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Prof. Adrian Lussi
Klinik für Zahnerhaltung,
Präventiv- und Kinder-
zahnmedizin
Freiburgstr. 7, 3010 Bern

In vitro evaluation of three curettes with edge retention technology after extended use

Massimo Sisera
Deborah J. Hofer
Beatrice Sener
Thomas Attin
Patrick R. Schmidlin

Department of Preventive Dentistry, Cariology, and Periodontology, University of Zurich, Center for Dental Medicine, Zurich, Switzerland

Corresponding author
PD Dr. Patrick Schmidlin
Clinic for Preventive Dentistry, Cariology, and Periodontology
Center for Dental and Oral Medicine and Maxillofacial Surgery
University of Zurich
Plattenstrasse 11
8032 Zurich
Switzerland
Tel. +41 44 634 32 84
Fax +41 44 634 43 08
E-mail: patrick.schmidlin@zzmk.uzh.ch

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Summary This study assessed the edge cutting efficiency of three new curettes with different edge retention technologies after simulated wear in vitro. Three test curettes (two with a titanium nitride coating and one without coating, but made of a cryogenically treated stainless steel alloy) were used to root plane prepared bovine dentin specimens. Nine curettes of each type were used to instrument one dentin sample each. Dentin removal was determined after the first ten strokes and again cumulatively for the strokes 500–510 and 1,000–1,010 by means of atomic absorption spectrophotometry (AAS). The effects of chemical and thermal stress were analysed after repeated disinfection and sterilization of the instruments then followed by a final 10-stroke sequence of dentin removal to determine cutting efficacy. A standard, untreated stainless steel curette was used as a control. Test and control instruments showed no statistical evidence of diminished dentin removal over 1010 strokes. Dentin surface roughness also displayed insignificant differences for all instruments. However, sterilization negatively affected the test and control instruments to an equal degree. Sterilization procedures appear to be an important factor in the dulling of curettes, which affected dentin removal efficacy but not surface roughness.

Introduction

Meticulous removal of hard and soft deposits from root surfaces represents the basis of periodontal therapy (Badersten et al. 1981, 1984; Hill et al. 1981; Lindhe et al. 1982; Cercek et al. 1983; Pihlström et al. 1983; Lindhe & Nyman 1985). A whole body of literature has been devoted to determining the best possible means of reaching this goal (Jones et al. 1972; Torfason et al. 1979; Thornton & Garnich 1982; Oosterwaal et al. 1987; Dragoo 1992; Drisko 1993, 1998). Literature reviews have shown that neither hand nor mechanical debridement is superior in removing subgingival deposits (Oosterwaal et al. 1987; Drisko et al. 2000; Oda et al. 2004; Suvan 2005). With regard to root roughness, previous in vivo studies have shown that ultrasonic instruments remove less root structure than hand instruments (Suppipat 1974; Torfason et al. 1979), but leave behind a rougher or more damaged surface (Benfenati et al. 1987). Ruppert et al. (2002) noted that hand instrumentation after ultrasonic use has been recommended as a final finishing procedure in the treatment of periodontally diseased roots.

Many studies have looked at the root surface morphology after root planing with curettes (Schaffer 1956, Green & Ramfjord 1966, Van Volkinburg et al. 1976, Ewen & Gwinnett 1977, Swan 1979, Coldiron et al. 1990, Zappa et al. 1991). A few have compared the resulting morphology with the cutting edge of the instrument used (Biller & Karlsson 1979, Benfenati et al. 1987, Rossi & Smulker 1995). Some mention is made in the literature of the number of strokes used before a dulling of the cutting edge was noticed and re-sharpening became necessary. O'Leary & Kafrawy (1983) sharpened their curettes after every five working strokes, Coldiron et al. (1990) every ten strokes, Rees et al. (1999) every twelve strokes, while Zappa et al. (1991) found the cementum and peripheral dentin removal to be effective at least during the first 20 working strokes. In this latter study, strokes 21–40 resulted in diminished hard tissue removal and a concomitant increase in pressure applied per stroke was noted.

Through all of these studies, it is evident that instrument sharpness is a deciding factor in the clinical application of curettes for therapeutic procedures. However, as Zappa et al. (1991) noted, very few clinical therapists appear to sharpen their curettes every 5–20 strokes. Further, repeated sharpening is known to destroy the original contour of an instrument, as well as create metal tags, which may also be harmful to soft and hard dental tissues.

