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Surface wear on cervical restorations and adjacent enamel and root cementum caused by simulated long-term maintenance therapy

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Abstract

Background: In an in vitro study, the surface wear on cervical restorations and adjacent enamel and root cementum caused by different tooth-cleaning methods in simulated long-term therapy was investigated.

Methods: Cervical restorations of amalgam (Oralloy®), modified composite resin (Dyract®), glass-ionomer cement (ChemFill Superior®), and composite (Tetric®) were instrumented by POL (polishing), CUR+POL (curette and polishing), US+POL (ultrasonic device with polishing) and the polishing agents Cleanic® and Proxyt® in a computer-controlled test bench. Treatment time corresponding to a real-time period of 5 or 10 years. Substance loss from instrumented surfaces was measured with a digital gauge. A three-way ANOVA was used in the statistical evaluation.

Results: The results showed that POL led to slight substance loss, which was greater using Cleanic® (27 μm) than Proxyt® (5 μm). CUR+POL produced a significantly greater substance loss than did US+POL, with 186 μm versus 35 μm on glass-ionomer cement, respectively, and 123 μm versus 18 μm, respectively, on root cementum, followed by composite (111 μm versus 27 μm, respectively), polyacid modified composite resin/compomer (89 μm versus 36 μm), amalgam (75 μm versus 19 μm), and enamel (32 μm versus 23 μm).

Conclusions: As opposed to the use of US+POL or POL, substance loss on cervical restorations and especially root cementum must be expected to result from tooth-cleaning during long-term maintenance treatment using CUR+POL.

Key words: cervical restorations; curettes; filling materials; maintenance therapy; surface wear; ultrasonic scaler

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Introduction

Regular professional tooth-cleaning occupies a central position in caries and periodontal prophylaxis (Axelsson & Lindhe 1981, Ramfjord 1989, Axelsson et al. 1991). Professional tooth-cleaning consists of removing plaque and calculus with hand- or machine-driven instruments, in addition to polishing the tooth and exposed root surfaces with polishing pastes and rotating or oscillating instruments. As a consequence of maintenance therapy over many years, substance loss and alterations in the surface roughness of tooth surfaces can result (Quirynen et al. 1990, Leknes et al. 1994, 1996, Quirynen & Bollen 1995); an increase in roughness can promote plaque formation and maturation (De Wet 1980, Quirynen & Bollen 1995).

The purpose of this study was to simulate the effect of 5 respectively 10 years of professional tooth-cleaning on different cervical restorations and adjacent enamel and root cement surfaces using bovine teeth and a computerized test bench and to measure substance loss. The conventional methods used were polishing alone (POL), curettes and polishing (CUR+POL), and an ultrasonic scaler with polishing (US+POL).

Two prophylaxis pastes (PPs) were used with each method: (1) Proxyt® is a system composed of three pastes with descending abrasiveness, and (2) Cleanic® (Hawe-Neos Dental, Bioggio, Switzerland), a Perlit-based paste, which is only strongly abrasive during the first phase of treatment (Lutz et al. 1991a, 1995).

Material and Methods

Test teeth

Seventy-two mandibular incisors from fresh bovine jaws were extracted in a manner, which prevented damage to the facial cervical aspect. The desmodontal tissue was carefully removed after 30 min of storage in 10% NaOH solution. The teeth were stored in 50% ethanol solution, and rehydrated for 24 h in isotonic saline solution prior to further use (Ritz et al. 1991). For each type of filling – amalgam, compomer, composite, and glass-ionomer cement – 3-mm-deep kidney-shaped undercut cavities 6 mm long and 3 mm wide were prepared in 18 teeth above the cementoenamel junction using diamond-coated tips (No. 6830.314.012, Komet, Brasseler, Lemgo, Deutschland) under water cooling, and finished with tungsten-carbide finishers (No. H47L. 314.012, Komet).

In the amalgam group, cavities were filled with amalgam (Oralloy-Magicaps®, Coltène AG, Altstätten, Switzerland), manually plugged, contoured, and burnished, then stored for 24 h in isotonic saline solution. Subsequently, fillings were shaped and polished under water-cooling using tungsten-carbide finishers and brown and green rubber polishers.

