J Clin Periodontol 2005; 32: 153–157 doi: 10.1111/j.1600-051X.2005.00651.x
Copyright © Blackwell Munksgaard 2005

Journal of Clinical Periodontology

Removal of root substance with the Vector™-system compared with conventional debridement in vitro

Andreas Braun, Felix Krause, Matthias Frentzen and Søren Jepsen

Department of Periodontology, Operative and Preventive Dentistry, University of Bonn, Germany

Braun A, Krause F, Frentzen M, Jepsen S: Removal of root substance with the Vector™-system compared with conventional debridement in vitro. J Clin Periodontol 2005; 32: 153–157. doi: 10.1111/j.1600-051X.2005.00651.x. © Blackwell Munksgaard, 2005.

Abstract

Objective: The aim of the present study was to assess the removal of root substance with the Vector™-system depending on different irrigation fluids and to compare the results with conventional methods for root debridement.

Material and Methods: Forty extracted human teeth were treated using four different methods: Vector™-system with polishing fluid and metal curette (VP), Vector™-system with abrasive fluid and metal curette (VA), conventional ultrasonic system (U) with insert tip ''P'' and hand instrument. Treatment of the calculus-free root surfaces was carried out for a total of 12 min. using an artificial periodontal pocket. At intervals of 120 s, the removal of dental hard tissues was assessed using a three-dimensional (3D) laser scanning device and the Match 3D software with an accuracy of 0.00001 mm^3.

Results: No difference in the removal of root substance with the hand instrument (0.0055 mm^3/s) and the Vector™-system using the abrasive fluid (0.0044 mm^3/s) could be observed ($p = 0.51$). Using these two systems, a larger amount of root substance ($p < 0.05$) was removed compared with the other methods (U: 0.0023 mm^3/s, VP: 0.0022 mm^3/s), which did not differ from each other ($p = 0.76$).

Conclusions: The present study indicates that the Vector™-system in combination with polishing fluid or conventional ultrasonics might be used for root debridement without extensive root substance removal.

Key words: artificial periodontal pocket; hand instrumentation; periodontal treatment; removal of root substance; ultrasonic instrumentation

Accepted for publication 25 May 2004

It is widely accepted that initiation and progression of periodontitis are dependent upon the presence of microorganisms capable of causing inflammation. Therefore, during initial periodontal treatment, supra- and subgingival plaque as well as firmly adhering calculus should be removed. As calculus takes months or years to build up again, the principal objective of supportive periodontal therapy is to remove subgingival plaque. Thus, the periodic mechanical removal of subgingival bacterial plaque is essential for controlling inflammation, because bacteria can re-populate pockets within a few weeks following active therapy (Sbordone et al. 1990). In the past, periodontal debridement was primarily performed with hand instruments. More recently, power-driven instruments have been modified to provide better access to deep probing sites, offering the possibility of more efficient subgingival instrumentation (Holbrook & Low 1994). Clinically, the available data do not indicate a difference between ultrasonic and manual debridement in the treatment of chronic periodontitis (Drisko et al. 2000, Tunkel et al. 2002). Using these instruments, it is not always possible to prevent loss of root substance. Because of cumulative effect, even minor substance removal per scaling session may result in severe root damage over time (Zappa et al. 1991).

A novel ultrasonic device (Vector™) generates ultrasonic vibrations that are converted by a resonating ring, so that a horizontal oscillation is deflected vertically. As a result, the instrument tip moves parallel to the root surface and is recommended to be used in conjunction with irrigation fluids containing hydroxyl apatite or silicon carbide (Hahn 2000). The tooth surface is supposed to be cleaned because of hydrodynamic forces such as cavitation or acoustic microstreaming (Walmsley et al. 1990, Khambay & Walmsley 1999) rather than by the chipping action of the instrument tip (Hahn 2000). The manufacturers claim the system to be less aggressive than hand instruments concerning removal of root cementum and periodontal soft tissues (Hahn 2000). This principle is comparable with ultrasonic cleaning baths or lithotriptor systems. Avoiding vibrations applied horizontally to the root surface, the treatment with the Vector™-system has been shown to be less painful than treatment with conventional systems (Braun et al. 2003). It could be demonstrated that clinical parameters such as pocket depths and bleeding on probing improved in a similar way, following the use of the Vector™-system or hand instruments (Klinger et al. 2000). The ultrasonic device is recommended to be used in conjunction with different irrigation fluids; therefore, effects on the root surface might be different.