Industry and clinicians alike have been seeking instruments that allow maximal effectiveness in calculus and biofilm removal, leaving a smooth surface without causing trauma to patient's tissues or operator fatigue over long periods of time. Different metal alloys used for manufacturing curettes, including stainless steel, high speed steel, carbon steel and tungsten carbide, have been shown to influence the efficacy and life expectancy of the instrument (Tal et al. 1989). Several instruments claiming to possess "edge retention" properties have recently been introduced to the market. The manufacturers claim that these instruments need no or less sharpening, allow unproblematic maintenance and display long time effectiveness.

This study was undertaken to assess the edge retention of test curettes with edge retention technologies in comparison to a control curette made of a standard stainless steel alloy. By simulating clinical conditions in the laboratory, the actual concurrent removal of dental hard tissue, at predetermined intervals (number of strokes), was evaluated to monitor the effectiveness and aggressivity of the instruments. Concomitantly, the surface roughness was assessed. The influence of the sterilization processes, which may potentially harm the curette material by changing the structural components, was also assessed. The null hypotheses tested were that i) there is no difference in substance removal and surface roughness over time and that ii) chemical and thermal influences of repeated sterilization processes do not hamper curette effectiveness.

Materials and methods

Instruments tested

Three curettes with edge retention technology from three different manufacturers were tested in this study (Fig. 1 and Tab. I). Two of the test curettes had a titanium nitride coating (Fig. 2) and one was made of a stainless steel treated cryogenically. The control curette was made of standard untreated stainless steel.

Specimen preparation

One hundred forty-four bovine central incisors were prepared as follows: the roots were separated from the crowns and ground in half by a rotating sandpaper (180 grit silicon carbide sandpaper, Struers GmbH, Birmensdorf, Switzerland) device at 150 rev./min. (Planopol-2®, Struers,). These root fragments were glued on their ground side to roughened SEM mounts (Baltec AG, Blazers, Liechtenstein) with superglue (Renford Sekundenkleber Nr. 1733, Dentex AG, Zurich, Switzerland) and embedded with a chemically curing acrylic resin (Paladur®, Heraeus Kulzer GmbH, Wehrheim, Germany). These specimens were finished on the rotating device (Planopol-2, Struers) using sandpaper with consecutive grit sizes of 1000 grit (Struers). This polishing procedure ensured a comparable surface roughness