In the compomer group, cavities were conditioned twice with Dyract-PSA® (Dentsply De Trey, Konstanz, Germany). Dyract® (Dentsply De Trey) was applied in one coat and photocured for 40 s. Excess was removed with diamond-coated flame finishers (No. 8862.314.012, Komet), the filling finished with finishing disks (Super-Snap, Shofu Dental, Ratingen, Germany) of descending grain size down to ultrafine, and finally polished under water cooling with silicon polishers (No. 9663.204. 030, Komet).

In the cavities of the composite group, a ca. 1-mm-wide bevel at an approx. 15° angle was prepared in the enamel-bordered region using bud-shaped finishing diamonds (No. 8368.314.021, Komet). The bevelled enamel was etched with 37% phosphoric acid gel (Espe, Seefeld, Germany) for 45 s and conditioned with Syntac-Classic Primer (Vivadent, Liechtenstein). The adhesive bonding material was applied and photopolymerized for 10 s. The fine hybrid composite Tetric® (Vivadent, Schaan, Liechtenstein) was applied without a base in one layer and photocured for 60 s. Fillings were shaped and polished as is appropriate for compomers.

The glass-ionomer filling material (ChemFill Superior®, Dentsply De Trey) was applied according to the manufacturer's instructions. The capsules were activated, and then mixed for 10 s. The material was applied without a base into the cavity, and covered with a cervical matrix for 4 min until hardened. A coat of bonder (Prime & Bond 2.0, Dentsply De Trey) was applied to the filling, light cured for 20 s, and kept in isotonic saline solution for 24 h. Arkansas oilstone was used for fine shaping.

Test bench

To determine the influence of relevant factors on root surface instrumentation, a test bench was used with which the following parameters can be reproducibly set: application force, stroke angle, instrumentation frequency, instrument stroke, and incremental-advance speed. The test bench consists of a v-shaped air-cushioned track over which a slide hovers. In this, the test specimen to be instrumented is placed in a rotationally stable holder. In order to position the instrument properly, the holder containing the test specimen can be tilted via a ball-and-socket joint up to 45° in all directions. By tilting the track, the slide with the attached test specimen is pressed against the instrument; the application force is thus determined by the inclination and weight of the slide. The given application force is checked with a spring balance. The mounted instrument is moved with two computer-driven stepper motors over the test specimen in the *x*- and *y*-directions (horizontally and vertically) to the test specimen (Kocher et al. 2001b).

Cleaning Methods

Polishing

For each of the six different surfaces (cementum, enamel, amalgam, compomer, composite, glass-ionomer), three teeth were polished with the paste system Proxyt® (Vivadent, Schaan, Liechtenstein) and three with the PP Cleanic® (Hawe-Neos Dental) for 40 polishing cycles, which was intended to correspond to professional tooth-cleaning every 3 months for ca. 10 years. In the POL group, polishing cups (Polier-Kelch No. 12.2002.91, Produits Dentaires S.A., Vevey, Switzerland) were used with either Cleanic® or Proxyt®. A surface area of 8×4 mm was polished as six strips. Instrumentation time was ca. 7.5 s, and the speed with which the polishing cup moved over the tooth surface was ca. 6 mm/s. The angle of the machine was set so that the application pressure resulting on the tooth was 1.5 N. The micromotor of the angled handpiece (Kavo, Biberach, Deutschland) was set at a torque of 80% and 20,000 rpm, yielding 2500 revolutions/min. Thus, rpm and application pressure are oriented according to the values determined in vivo by Christensen & Bangarter (1984). In order to take the special properties of the Perlit polishing particles contained in the Cleanic® paste into account, the same surface was polished twice with the same amount of paste (total polishing time: 15 s). When using the Proxyt® system, polishing was done once with the medium paste (RDA 36) and once with the fine paste (RDA 7) (total polishing time: 15 s). When changing from one paste to the other, paste residue was removed from the tooth and polishing cup with a paper towel.

Curettes and Polishing

For each of the six different surfaces, three teeth were instrumented with curettes and then polished (CUR+POL). Because of the greater load to the fillings expected due to scaling, only 10 instrumentation cycles were conducted. This was intended to correspond to semiannual professional tooth-cleaning for 5 years. For scaling, Gracey curettes 5/6 (Nordent, Elk Grove Village, IL, USA) were used, which were power sharpened (Periostar, Hawe-Neos Dental, Bioggio, Switzerland) before first use and then after every five instrumentation cycles. A surface area of 12×5 mm was scaled as 10 strips, with an application force of 5 N and instrumentation speed of 15 mm/s; one instrumentation cycle lasted 15 s. The application force corresponded to in vivo values determined by Zappa et al. (1991a). Specimens were loaded only during the working stroke. After every instrumentation cycle with the curette, polishing was done with Cleanic® or Proxyt® (RDA 7) at a force of 1.5 N and duration of 15 s.