Hence, the aim of the present in vitro study was to assess subgingival removal of root substance by the Vector™-system depending on different irrigation fluids and to compare the results with conventional periodontal techniques for root instrumentation.

Material and Methods

A total of 40 periodontally involved freshly extracted human teeth were collected from different patients and stored in a physiological saline solution. The time span between tooth extraction and the following treatment of the teeth did not exceed 1 week. For each tooth, the entire root surface was gently cleaned using hand instruments (Hu-Friedy, Leimen, Germany) until it appeared devoid of calculus and periodontal ligament, using a loupe at $\times$ 3.5 magnification. Baseline scanning images of the root surfaces were captured and subsequently, 10 teeth each were treated using four different methods: Vector™-system (Duerr Dental, Bietigheim-Bissingen, Germany) turned to the usual ''70%'' setting with hydroxyl-apatite-containing polishing fluid and metal curette insert at 25 kHz (VP), Vector™-system with silicon-carbide-containing abrasive fluid and metal curette insert at 25 kHz (VA), conventional ultrasonic system (U) turned to the ''high'' setting with insert tip ''P'' at 31 kHz (EMS, Nyon, Switzerland) and hand instrument (Hu-Friedy). The teeth were cleaned before treatment and the prior attachment levels were not recognizable to the operator. Laser scanning of the root surface allowed detection of root substance removal along the whole surface, so that there was no need to define an exact area to be treated. Ultrasonic instruments were used with the tip parallel to the root surface and with continuous adaptation to the root surface. When using the curette, the cutting edge was first identified and placed against the tooth surface to be scaled with the terminal shank parallel to that surface. In this position, the ideal working angulation for the cutting edge according to the manufacturer's instruction could be achieved. The instrumentation of all teeth was performed by one investigator well trained in periodontal treatment, who was endeavoured to use all instruments with a clinically appropriate force of application. Additionally, prior to the instrumentation of the 40 teeth in the experimental groups, lateral force measurements were performed. Using an artificial periodontal pocket model as shown below and a vice-like support placed on a laboratory balance (BL 510-OCE, Sartorius, Goettingen, Germany), the investigator treated a root surface devoid of calculus with the four different methods included in the study for a total of 200 s each. At intervals of 10 s, the applied force was recorded by a second investigator. This preliminary survey showed that the operator applied a lateral force of 4.76 ± 0.24 N with the hand instrument, 0.83 ± 0.11 N (U), 0.68 ± 0.10 N (VP) and 0.69 ± 0.09 N (VA) while treating the root surfaces.

Treatment of the root surfaces was carried out for a total of 12 min. using an artificial periodontal pocket model; teeth were fixed on glass slides and covered with a non-transparent rubber dam (Coltène/Whaledent, Langenau, Germany), so that the root surface was not visible to the operator. At intervals of 120 s, the removal of dental hard tissues was assessed by a second operator, using a three-dimensional (3D) laser scanning device (Willytec, Munich, Germany), built to measure complex, 3D tooth surfaces (Fig. 1). Each sample was prepared for laser scanning with a dye surface coating (Met-L-Chek, Santa Monica, CA, USA) and scanned from apical to coronal by a laser beam, projected via an optic system onto the root surface. The reflection of the beam was observed at an angle of 20° by a high-resolution CCD camera (Sony, Köln, Germany) with an accuracy of 28 μm (width), 25 μm (length) and 2.5 μm (height). The trimmed tooth surface opposite to the surface treated with an experimental procedure was fixed by means of a silicone impression material (Voco, Cuxhaven, Germany) to facilitate a reproducible position of the tooth in the scanning device. To evaluate root substance loss, scanning images of the root surfaces were superimposed and subtracted using the Match 3D superimposition software (Willytec) (Fig. 2).