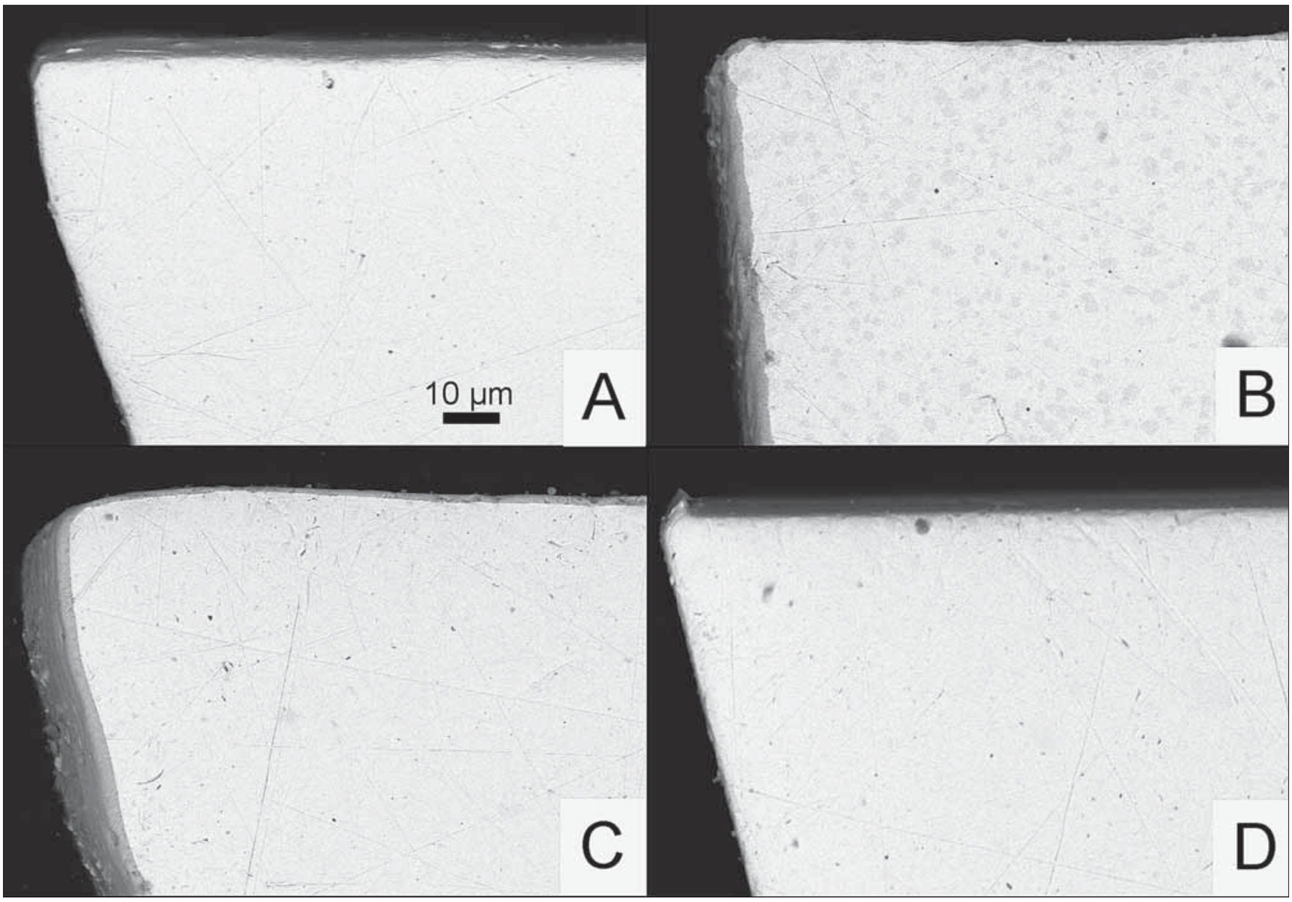

Fig. 1 Transsection SEM images of the working edge of the tested curettes at a magnification of 3,000× (A: Dep-N, B: Dep-S, C: AmE, D: HuF).

Tab. I Instruments tested in the present investigation.

Code	Type		Manufacturer
Dep-N	7GE8 Control		A Deppeler S.A. Rolle, Switzerland
Dep-S	7GE8 TitanS (titanium nitride coating)		A Deppeler S.A. Rolle, Switzerland
AmE	AE G 7–8 XPX XP (titanium nitride coating)		American Eagle Instruments, Inc. Missoula, MT, USA
HuF	SG7/897 EverEdge (cryogenically treated)		Hu-Friedy Mfg. Co. Inc. Chicago, IL, USA