Ultrasonic Scaler and Polishing

For each of the six different surfaces, three teeth were instrumented with an ultrasonic scaler and subsequent polishing (US+POL) for 10 cycles, which was intended to simulate semiannual professional tooth-cleaning for 5 years. A Cavitron®-Jet ultrasonic scaler (model from 1998, Dentsply De Trey, Konstanz, Germany) with SlimLine® tips (Dentsply De Trey) was employed. Spray water flow was set at medium, and power at the end of the blue zone, which corresponds to the minimum necessary for subgingival plaque removal. An area of 10×5 mm was instrumented as 10 strips for 15 s with an application force of 0.3 N. In order to instrument cementum, filling, and enamel equally, the ultrasonic scaler was applied toward the tooth's axis, with the working end placed at a right angle to the tooth axis. Care was taken to instrument broadly, avoiding direct contact between the tooth surface and the instrument's tip. Both up and down movements were performed with loading. Instrumentation speed was ca. 6 mm/s, and the application pressure was chosen as described in Kocher & Plagmann (1997) and Kocher et al. (2001a). Following every ultrasonic scaling cycle, the specimens were polished for 15 s at an application pressure of 1.5 N with Cleanic® or Proxyt® (RDA 7).

Measuring substance loss

Substance loss was measured on a bench equipped with a precision slide (Cleveland Präzisions-Systeme, Löffingen, Germany) and a digital μm gauge (Digimatic Indicator, Mitutoyo, Tokyo, Japan), similar to that described by Ritz et al. (1991) and Zappa et al. (1991b). The probe of the gauge was placed in the coronal area of the tooth, outside the instrumented surface on the highest point of the convexity of the tooth cross-section, and calibrated to zero. With the probe moving along the highest ridge of the tooth cross-section, the tooth was measured from incisal to apical in a straight line. Within each instrumented area (enamel, filling, cementum), three points were measured 0.5 mm apart (a total of nine points measured per tooth). The exact coronal–apical position of these points could be read off of the adjustment screw of the slide. At the times named after instrumentation, the same points were remeasured. From the difference in heights of the tooth cross-section, substance loss was directly determined in μm. To check the reproducibility of the measurements, on each of 12 teeth the nine points were measured once, the specimen holder was removed from the bench, remounted, and the measurements repeated. Deviations of a maximum of 3 ± 0.7 μm were found.

Statistical analysis

The study design was chosen to allow evaluation by a three-way analysis of variance (three-way ANOVA). The three factors were ''surface'' (SF) on six levels (enamel, root cementum, composite, compomer, amalgam, glass-ionomer), ''treatment modality'' (TM) on three levels (POL, CUR+POL, US+POL), and PP on two levels (Cleanic®, Proxyt®). Three observations were present for each combination of the levels of factors, making a total of $6 \times 3 \times 2 \times 3 = 108$ observations. In the saturated model, we used type III estimations for the factors, that is, a factor is adjusted in terms of all other factors and interactions. A significant factor thus indicates differences between the levels of this factor, which go beyond the influence of possible interactions.

The ANOVA tests the hypothesis of whether the main factors TM, PP, and SF differed in terms of substance loss, and whether interactions between the main factors existed (significance level = 0.05). For the main factor TM, post hoc tests (Student–Newman–Keuls' test for equal variances, Tamhane's test for unequal variances) were conducted to compare the levels of a factor. The main factor SF was only compared with the reference level ''enamel''. Post hoc tests were not required for the main factor PP, because it, due to its two levels, agrees with the global test. The effect quantity η (eta) can assume values between 0 and 1; larger values mean a greater influence (Bortz 1993). Further, the observed power is given in order enable an estimation of whether the sample size is sufficient. All calculations were performed with SPSS (Version 11.0).

Results

Fig. 1 and Table 1 show the amount of substance loss after treatments POL, US+POL, and CUR+POL on the different tooth and restoration surfaces. Significant effects were found for the main factors TM and SF, and for interactions between TM and SF, and between TM and PP (Table 2). The significance level was corrected from $\alpha = 0.05$ to 0.01, because the requirement of equality of variances was not met. Correspondingly, the Tamhane test (as a test for unequal variances) was chosen for the post hoc tests in terms of instrumentation method.