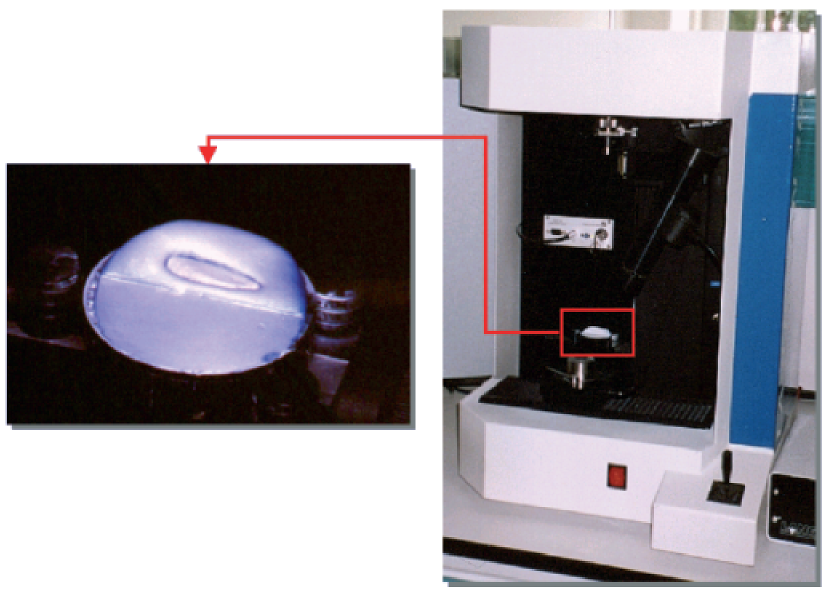

Fig. 1. Laserscan 3D (Willytec), with tooth prepared for laser scanning.

For statistical analysis, normal distribution of the values was analysed with the Shapiro–Wilk test. Since not all values were normally distributed, analysis of variances of the ranks with subsequent comparison of mean ranks and calculation of homogeneous groups (Scheffé) were used to analyse the amount of root substance removal depending on the different treatment methods. Differences were considered as statistically significant at $p < 0.05$.

Results

Measuring the volumes of teeth repositioned in the scanning device without root instrumentation revealed an accuracy of 0.00001 mm^3 (Table 1). Comparing values for root substance removal at intervals of 2 min. within each single experimental group, no statistical difference could be observed between the intervals ($p > 0.05$). Removal of root substance with the Vector™-system depended on the used fluid (VA: 0.0044 mm^3/s, VP: 0.0022 mm^3/s, $p < 0.05$, Fig. 3, Table 1). The amount of removed root substance with the hand instrument (H: 0.0055 mm^3/s) did not differ significantly from the value measured for the Vector™-system using the abrasive fluid ($p = 0.51$). Values for the conventional ultrasonic system (U: 0.0023 mm^3/s) and the Vector™-system using the polishing fluid were statistically not different ($p = 0.76$). Using these two systems, a minor amount of root substance was removed compared with hand instrumentation and the Vector™-system with abrasive fluid ($p < 0.05$, Table 2).

