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Efficiency of subgingival calculus removal with the Vector™-system compared to ultrasonic scaling and hand instrumentation *in vitro*

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Objective: The recently introduced Vector™-system (Duerr Dental, Bietigheim-Bissingen, Germany) is recommended to be used in conjunction with different insert tips and irrigation fluids. The aim of the study was to assess subgingival calculus removal depending on the mode of operation and to compare the results to conventional methods for root debridement.

Methods: Sixty extracted human teeth with calculus on the root surface were treated in an artificial periodontal pocket model using six methods: Vector™-system with metal probe insert (VPP) or metal curette insert (VPC), both used with polishing fluid, Vector™-system with metal probe insert (VAP) or metal curette insert (VAC), both used with abrasive fluid, EMS-ultrasonic system (U) and hand instrument (Gracey curette). Photographs of the root surface were taken at intervals of 10 s and calculus removal was assessed using a surface analysis software until the root surfaces were cleaned completely. Analysis of variances (ANOVA) of the ranks with subsequent comparison of mean ranks and calculation of homogeneous groups (Scheffé) were used for statistical analysis.

Results: Employing the hand instrument, highest efficiency could be observed (0.340 mm^2/s). Calculus removal with the Vector™-system and metal probe insert (VPP: 0.036 mm^2/s; VAP: 0.067 mm^2/s) was less effective ($p < 0.05$) than using the system with metal curette inserts (VPC: 0.122 mm^2/s; VAC: 0.209 mm^2/s). Employing the abrasive fluid, removal of deposits with the metal curette insert was as efficient as with the conventional ultrasonic system (U: 0.199 mm^2/s, $p > 0.05$).

Conclusion: The present *in vitro* study indicates that the efficiency of calculus removal with the Vector™-system is significantly dependent on the selection of inserts and irrigation fluids.

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The principal objective of periodontal therapy is to reduce supra- and subgingival plaque and calculus and to prevent recolonization of periodontal pockets by pathogenic bacteria. Therefore, the initial hygiene phase is fundamental to successful periodontal therapy, requiring high efficacy of the instruments for subgingival calculus removal without causing root damage. Although apical migration of plaque is the primary reason for periodontal destruction, calculus, which may retain plaque and its products, creates the conditions for further destruction and adds to the chronicity of the periodontal lesion (1, 2). Instruments that are available for root debridement include hand scalers, ultrasonic instruments, air-powder abrasive systems, diamond burs and lasers. Employing these instruments, it is not always possible to prevent loss of root substance. Due to cumulative effect, even minor substance removal per scaling may result in severe root damage over time (3). Sonic and ultrasonic instruments are used to mechanize the procedure of scaling and root planing. Adjustments in working parameters shall allow the adaption of an ultrasonic scaler's efficacy to various clinical needs (4, 5). Clinically, the available data do not indicate a difference between ultrasonic and manual debridement in the treatment of chronic periodontitis (6, 7).

Recently a novel ultrasonic device has been introduced. The Vector™-system (Duerr Dental, Bietigheim-Bissingen, Germany) generates ultrasonic vibrations at a frequency of 25 kHz, which are converted by a resonating ring so that a horizontal oscillation is deflected vertically. As a result the instrument tip moves parallel along the axis of the used insert and is recommended to be used in conjunction with a hydroxyl-apatite containing polishing fluid or a silicon-carbide containing abrasive fluid (8). The fluid directed to the instrument tip is supposed to establish indirect coupling of ultrasonic energy to the root surface, so that the tooth surface is cleaned due to hydrodynamic forces such as cavitation or acoustic microstreaming (9, 10) rather than by the chipping action of the instrument tip (8). Avoiding vibrations applied horizontally on the root surface, in a previous study the treatment with the Vector™-system has been shown to be less painful than treatment with conventional systems (11). As it is recommended to use this ultrasonic device in conjunction with different insert tips and either a polishing fluid containing hydroxyl apatite particles or an abrasive fluid with silicon carbide particles, effects on the root surface might depend on the mode of operation.

Hence, the aim of the present *in vitro* study was to assess subgingival calculus removal by the Vector™-system depending on different inserts and fluids and to compare the results to conventional periodontal debridement methods.