The interaction of TM and PP was thus: for the levels POL and US+POL of the main factor TM, the level ''Cleanic®'' of the main factor PP

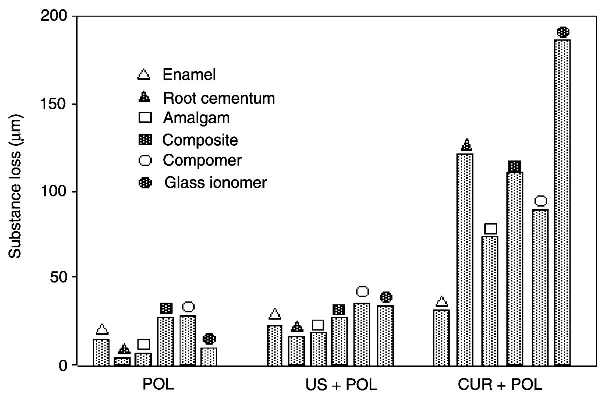

Fig. 1. Surface wear (μm) on tooth surfaces and filling materials following treatment by different cleaning procedures. POL (polishing), US+POL (ultrasonic device plus polishing) and CUR+POL (curettes plus polishing).

Table 1. Surface wear (μm, estimated mean ± SE) on tooth surfaces and filling materials following treatment with POL (polishing), US+POL (ultrasonic device plus polishing) and CUR+POL (curettes plus polishing)

Surface	Treatment modality	Mean ± SE	Confidence interval	
Enamel	POL	14.11 ± 12.09	− 9.99	38.21
	US+POL	23.44 ± 12.09	− 0.65	47.54
	CUR+POL	32.67 ± 12.09	7.57	55.77
	POL	5.06 ± 12 09	− 19.04	29.15
Root cementum	US+POL	17.67 ± 12.09	− 6.43	41.77
	CUR*POL	123.06 ± 12.09	98.96	147.15
	POL	7.17 ± 12.09	− 16.93	31.27
Amalgam	US 4 POL	18.89 ± 12. 09	− 5.21	42.99
	CUR+POL	75.33 ± 12.09	51.24	99.43
	POL	28.0 ± 12.09	3.90	52.10
Composite	US+POL	27.33 ± 12.09	3.24	51.43
	CUR+POL	111.22 ± 12.09	87.12	135.32
	POL	29.06 ± 12.09	0.49	53.15
Compomer	US+POL	36.39 ± 12.09	12.29	60.49
	CUR+POL	89.06 ± 12.09	64.96	113.15
	POL	10.33 ± 12.09	− 13.77	34.43
Glass ionomer	US+POL	34.61 ± 12.09	10.51	58.71
	CUR+POL	186.44 ± 12.09	162.35	210.54

Table 2. Tests of main factors PP (prophylaxis paste), SF (surface), and TM (treatment modality), and intersubject effects

	Significance	Eta-quadrat	Observed power
PP	0.056559	0.050	0.481
SF	0.000018	0.332	0.998
TM	0.000000	0.720	1.000
SF × PP	0.064819	0.132	0.685
TM × PP	0.000007	0.281	0.998
TM × SF	0.000001	0.464	1.000
PP × SF × TM	0.216345	0.159	0.642
Corr. model	0.000000	0.825	1.000
Const. term	0.000000	0.799	1.000

The observed power was calculated with $\alpha = 0$ 05, $R^2 = 0.825$, adjusted $R^2 = 0.74$.

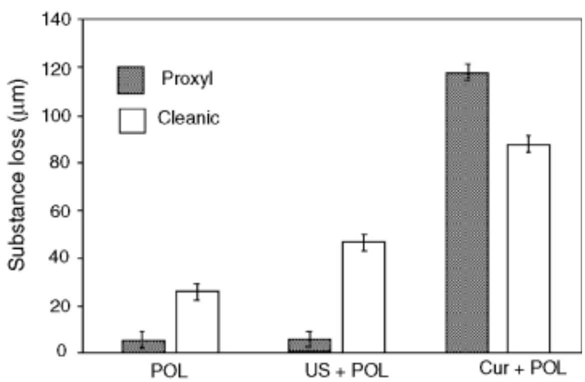

Fig. 2. Surface wear (estimated mean ± SE) using Cleanic® und Proxyt®. POL (polishing), US+POL (ultrasonic device plus polishing) CUR+POL (curettes plus polishing).