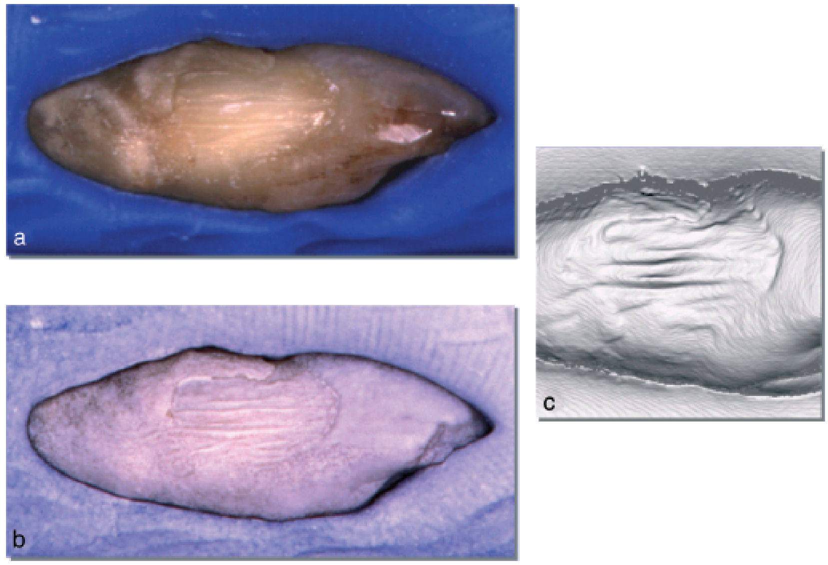

Fig. 2. Tooth after treatment (a), prepared with dye surface coating (b) and scanned with Laserscan 3D (c).

Table 1. Removal of root substance (mm^3/s)

	H	U	VP	VA	Control
Mean value	0.0055	0.0023	0.0022	0.0044	0.00000599
Standard deviation	0.0018	0.0012	0.0007	0.0021	0.00000399
Number of teeth	10	10	10	10	10

Highest removal of root substance with H and VA, least removal using U and VP.
U, conventional ultrasonic instrument; H, hand instrument; VP, Vector™-system with metal curette insert and polishing fluid; VA, Vector™-system with metal curette insert and abrasive fluid and control group without treatment.

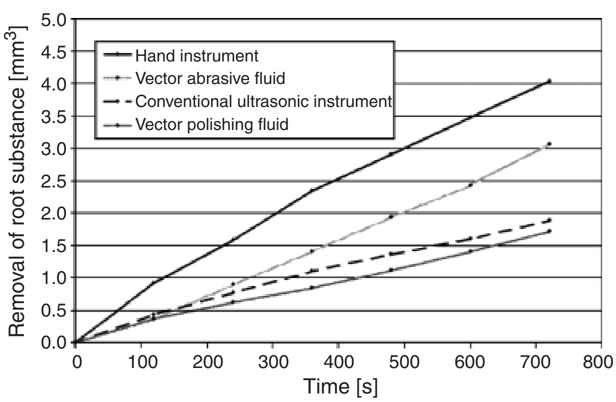

Fig. 3. Amount of root substance removal over time. Every group calculated from 10 teeth. Highest root substance loss was obtained using the hand instrument, and the slowest loss was obtained using the Vector™-system with polishing fluid.

Discussion

In the past, extensive cementum removal by scaling and planing of the root surface was required to remove root-associated endotoxins for successful mechanical periodontal therapy (Aleo et al. 1975). However, endotoxin is only superficially associated with cementum and calculus. As it is easily removed by washing, brushing, light scaling or polishing the tooth surface (Smart et al. 1990, Chiew et al. 1991, Drisko et al. 2000), periodontal healing can be achieved without extensive cementum removal. Avoiding vibrations applied horizontally on the root surface, the oscillation pattern of the Vector™-system avoids a hammering action of the insert tip against the tooth surface. Therefore, the system was claimed to be less aggressive than hand instruments concerning removal of root cementum and periodontal soft tissues (Hahn 2000). Indeed, this oscillation pattern might explain the little amount of root substance removed in the present study when using the system with the polishing fluid. Thus, higher values for root substance removal with the abrasive fluid seem to be caused solely by the choice of the irrigation fluid. Using the standard ultrasonic system, treatment could be shown to be as gentle as the Vector™-system with the polishing

Table 2. Statistical analysis of root substance loss using the different debridement modalities

Shapiro–Wilk-test (normal distribution)				
	H	U	VP	VA
w-value	0.90	0.96	0.96	0.84
Normal distribution	Yes	Yes	Yes	No

ANOVA of ranks				
sum of squares	degrees of freedom	mean square	F-value	p-value
3016.20	3	1005.40	15.65	<0.05
2313.30	36	64.26		

Multiple comparisons of mean ranks (Scheffé-test)			
treatment	number	homogeneous groups ($p<0.05$)	
		A	B
VP	10	10.2	
U	10	14.1	
VA	10		26.1
H	10		31.6
p-value within group		0.758	0.510