Material and methods

A total of 60 periodontally involved freshly extracted human teeth covered with calculus on the root surface were stored in physiological saline solution and then treated using six different methods: Vector™-system with metal probe insert (VPP) or metal curette insert (VPC), both used with hydroxylapatite containing polishing fluid (Duerr Dental) at 25 kHz, Vector™-system with metal probe insert (VAP) or metal curette insert (VAC), both used with silicon-carbide containing abrasive fluid (Duerr Dental) at 25 kHz, conventional piezoelectric ultrasonic system (U) turned to the 'high' setting with insert 'P' at 31 kHz (EMS, Nyon, Switzerland) and hand instrument (H) (Gracey-curette, Hu-Friedy, Leimen, Germany). According to the manufacturer's instruction, operation of the Vector™-system was set at an amplitude of 30 μm for all applications, corresponding to the first seven LEDs lighting up on the intensity display. In the hand instrument group, for each tooth a new curette was used to avoid dulling of the instruments. Incisors, premolars and molars were evenly assigned to six groups of 10 teeth with regard to tooth type and the amount of subgingival calculus present. These groups were then assigned to the treatment methods employing computer generated random numbers to avoid personal bias. Both ultrasonic and hand instruments were used according to the manufacturer's instructions. Employing ultrasonic instruments, the tip was aligned parallel and used with continuous adaptation to the root surface. The instrumentation of all teeth was performed by one investigator well-trained in periodontal treatment, who used all instruments with a clinically appropriate force of application. Additionally, prior to the instrumentation of the 60 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 with the six 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 (H), 0.83 ± 0.11 N (U), 0.67 ± 0.08 N (VPP), 0.68 ± 0.10 N (VPC), 0.68 ± 0.09 N (VAP) and 0.69 ± 0.09 N (VAC) while treating the root surfaces.

Treatment of the root surfaces was carried out 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 for the operator. With the rubber dam attached, indirect coupling of ultrasonic energy to the root surface was enabled, as the tooth could be surrounded by a fluid. At intervals of 10 s, treatment was interrupted, the rubber dam removed and standardized photographs of the roots were taken at a magnification of $1.5\times$ until the surfaces were cleaned completely. The digitized photographs were assessed with a surface analysis software (MegaCAD 4.8b, Megatech Software GmbH, Berlin, Germany), measuring the amount of remaining calculus with an accuracy of 0.1 mm^2. Diameters of the teeth were measured with a caliper (accuracy: 0.01 mm). These values could be assigned to the standardized photographs to calibrate the MegaCAD software. Based on the remaining calculus at intervals of 10 s, the amount of removed calculus per second was calculated to assess efficiency of the different methods for root debridement.

For statistical analysis, normal distribution of the data was checked with the Shapiro–Wilk test. As not all values were normally distributed, analysis of variances (ANOVA) of the ranks with subsequent comparison of mean ranks and calculation of homogeneous groups (Scheffé) were used to analyse differences between the treatment methods. Differences were considered as statistically significant at $p < 0.05$.

Results

Employing all methods, a gradual calculus reduction and finally complete calculus removal could be achieved (Fig. 1). Time required to debride the teeth differed significantly between the groups. Efficiency of the Vector™-system in calculus removal depended on the insert tip and fluid (Figs 2 and 3). Using the metal probe insert, with both the polishing and the abrasive fluid, a lower efficiency could be observed than for the metal curette insert ($p < 0.05$). The metal probe insert used with the abrasive fluid (VAP: $0.067 \pm 0.028\ mm^2/s$) tended to remove less calculus per second than the metal curette insert used with the polishing fluid (VPC: $0.122 \pm 0.031\ mm^2/s$, $p = 0.052$). Comparing different fluids with the same insert tip, efficiency employing the abrasive fluid with the probe insert (VAP: $0.067 \pm 0.028\ mm^2/s$) was statistically not higher than using the polishing fluid (VPP: $0.036 \pm 0.019\ mm^2/s$, $p = 0.217$). The curette insert used with abrasive fluid (VAC: $0.209 \pm 0.062\ mm^2/s$) was more efficient than this insert used with polishing fluid (VPC: $0.122 \pm 0.031\ mm^2/s$, $p < 0.05$). Efficiency using the conventional ultrasonic instrument (U: $0.199 \pm 0.065\ mm^2/s$) was not different compared to Vector™-system used with abrasive fluid and metal curette insert (VAC, $p > 0.05$), which removed more calculus per second compared to all other configurations of the Vector™-system evaluated ($p < 0.05$). Highest efficiency could be observed for the hand instrument (H: $0.340 \pm 0.071\ mm^2/s$, $p < 0.05$).

