical Periodontology* **18**, 505–507.

Christgau, M., Männer, T., Beuer, S., Hiller, K. A. & Schmalz, G. (2007) Periodontal healing after non-surgical therapy with a new ultrasonic device: a randomized controlled clinical trial. *Journal of Clinical Periodontology* **34**, 137–147.

Costerton, J. W., Lewandowski, Z., Caldwell, D. E., Korber, D. R. & Lappin-Scott, H. M. (1995) Microbial biofilms. *Annual Review of Microbiology* **49**, 711–745.

Cross-Poline, G. N., Stach, D. J. & Newman, S. M. (1995) Effects of curet and ultrasonics on root surfaces. *American Journal of Dentistry* **8**, 131–133.

Del Peloso Ribeiro, E., Bittencourt, S., Ambrosano, G. M., Nociti, F. H. Jr., Sallum, E. A., Sallum, A. W. & Casati, M. Z. (2006) Povidone-iodine used as an adjunct to non-surgical treatment of furcation involvements. *Journal of Periodontology* **77**, 211–217.

Del Peloso Ribeiro, E., Bittencourt, S., Nociti, F. H. Jr., Sallum, E. A., Sallum, A. W. & Casati, M. Z. (2007) Comparative study of ultrasonic instrumentation for the non-surgical treatment of interproximal and non-interproximal furcation involvements. *Journal of Periodontology* **78**, 224–230.

Dragoo, M. R. (1992) A clinical evaluation of hand and ultrasonic instruments on subgingival debridement. 1. With unmodified and modified ultrasonic inserts. *International Journal of Periodontics and Restorative Dentistry* **12**, 310–323.

Drisko, C. L., Cochran, D. L., Blieden, T., Bouwsma, O. J., Cohen, R. E., Damoulis, P., Fine, J. B., Greenstein, G., Hinrichs, J., Somerman, M. J., Iacono, V. & Genco, R. J. (2000) Position paper: sonic and ultrasonic scalers in periodontics. Research, Science and Therapy Committee of the American Academy of Periodontology. *Journal of Periodontology* **71**, 1792–1801.

Flemmig, T. F., Petersilka, G. J., Mehl, A., Hickel, R. & Klaiber, B. (1998a) Working parameters of a magnetostrictive ultrasonic scaler influencing root substance removal in vitro. *Journal of Periodontology* **69**, 547–553.

Flemmig, T. F., Petersilka, G. J., Mehl, A., Hickel, R. & Klaiber, B. (1998b) The effect of working parameters on root substance removal using a piezoelectric ultrasonic scaler in vitro. *Journal of Clinical Periodontology* **25**, 158–163.

Flemmig, T. F., Petersilka, G. J., Mehl, A., Rüdiger, S., Hickel, R. & Klaiber, B. (1997) Working parameters of a sonic scaler influencing root substance removal in vitro. *Clinical Oral Investigations* **1**, 55–60.

Folwaczny, M., Merkel, U., Mehl, A. & Hickel, R. (2004) Influence of parameters on root surface roughness following treatment with a magnetostrictive ultrasonic scaler: an in vitro study. *Journal of Periodontology* **75**, 1221–1226.

Haffajee, A. D., Teles, R. P. & Socransky, S. S. (2006) The effect of periodontal therapy on the composition of the subgingival microbiota. *Periodontology 2000* **42**, 219–258.

Hoang, T., Jorgensen, M. G., Keim, R. G., Pattison, A. M. & Slots, J. (2003) Povidone–iodine as a periodontal pocket disinfectant. *Journal of Periodontal Research* **38**, 311–317.

Jepsen, S., Ayna, M., Hedderich, J. & Eberhard, J. (2004) Significant influence of scaler tip design on root substance loss resulting from ultrasonic scaling: a laserprofilometric in vitro study. *Journal of Clinical Periodontology* **31**, 1003–1006.

Kahl, M., Haase, E., Kocher, T. & Rühling, A. (2007a) Clinical effects after subgingival polishing with a non-aggressive ultrasonic device in initial therapy. *Journal of Clinical Periodontology* **34**, 318–324.

Kahl, M., Haase, E., Kocher, T. & Rühling, A. (2007b) Clinical effects after subgingival polishing with a non-aggressive ultrasonic device in initial therapy. *Journal of Clinical Periodontology* **34**, 318–324.