Not all values were normally distributed and therefore analysed using a non-parametric test ($\alpha = 0.05$).
U, conventional ultrasonic instrument; H, hand instrument; VP, Vector™-system with metal curette insert and polishing fluid; VA, Vector™-system with metal curette insert and abrasive fluid; ANOVA, analysis of variance.

fluid. Higher aggressiveness of hand instruments to the root substance compared with the Vector™-system in combination with the polishing fluid may have been because of the lack of a true cutting edge of the Vector™ instruments. An in vitro study compared the volume of bovine root substance loss using sonic, ultrasonic and hand instruments (Schmidlin et al. 2001). In accordance with the present study, the results showed that hand instruments removed most root substance. Evaluating different working parameters on root substance removal using the EMS Piezon Master 400 piezoelectric ultrasonic scaler (Electro Medical Systems SA, Nyon, Switzerland), the volume of substance removal was measured (Flemmig et al. 1998a). The overall influence of time on defect volume for pooled lateral forces, tip angulations and power settings revealed an efficacy of approximately 0.33 mm^3 per 80 s. This value (0.0041 mm^3/s) is comparable with the values in the present study (0.0022 mm^3/s up to 0.0055 mm^3/s). Evaluating the Sonicflex Lux 2000 sonic scaler (KaVo America Corp. Biberach, Germany) an efficacy of 0.4 mm^3 per 80 s could be observed (Flemmig et al. 1997). This value (0.005 mm^3/s) is also comparable with the values of the present study. The result for the CaviMed magnetostrictive ultrasonic scaler (Dentsply, Konstanz, Germany) (approximately 0.0055 mm^3/s, Flemmig et al. 1998b) corresponds to the value measured for the hand instrument in the present study. In an attempt to quantitate root substance loss by scaling with hand instruments, a profilometer was used (Zappa et al. 1991). In contrast to the present study, only the depth of substance loss could be measured with the profilometer. Depending on the force applied to the instrument, 40 strokes with a curette removed an amount of 148.7 up to 343.3 μm root substance. This demonstrates the great importance of adjusting lateral forces when substance loss is evaluated. Additionally, with an increasing number of strokes the amount of substance removed per stroke can become less (Zappa et al. 1991). This may be because of the dulling of the curettes. A standardization of applied lateral forces was realized with the performance of all treatments by one investigator. As different investigators may tend to remove either small or large amounts of root substance, the limitation to one operator allows for an inter-instrumentation comparison within the experimental set-up. Not only lateral forces but also power settings and tip angulations can influence root substance removal (Flemmig et al. 1997, 1998a, b). In the present study, instruments were used with the tip or terminal shank adapted parallel to the root surface, according to the common use of ultrasonic and hand instruments. The root surface was covered with a non-transparent rubber dam. Therefore, it was difficult to retain this condition. However, this set-up resembles the clinical situation of a root surface instrumentation without surgical access. Investigating working parameters of a sonic and piezoelectric ultrasonic scaler on root substance removal, it was shown that this angulation might prevent severe root damage (Flemmig et al. 1997, 1998a, b). All ultrasonic instruments were used with the same power settings and with continuous adaptation to the root surface. This should have resulted in a lateral pressure of approximately 0.75 N (Clark et al. 1968). This assessment is in accordance with the results of the preliminary survey of this study. Lateral forces of 0.83 ± 0.11 N with the conventional ultrasonic instrument, 0.68 ± 0.09 N with the Vector™-system and the polishing fluid and 0.69 ± 0.10 N with the Vector™-system and the abrasive fluid were applied by the operator. Lateral forces were not measured during treatment of the experimental groups, as the investigator was well trained in periodontal treatment and the standard deviation of the applied forces in the preliminary survey was low. Assessing calculus removal with a sonic scaler, the mean debridement force was 0.87 ± 0.27 N for a novel paddle-like scaler tip and 0.79 ± 0.22 N for a conventional scaler tip (Petersilka et al. 2003). In general, application forces influence defect depth (Ritz et al. 1991, Kocher & Plagmann 1997b). However, at lateral forces higher than 0.5 or 1.0 N the resulting defect depth decreased (Kocher & Plagmann 1997a). This observation was as a result of dampening of the instrument, although in some studies only a slight or no decrease of defect depth at higher lateral forces could be measured (Flemmig et al. 1997, Kocher et al. 2001). Lateral forces observed when using hand instruments in the present study are in the range of values measured for working strokes by means of a piezoelectric receiver built into the upper shank of a curette (Zappa et al. 1991).