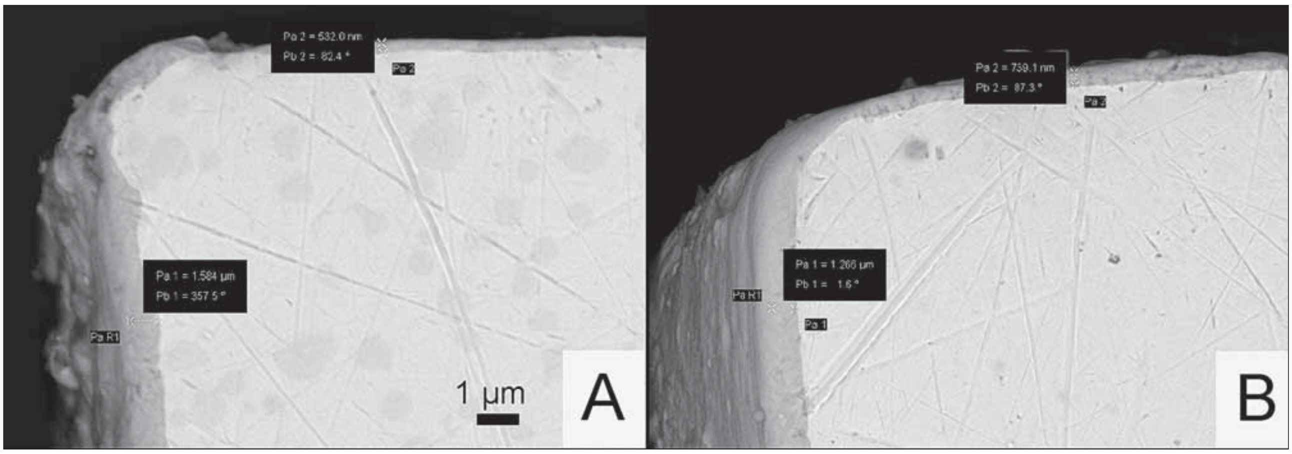

Fig. 2 Detail SEM images of the coated curettes (A: Dep-S, B: AmE) at a magnification of 10,000×. The thickness of the coating varied between 0.4 and 1.7 µm for the Dep-S and 0.6 and 1.4 µm for the AmE.

and served as baseline before instrumentation. All roots were stored in distilled water.

Treatment, determination of substance loss and wear simulation

An overview of the experimental conditions is presented in Figure 3. Thirty-six samples were randomly assigned for root planing in one of four test groups (n=9 per instrument type). Ten strokes were performed using a load of 250 g with each instrument. The working strokes ran from apical to coronal, parallel to the axis of the tooth. Standardized application force for each treatment stroke was achieved by mounting the sample holders in a specially adapted pressure sensitive electronic device (TM 503 Power Module, Tektronix®, Inc., Beaverton, Oregon, USA). It was up to the operator to ensure that the applied force was exerted within the defined range (± 50 g). With the hand curette a force of 500 g was applied (range 450 to 550 g). After the ten strokes, the loss of substance was detected using atomic absorption spectrophotometry (AAS). The dentin particles were collected by carefully rinsing specimens and curettes with 10 ml of distilled water each. Collected sample solution was diluted with 10 ml of hydrochloric acid (2M). The specimen solutions were placed in an ultrasonic bath for five minutes to dissolve the insoluble dentin particles and to avoid precipitation. Aqua destillata was added to an end volume of 50 ml; 2 ml of the solution was extracted and 4.6 ml distilled water, as well as 3.4 ml $SrCl_3$ complimented the solution for AAS analysis (PERKIN ELMER 2380, Dietikon, Switzerland). The calcium was determined from standard solutions in ppm.

After this first test sequence, the curettes were subjected to wear by root planing the dentin specimens for 490 strokes. Pressure was read again on the pressure sensitive electronic device, and a correct angulation of the working tip was ensured. After this wear phase, a second test sequence of ten strokes was