Kawashima, H., Sato, S., Kishida, M. & Ito, K. (2007) A comparison of root surface instrumentation using two piezoelectric ultrasonic scalers and a hand scaler in vivo. *Journal of Periodontal Research* **42**, 90–95.

Khambay, B. S. & Walmsley, A. D. (1999) Acoustic microstreaming: detection and measurement around ultrasonic scalers. *Journal of Periodontology* **70**, 626–631.

Kishida, M., Sato, S. & Ito, K. (2004) Effects of a new ultrasonic scaler on fibroblast attachment to root surfaces: a scanning electron microscopy analysis. *Journal of Periodontal Research* **39**, 111–119.

Kocher, T., Fanghänel, J., Sawaf, H. & Litz, R. (2001) Substance loss caused by scaling with different sonic scaler inserts – an in vitro study. *Journal of Clinical Periodontology* **28**, 9–15.

Kocher, T., Fanghänel, J., Schwahn, C. & Rühling, A. (2005) A new ultrasonic device in maintenance therapy: perception of pain and clinical efficacy. *Journal of Clinical Periodontology* **32**, 425–429.

Koshy, G., Kawashima, Y., Kiji, M., Nitta, H., Umeda, M., Nagasawa, T. & Ishikawa, I. (2005) Effects of single-visit full-mouth ultrasonic debridement versus quadrant-wise ultrasonic debridement. *Journal of Clinical Periodontology* **32**, 734–743.

Lea, S. C., Landini, G. & Walmsley, A. D. (2002) Vibration patterns of ultrasonic scalers with scanning laser vibrometry. *Journal of Dentistry* **30**, 147–151.

Lea, S. C., Landini, G. & Walmsley, A. D. (2003a) The displacement amplitude of ultrasonic scaler inserts. *Journal of Clinical Periodontology* **30**, 505–510.

Lea, S. C., Landini, G. & Walmsley, A. D. (2003b) Ultrasonic scaler tip performance under various load conditions. *Journal of Clinical Periodontology* **30**, 876–881.

Lea, S. C., Landini, G. & Walmsley, A. D. (2004a) Thermal imaging of ultrasonic scaler tips during tooth instrumentation. *Journal of Clinical Periodontology* **31**, 370–375.

Lea, S. C., Landini, G. & Walmsley, A. D. (2004b) Assessing the vibrations of dental ultrasonic scalers. *Journal of Sound and Vibration* **271**, 1113–1120.

Lea, S. C., Landini, G. & Walmsley, A. D. (2006) The effect of wear on ultrasonic scaler tip displacement amplitude. *Journal of Clinical Periodontology* **33**, 37–41.

Lea, S. C., Price, G. J. & Walmsley, A. D. (2005) A study to determine whether cavitation occurs around dental ultrasonic scaling instruments. *Ultrasonics Sonochemistry* **12**, 233–236.

Leonhardt, A., Bergström, C., Krok, L. & Cardaropoli, G. (2006) Healing following ultrasonic debridement and PVP–iodine in individuals with severe chronic periodontal disease: a randomized, controlled clinical study. *Acta Odontologica Scandinavica* **64**, 262–266.

Leonhardt, A., Bergström, C., Krok, L. & Cardaropoli, G. (2007) Microbiological effect of the use of an ultrasonic device and iodine irrigation in patients with severe chronic periodontal disease: a randomized controlled clinical study. *Acta Odontologica Scandinavica* **65**, 52–59.

Meissner, G., Oehme, B., Strackeljan, J. & Kocher, T. (2006) In vitro calculus detection with a moved smart ultrasonic device. *Journal of Clinical Periodontology* **33**, 130–134.

Meyer, K. & Lie, T. (1977) Root surface roughness in response to periodontal instrumentation studied by combined use of microroughness measurements and scanning electron microscopy. *Journal of Clinical Periodontology* **4**, 77–91.

O'Leary, R., Sved, A. M., Davies, E. H., Leighton, T. G., Wilson, M. & Kieser, J. B. (1997) The bactericidal effects of dental ultrasound on Actinobacillus actinomycetemcomitans and Porphyromonas gingivalis. An in vitro investigation. *Journal of Clinical Periodontology* **24**, 432–439.

Petersilka, G. J., Draenert, M., Mehl, A., Hickel, R. & Flemmig, T. F. (2003) Safety and efficiency of novel sonic scaler tips in vitro. *Journal of Clinical Periodontology* **30**, 551–555.