A gentle root-surface instrumentation has a high priority during the periodontal maintenance phase. In conclusion, the present study indicates that the Vector™ instruments in combination with the polishing fluid might be used for debridement without extensive root substance removal. The amount of root substance removal was shown to be similar to a conventional ultrasonic instrument. Because it is not known which forces must be applied to remove firmly adhering calculus, the volume of removed root substance cannot be equated with the calculus volume. Thus, further studies have to evaluate calculus removal by the treatment methods used in this study.

References

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

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.

Chiew, S. Y., Wilson, M., Davies, E. H. & Kieser, J. B. (1991) Assessment of ultrasonic debridement of calculus-associated periodontally-involved root surfaces by the limulus amoebocyte lysate assay. An in vitro study. *Journal of Clinical Periodontology* **18**, 240–244.

Clark, S., Grupe, H. & Mahler, D. (1968) The effect of ultrasonic instrumentation on root surfaces. *Journal of Periodontology* **31**, 135–137.

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

Flemmig, T. F., Petersilka, G. J., Mehl, A., Hickel, R. & Klaiber, B. (1998a) 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., Hickel, R. & Klaiber, B. (1998b) 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., Ruediger, S., Hickel, R. & Klaiber, B. (1997) Working parameters of a sonic scaler influencing root substance removal in vitro. *Clinical Oral Investigations* **1**, 55–60.

Hahn, R. (2000) Therapy and prevention of periodontitis using the Vector-method. *Das Deutsche Zahnaerzteblatt* **109**, 642–645.

Holbrook, T. E. & Low, S. B. (1994) Power-driven scaling and polishing instruments. In: Clark, J. W. (ed.). *Clark's Clinical Dentistry*, pp. 1–24. Philadelphia: Lippincott.

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

Klinger, G., Klinger, M., Pertsch, J., Guentsch, A. & Boerner, D. (2000) Periodontal therapy using the ultrasonic Vector-system. *Die Quintessenz* **51**, 813–820.

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. & Plagmann, H. C. (1997a) The diamond-coated sonic scaler insert. Part I. Oscillation pattern of different sonic scaler inserts. *International Journal of Periodontics and Restorative Dentistry* **17**, 393–399.

Kocher, T. & Plagmann, H. C. (1997b) The diamond-coated sonic scaler insert. Part II. Loss of substance and alteration of root surface texture after different scaling modalities. *International Journal of Periodontics and Restorative Dentistry* **17**, 485–493.

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.

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

Sbordone, L., Ramaglia, L., Guletta, E. & Iacono, V. (1990) Recolonization of the subgingival microflora after scaling and root planing in human periodontitis. *Journal of Periodontology* **61**, 579–584.

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.

Smart, G. J., Wilson, M., Davies, E. H. & Kieser, J. B. (1990) The assessment of ultrasonic root surface debridement by determination of residual endotoxin levels. *Journal of Clinical Periodontology* **17**, 174–178.

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**, 72–81.

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

Zappa, U., Smith, B., Simona, C., Graf, H., Case, D. & Kim, W. (1991) Root substance removal by scaling and root planing. *Journal of Periodontology* **62**, 750–754.

Address:
Andreas Braun
Department of Periodontology, Operative and Preventive Dentistry
University of Bonn
Welschnonnenstr. 17
53111 Bonn
Germany
E-mail: andreas.braun@uni-bonn.de

This document is a scanned copy of a printed document. No warranty is given about the accuracy of the copy. Users should refer to the original published version of the material.