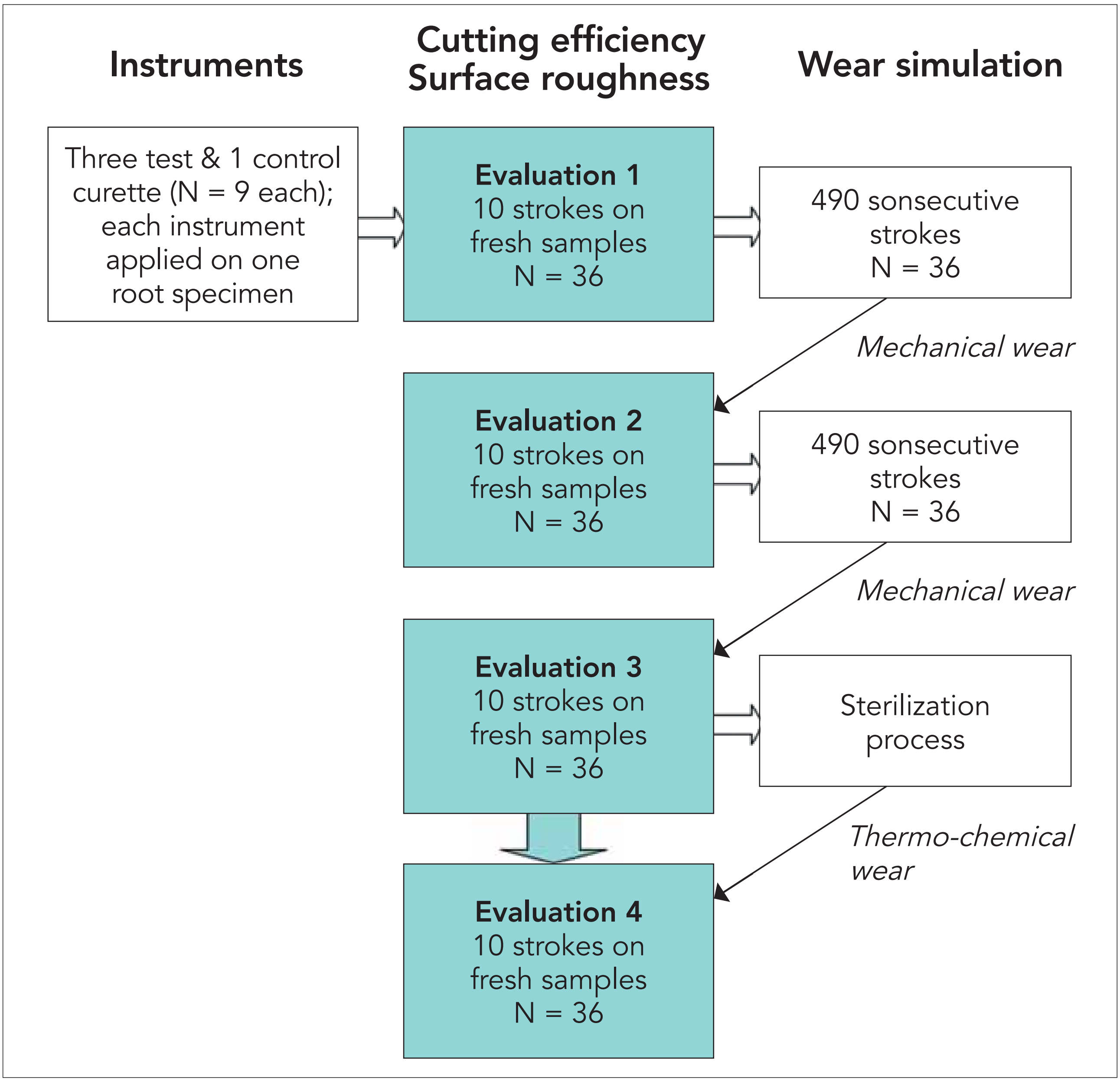

Fig. 3 Flow-chart of the experimental set-up. Nine instruments per test group were evaluated for dentin removal, without sharpening, at defined points. At the initial and before three following 10-stroke dentin collection points, fresh dentin samples were used to insure standardized surface characteristics at the test phase.

performed with each curette applying the same pressure on new standardized flat dentin samples as described above. A final wear sequence was performed for strokes 510–1,000. Again new standardized flat dentin specimens were employed for the next test sequence of ten stokes, ending this part of the experiment at the 1,010-stroke mark. No sharpening of the curettes had been performed at any time. Dentin was collected and the loss of tooth substance was evaluated using AAS.

To simulate the influence of chemical and thermal stress induced during sterilization processes, curettes were subjected to sterilization: for each cycle, curettes were immersed in an instrumentation disinfection solution (ID 212 forte, Dürr Dental, Bietigheim-Bissingen, Germany) for 30 minutes, then carefully rinsed with water, dried, subjected to a thermo-disinfecting device at a standard program (Miele G 7735 CD, Spreitenbach, Switzerland) for one hour and finally subjected to sterilization (unisteri, MMM Sterilisatoren AG, Rudolfstetten, Switzerland) comprised of a pre-vacuum period of 8 minutes, an actual sterilization period of 18 minutes at 134 °C and a drying period of ten minutes. This process was repeated five times without instrumentation between the sterilization cycles. After this sterilization procedure and a total mechanical wear interval of 1,000 strokes, curettes were re-subjected to another ten strokes under the same standardized conditions (on uninstru-