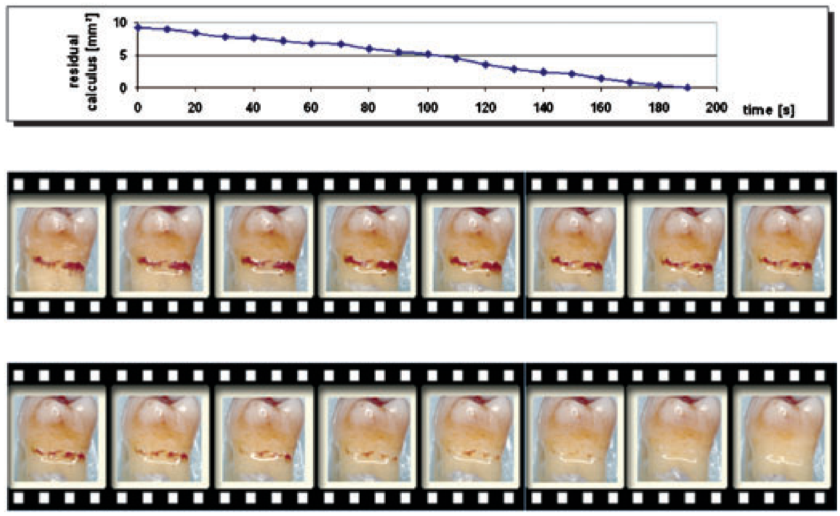

Fig. 1. Calculus removal using the Vector™-system with metal curette insert and abrasive fluid. Photographs taken at intervals show the amount of remaining calculus. Chart shows the amount of residual calculus on this tooth at intervals of 10 s.

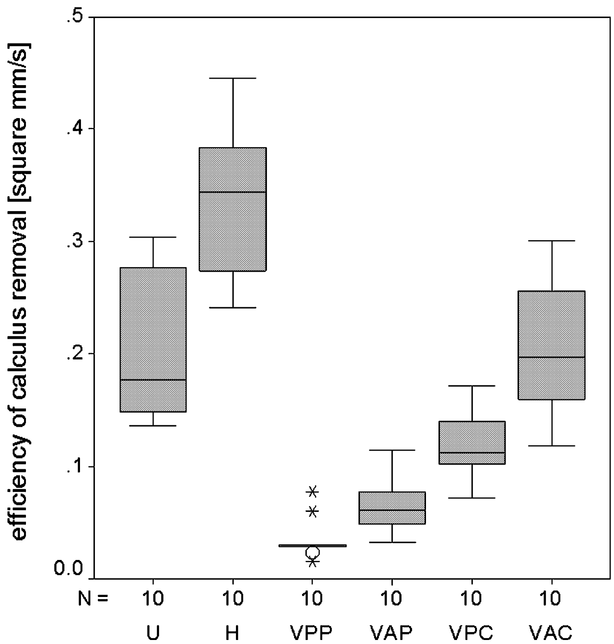

Fig. 2. Box plots for the efficacy of calculus removal employing the different debridement modalities. U, conventional ultrasonic instrument; H, hand instrument; VPP, Vector™-system with metal probe insert used with polishing fluid; VPC, Vector™-system with metal curette insert used with polishing fluid; VAP, Vector™-system with metal probe insert used with abrasive fluid; VAC, Vector™-system with metal curette insert used with abrasive fluid. Highest efficacy with hand instrumentation, least efficiency employing VPP.

Discussion

Selection of the most suitable instrument and appropriate technique for root planing improves the comfort and cost-effectiveness for both the patient and the clinician (12). In the present study the time required for calculus removal differed significantly among the methods investigated. It could be shown that the metal probe insert of the Vector™-system did not remove