Rees, J. S., Addy, M. & Hughes, J. (1999) An in vitro assessment of the dentine lost during instrumentation using the Periosonic system. *Journal of Clinical Periodontology* **26**, 106–109.

Rosling, B., Hellström, M. K., Ramberg, P., Socransky, S. S. & Lindhe, J. (2001) The use of PVP–iodine as an adjunct to non-surgical treatment of chronic periodontitis. *Journal of Clinical Periodontology* **28**, 1023–1031.

Ryan, D. L., Darby, M., Bauman, D., Tolle, S. L. & Naik, D. (2005) Effects of ultrasonic scaling and hand-activated scaling on tactile sensitivity in dental hygiene students. *Journal of Dental Hygiene* [internet] [cited Feb 6 2008] **79**, e9. Available from http://www.adha.org.

Schmidlin, P. R., Beuchat, M., Busslinger, A., Lehmann, B. & Lutz, F. (2001) Tooth substance loss resulting from mechanical, sonic and ultrasonic root instrumentation assessed by liquid scintillation. *Journal of Clinical Periodontology* **28**, 1058–1066.

Sculean, A., Schwarz, F., Berakdar, M., Romanos, G. E., Brecx, M., Willershausen, B. & Becker, J. (2004) Non-surgical periodontal treatment with a new ultrasonic device (Vector-ultrasonic system) or hand instruments. *Journal of Clinical Periodontology* **31**, 428–433.

Slots, J. (1979) Subgingival microflora and periodontal disease. *Journal of Clinical Periodontology* **6**, 351–382.

Slots, J. & Ting, M. (1999) *Actinobacillus actinomycetemcomitans* and *Porphyromonas gingivalis* in human periodontal disease: occurrence and treatment. *Periodontology 2000* **20**, 82–121.

Tomasi, C., Bertelle, A., Dellasega, E. & Wennström, J. L. (2006) Full-mouth ultrasonic debridement and risk of disease recurrence: a 1-year follow-up. *Journal of Clinical Periodontology* **33**, 626–631.

Trenter, S. C., Landini, G. & Walmsley, A. D. (2003) The effect of loading on the vibration characteristics of thin magnetostrictive ultrasonic scaler inserts. *Journal of Periodontology* **74**, 1308–1315.

Trenter, S. C. & Walmsley, A. D. (2003) Ultrasonic dental scaler: associated hazards. *Journal of Clinical Periodontology* **30**, 95–101.

Tunkel, J., Heinecke, A. & Flemmig, T. F. (2002) A systematic review of efficacy of machine-driven and manual subgingival debridement in the treatment of chronic periodontitis. *Journal of Clinical Periodontology* **29** (Suppl. 3), 72–81.

Vastardis, S., Yukna, R. A., Rice, D. A. & Mercante, D. (2005) Root surface removal and resultant surface texture with diamond-coated ultrasonic inserts: an in vitro and SEM study. *Journal of Clinical Periodontology* **32**, 467–473.

Walmsley, A. D., Laird, W. R. E. & Williams, A. R. (1986) Displacement amplitude as a measure of the acoustic output of ultrasonics. *Dental Materials* **2**, 97–100.

Walmsley, A. D., Laird, W. R. E. & Williams, A. R. (1988) Dental plaque removal by cavitational activity during ultrasonic scaling. *Journal of Clinical Periodontology* **15**, 539–543.

Walmsley, A. D., Walsh, T. F., Laird, W. R. E. & Williams, A. R. (1990) Effects of cavitational activity on the root surface of teeth during ultrasonic scaling. *Journal of Clinical Periodontology* **17**, 306–312.

Wennström, J. L., Tomasi, C., Bertelle, A. & Dellasega, E. (2005) Full-mouth ultrasonic debridement versus quadrant scaling and root planing as an initial approach in the treatment of chronic periodontitis. *Journal of Clinical Periodontology* **32**, 851–859.

Yukna, R. A., Vastardis, S. & Mayer, E. T. (2007) Calculus removal with diamond-coated ultrasonic inserts in vitro. *Journal of Periodontology* **78**, 122–126.

Address:
A. D. Walmsley
School of Dentistry
The University of Birmingham
St. Chad's Queensway
Birmingham
B4 6NN
UK
E-mail: a.d.walmsley@bham.ac.uk