demonstrated greater substance loss than the level ''Proxyt®'', while the opposite was true for CUR+POL (Fig. 2). A further interaction between TM and SF is recognizable, since the differences between surfaces in POL and US+POL were only slight and in contrast, those in CUR+POL were obvious (Fig. 1). Restricting the analysis to the level CUR+POL, three homogeneous subgroups can be identified: Group 1 with enamel, amalgam, and compomer; Group 2 with amalgam, compomer, composite, and cementum; Group 3 only with glass-ionomer (Student–Newman–Keuls' test in a two-way ANOVA with SF and TM equality of variances given).

The effect of main factors TM and SF is depicted in Fig. 3. The difference between CUR+POL on the one hand and US+POL and POL on the other was significant in the Tamhane post hoc text ($p = 0.000$ for each). The difference between POL and US+POL was not significant ($p = 0.206$). Enamel substance loss was significantly lower than that of composite ($p = 0.002$), compomer (0.005), and glass-ionomer ($p = 0.000$). The effect of TM ($\eta = 0.720$) was much more pronounced than that of SF ($\eta = 0.332$), TM × SF ($\eta = 0.464$), or TM × PP ($\eta = 0.281$) (Table 2). The observed power is considered high, since the differences between the levels of main factor PP were not relevant and because PP participates in a significant interaction (TM × PP). The adjusted coefficient of determination ($R^2 =$ 0.74) was also quite high, that is, this model explains the observed substance loss well.

Discussion

In the present study, the substance loss from different cervical restorations (amalgam, compomer, glass-ionomer cement, composite) and from the adjacent natural tooth surfaces (enamel, root cementum) was measured after different tooth-cleaning methods had been performed (POL, US+POL, CUR+POL) with two different polishing pastes (Cleanic®, Proxyt®).

Up to now, the available studies have been conducted under very different conditions (Plagmann et al. 1989, Bjornson et al. 1990, Ritz et al. 1991, Zappa et al. 1991b, Bose & Ott 1996). This concerns instrumentation parameters (time, application pressure, equipment settings, instrumentation angle), the surfaces examined (material, initial condition polished or uninstrumented; in vivo/vitro), and various evaluation methods (qualitative/quantitative, diverse measuring procedures). Enamel and/or dentin specimens obtained from bovine teeth have been instrumented (Roulet & Roulet-Mehrens 1982, Lutz et al. 1991a, 1995), as have specimens of restorative

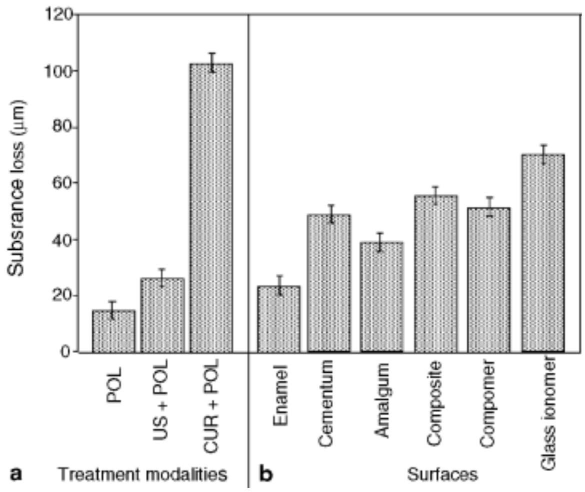

Fig. 3. Surface wear (means ± SE) related to treatment modalities (A) and different surfaces (B). POL (polishing), US+POL (ultrasonic device plus polishing) and CUR+POL (curettes plus polishing).

materials (De Wet 1980; Roulet & Roulet-Mehrens 1982, Bjornson et al. 1990, Bose & Ott 1996).