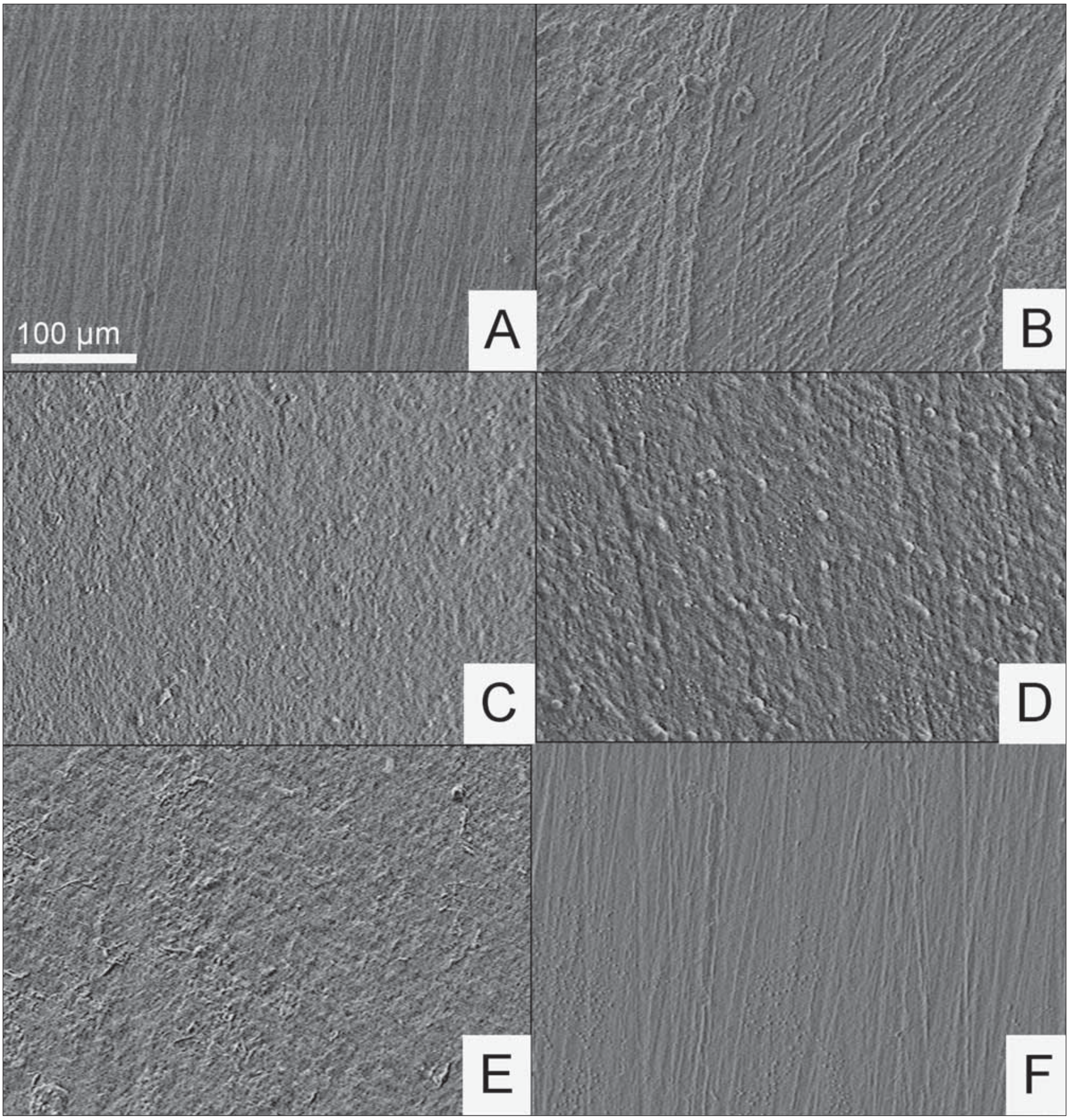

Fig. 4 Panel A represents a polished dentin surface before curette treatment. Panels B–E show representative SEM images of dentin surfaces after ten strokes on polished dentin samples, after total wear of 1,010 strokes (B: Dep-N, C: Dep-S, D; AmE, F: HuF). Panel F shows a representative dentin surface treated with the AmE instrument after the sterilization process. Note the resemblance to the polished dentin surface at baseline.

mented dentin specimens) and loss of substance was again measured.

Profilometric and SEM analyses

Before the first mechanical treatment, and after each ten strokes at respective treatment intervals, the root specimens were washed and dried. Impressions were taken using an addition-type polyvinylsiloxane of low viscosity (President light body, Coltène AG, Switzerland) and replicas (Stycast®, Belgium) of the surfaces were cast. The average surface roughness (Ra) was quantified with a computerised profilometer (Form Talysurf 50, Rank Taylor Hobson, Leicester, England). The average readings of ten measurements per specimen were compared.

In addition, the replicas were glued to SEM mounts (Balzers Union AG, Fürstentum Liechtenstein) with superglue (Renfert Sekundenkleber Nr. 1733, Dentex AG, Zurich, Switzerland). The mounted replicas were gold sputtered and analysed under the SEM (AMRAY1810, AMRAY Inc., Bedford MA, USA) to assess the surface morphology of the dentin before and resulting after instrumentation at magnifications of 250× (Fig. 4).