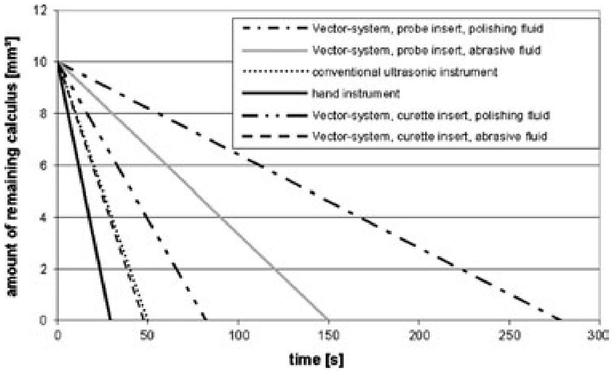

Fig. 3. Relative efficiency in subgingival calculus removal. Values are based on a virtually calculated 10 mm^2 deposit. Every group calculated from 10 teeth. Fastest calculus removal using hand instrument, slowest removal using Vector™-system with metal probe insert and polishing fluid.

calculus as efficiently as the other methods. A possible explanation might be the comparatively smaller surface area of the metal probe insert resulting in less hydrodynamic forces acting on the root surface or less interaction of the tip with the calculus. Accordingly, the metal curette insert with a larger surface demonstrated higher efficiency, comparable to conventional ultrasonic instruments.

Other studies also investigated differences between efficiencies of hand instruments and ultrasonic systems. Comparing the EVA™ reciprocating handpiece (Dentatus International AB, Stockholm, Sweden) with Per-io-tor™ inserts (Dentatus International AB) to the Cavitron™-system (Dentsply International, York, PA, USA) and hand instrumentation, longest mean time was found for debridement with the EVA™-system (13). The Cavitron™-system required least time to achieve visible cleanliness of the root surface. Evaluating time for instrumentation of extracted teeth, in another *in vitro* study 126.1 ± 38.2 s were needed with a hand instrument, 74.1 ± 27.6 s with a piezoelectric ultrasonic instrument and 104.9 ± 25.4 s with a magnetostrictive ultrasonic instrument to achieve a visually and tactile clean and smooth root surface (14). These results are in contrast to those of the present study, finding highest efficiency for hand instruments. The difference may be explained by the fact that the root surface treatment in the present study was carried out using an artificial periodontal pocket model, simulating subgingival debridement under *in vivo* conditions. As the operator did not have the possibility to see calculus on the root surface during treatment, higher efficiency of hand instrumentation may have been due to the lack of a true cutting edge of the Vector™ instruments. Evaluating residual stainable deposits after root surface instrumentation *in vivo* and subsequent extraction for periodontal or prosthetic reasons, the range for surface staining was 5.8% to 61% for all ultrasonic treated specimens and 13.3% to 50.0% for all hand-instrumented teeth (15).

In the present study all oscillating instruments were used with a tip angulation close to 0 degrees. Investigating working parameters of a sonic and piezoelectric ultrasonic scaler on root substance removal, it could be shown that this angulation might prevent severe root damage (4, 5, 16). In the same studies it could also be demonstrated that lateral forces and power settings could influence root substance removal of the used instruments. To control for these effects, in the present study instruments were always used with the same power settings. Instrumentation of all teeth was undertaken by one investigator, allowing an inter-instrumentation comparison within the experimental set-up. All ultrasonic instruments were used with continuous adaptation to the root surface. This should have resulted in a lateral pressure of approximately 0.75 N (17). The results of the preliminary survey are in accordance with this assessment. Also calculus removal with a sonic scaler resulted in a comparable mean debridement force of 0.87 ± 0.27 N for a novel paddle-like scaler tip and 0.79 ± 0.22 N for a conventional scaler tip (18).

The principal objective of the present study was to assess efficiency in calculus removal and not the effect of treatment on clinical conditions or the degree of root damage that may be inflicted by the different methods of instrumentation. Hence, clinical parameters, root surface morphology after instrumentation or root substance removal by the Vector™-system will have to be investigated in further studies. Recently, the capability of the Vector™ treatment to improve clinical parameters (e.g. pocket depths and bleeding on probing) in a similar way as hand instruments was demonstrated (19). Improvements of these parameters indicate that the system allows controlling the plaque biofilm under *in vivo* conditions (20), thus offering an alternative option for disruption of biofilms during supportive periodontal care.

In conclusion, the present study indicates that the efficiency of calculus removal with the Vector™-system is significantly dependent on the selection of inserts and irrigation fluids. A similar degree of efficiency in subgingival calculus removal as for conventional ultrasonic systems can be obtained when the system is operated with a metal curette insert and abrasive fluid.

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