In order to approximate the clinical situation as closely as possible, this study employed natural surfaces of bovine teeth into which cervical restorations were placed under clinically realistic conditions. In order to standardize instrumentation, a computerized instrumentation bench developed by Kocher et al. (2001b) was employed, with which – via simple gravity – the application pressure can be reproducibly set and instrumental working movements performed in a manner approximating the clinical situation. Because application pressure is a function of force and area, this improved method of standardizing instrumentation allows only slight fluctuations of the actual application pressure, when the area itself increases somewhat – depending on the different convexities of the tooth surface – due to substance loss. The substance loss measurements were taken on a test bench with a digital gauge, similar to that described by Ritz et al. (1991) and Zappa et al. (1991b). The measurement error of 0.7 μm corresponded to the measurement error of ± 1.5 μm found by Ritz et al. (1991) with similar measurement equipment and to the 0.46-μm error determined by Zappa et al. (1991b) with their nearly identical measurement design.

As expected, polishing alone (POL) caused the least substance loss; polishing with Cleanic® produced more loss of substance than did Proxyt® (Fig. 2). For POL and US+POL, the substance loss values from enamel, root cementum, and amalgam were very similar and lower than from compomer and composite in the POL and US+POL groups, and in US+POL also lower than from glass-ionomer cement (Fig. 1, Table 1).

Independent of instrumentation method, the highest substance loss was measured from glass-ionomer (Fig. 3). This is in concordance with the physical properties of this material (Gladys et al. 1997), although this could also be due to the special properties of the Cleanic® paste. The sharp-edged Perlite particles contained in Cleanic® arrange themselves during polishing parallel to the tooth surface and round off their edges, which makes the initially quite abrasive Cleanic® a rather gentle polishing paste (Lutz et al. 1991a, b, 1995). Thus, one could assume that the speed with which the polishing particles wear down is dependent upon the instrumented surface itself. This process seems to occur considerably more slowly on glass-ionomer than on the other surfaces, so that the abrasiveness of Cleanic® remains high over a longer period of time.

The substance loss values with POL alone did not differ significantly from those obtained with US+POL, while they were significantly greater with CUR+POL (Fig. 1, Table 1). It must be mentioned here that the instrumentation duration of POL corresponded to 10 years, and only to 5 years for US+POL and CUR+POL. Because of the low loss expected from POL, the number of instrumentation cycles was doubled in order to obtain measurable results. However, because it was expected that such a large number of instrumentation cycles with CUR+POL and US+POL would excessively load the restorations, only 5 years' worth was performed.

High substance loss with CUR+POL resulted, which would be clinically relevant in terms of root cementum: complete loss of the root cementum would result in exposure and abrasion of dentin, which in turn can lead to cervical hypersensitivity, pulpal irritation, and a threat to the vitality of the tooth (Haugen & Johansen (1998), Tammaro et al. 2000). In the present study, instrumentation with CUR+POL corresponding to 5 years produced a substance loss on root cementum of 123 μm, compared with 18 μm with US+POL (Table 1); this would mean that given an average cervical cementum thickness of 100 μm, as described by Schroeder (1992) for 31–40-year-old patients, the root cementum would be lost entirely.

Substance loss from filling materials could lead to a detrimental increase in roughening depth, damage of the filling margins, structural weakening, or even loss of the filling, which would be – aside from secondary damage due to restoration replacement and cost considerations – reparable damage, in contrast to the consequences of the loss of dental hard substance. Not only tooth-cleaning procedures but also surface wear due to erosion or abrasion via tooth-brushing can lead to substance loss. Folwaczny et al. (2000) examined the in vivo wear of different cervical class V fillings after 36 months using an optical three-dimensional laser scanning device, and found wear on Tetric® of 18 ± 12 μm and on Dyract® of 71 ± 47 μm.

Although sharp metal curettes are today still the standard instruments for scaling and root planing during periodontal therapy and maintenance treatment, and can be employed with great efficacy, it should nonetheless not be forgotten that substance loss after several years of treatment – particularly when the application force level is not monitored – can cause substantially greater substance loss than measured here under ideal conditions. Zappa et al. (1991a, b) examined the amount of root substance removed by scaling and root planing with curettes at low (3.04 N) and high forces (8.48 N). Mean cumulative loss of root substance over 40 strokes was 148.7 μm at low forces and

343.3 μm at high forces. Not only because studies have shown that endotoxins are located on the periodontally diseased root surfaces rather than within it (Nakib et al. 1982, Eide et al. 1984, Hughes & Smales 1986, Corbet et al. 1993) and bearing in mind suggestions that the root surface can be treated less aggressively during periodontal therapy (Nyman 1988), but also based on findings that wear of root substance due to maintenance therapy can be clinically relevant, there is a need for less aggressive TMs for both periodontal and long-term maintenance therapy.

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