Statistical analysis

For both test parameters, calcium loss and surface roughness, the results were statistically analyzed using ANOVA. Individual post hoc comparisons were performed using Scheffé-test and paired t-test. Significance was set at 95% ($p \leq 0.05$).

Results

Substance loss

There was no statistically significant difference between the instruments at all evaluation time points (Tab. II). When looking at the mean values, there was, however, a trend for Dep-S to remove less dentin than the other instruments at all intervals (Dep-S: 0.33 ± 0.11 to 0.37 ± 0.18 µg calcium versus 0.47 ± 0.13 to 0.61 ± 0.33 µg calcium).

After 1,010 strokes and five sterilization cycles, the dentin removal significantly decreased for all curettes ($p \leq 0.05$) with mean values ranging from 0.11 ± 0.03 µg calcium to 0.13 ± 0.03 µg calcium. There was no difference between test and control instruments.

Surface roughness and micromorphology

Data concerning the measurements of mean surface roughness (Ra) changes are presented in Table III. After the initial ten strokes (baseline), the lowest surface roughness change was recorded for Dep-S (0.09 ± 0.08 µm), which was comparable to Dep-N and HuF. AmE showed a statistically significant higher increase in mean surface roughness as compared to the latter instruments (0.34 ± 0.11 µm, $p \leq 0.05$).

At the second test interval, AmE presented with the lowest mean surface roughness (0.12 ± 0.05 µm), which was comparable to Dep-N, Dep-S, and HuF. The mean surface roughness remained more or less constant through the end point of 1,010 strokes, as well as after the sterilization procedures.

Discussion

The three test instruments examined in this study all claim to retain a sharp cutting edge over multiple usage without re-sharpening. Two of the instruments are made of a stainless steel alloy with a titanium nitride coating. The third test instrument, without coating, is made of a specially tempered, then cryogenically treated stainless steel alloy. The control instrument is made of an untreated stainless steel alloy. The results appear to confirm all the manufacturers' claims, in that there was no significant loss of efficacy over 1,010 strokes for any of the test instruments, and no apparent need to re-sharpen even at that end point. Interestingly, this was also true for the control curette. Hence, it can be said that the first part of our initial hypothesis, that there is no difference in substance removal over the time tested, was confirmed.

The second part of our initial hypothesis, that chemical and thermal influences of repeated sterilization do not hamper curette effectiveness, was refuted. All the curettes, both test and control, lost efficacy after sterilization. Since the instru-

Tab. II Measurement of calcium loss in µg (mean values and standard deviation). Different superscript capitals within one evaluation time point represent statistically different calcium loss between the different curettes ($p < 0.05$, $n = 9$; read vertically). Different superscript lower case letters within one curette represent statistical differences between different evaluation time points ($p < 0.05$, $n = 9$; read horizontally).

	Baseline	500 strokes	1,000 strokes	After sterilization
Dep-N	^{A}0.49 ± 0.25^{a}	^{A}0.59 ± 0.23^{a}	^{A}0.47 ± 0.13^{a}	^{A}0.13 ± 0.03^{b}
Dep-S	^{A}0.37 ± 0.18^{a}	^{A}0.33 ± 0.11^{a}	^{A}0.35 ± 0.12^{a}	^{A}0.11 ± 0.02^{b}
AmE	^{A}0.55 ± 0.21^{a}	^{A}0.57 ± 0.26^{a}	^{A}0.55 ± 0.23^{a}	^{A}0.13 ± 0.03^{b}
HuF	^{A}0.56 ± 0.26^{a}	^{A}0.58 ± 0.21^{a}	^{A}0.61 ± 0.33^{a}	^{A}0.11 ± 0.03^{b}

Tab. III Measurement of mean surface roughness (Ra) changes in µm (Ra [standard polishing] – Ra [after strokes at respective evaluation times]) expressed as mean values and standard deviations. Different superscript capitals within one evaluation time point represent statistically different roughness values between the different curettes ($p < 0.05$, $n = 9$; read vertically). Different superscript lower case letters within one curette represent statistical differences between different evaluation time points ($p < 0.05$, $n = 9$; read horizontally).

	Baseline	500 strokes	1,000 strokes	After sterilization
Dep-N	^{AB}0.21 ± 0.09^{a}	^{A}0.21 ± 0.20^{a}	^{A}0.18 ± 0.17^{a}	^{AB}0.15 ± 0.07^{a}
Dep-S	^{A}0.09 ± 0.08^{a}	^{A}0.17 ± 0.26^{a}	^{A}0.12 ± 0.11^{a}	^{AB}0.11 ± 0.05^{a}
AmE	^{B}0.34 ± 0.11^{a}	^{A}0.12 ± 0.05^{b}	^{A}0.07 ± 0.05^{b}	^{A}0.09 ± 0.04^{b}
HuF	^{A}0.16 ± 0.16^{b}	^{A}0.16 ± 0.19^{a}	^{A}0.18 ± 0.16^{a}	^{B}0.18 ± 0.08^{a}

ments were not retested between the chemical and thermal stages of the sterilization process, it is difficult within the confines of this study to pinpoint the exact cause of this loss of substance removal capacity.

A review of the literature showed a limited number of studies that have previously examined the issue of cutting edge retention (Tal et al. 1985, Tal et al. 1989, Bonini 2005). The studies compared stainless steel with carbon steel, to see how the alloy mix affects the hardness of the cutting edge. In the study done by Tal and co-workers (1985, 1989), the stainless steel curettes showed significant edge attrition after 45 strokes as compared to the high speed steel, cemented carbide steel and high carbon steel instruments tested. Conversely, Bonini (2005) showed significantly less wear on the stainless steel used in his study as compared to the carbon steel instruments in the test group. In all of these studies, bevel width or notching on the cutting edge was evaluated, not the amount of cementum or dentin removed.

Also in contrast to our results was the finding reported by Gorokhovsky et al. (2005) that sterilization had no negative effects on either the coated or stainless steel curettes. In their study, both new titanium-coated curettes and control stainless steel curettes where subjected to 215 cycles of ultrasonic cleaning in a general purpose aqueous cleaner (IMS Daily Clean) followed by steam sterilization at 260 °C for 30 minutes. The instruments were then evaluated for tarnishing and/or pitting corrosion. Neither was found, however, the actual efficacy of the new instruments used in this section of their study does not appear to have been tested.

Dentin removal and surface roughness have been examined in earlier instrumentation studies (Jones et al. 1972, Pameijer et al. 1972, Wilkinson & Maybury 1973, Van Volkinburg et al. 1976, Ewen & Gwinnett 1977, Meyer & Lie 1977, Mengel et al. 1994). Benfenati et al. (1987), through the analysis of SEM images, observed that patterns left on the root surfaces after instrumentation reflected the microscopic irregularities of the curette used, like a negative impression of its cutting edge. They further observed that a dull curette created a very smooth root surface. Despite the fact that some deposits were still present after the use of a dull curette, a smear effect seems to have provided the smooth surface observed. Only a damaged curette created severe, wavy scratches on top of a surface smear with residual calculus.

In more recent studies, where not only a visual assessment of surface roughness was determined, curettes have proven to create a relatively smooth surface morphology, as determined by profilometric findings (Schmidlin et al. 2001, Vastardis et al. 2005). The results of the current study show a strong similarity to the results of these previous studies. All the curettes tested provided a mean surface roughness (Ra) of between 0.09 ± 0.08 µm and 0.34 ± 0.11 µm. This initial variability was only observed after the first ten strokes. The variability did not become statistically significant after this point, with all mean surface roughness values in a range of 0.12 ± 0.05 to 0.21 ± 0.20 at 510 strokes and 0.07 ± 0.05 to 0.18 ± 0.17 at 1,010 strokes. These results confirm our hypothesis that there is no difference among the instruments tested in resultant surface roughness over time. Even after sterilization, when all instruments removed significantly less dentin in the final ten strokes tested, the resulting mean surface roughness remained essentially unchanged.

While the results of this study show no significant differences in the efficacy or edge retention characteristics of the various curettes tested, it should be noted that we confined our test model to 1,010 strokes on bovine dentin. The work done by Gorokhovsky et al. (2005), which showed superior capabilities of a titanium nitride coating, used the instruments up to 15,000 strokes before the coating was removed and the underlying stainless steel alloy exposed. Further, their test was performed on bovine enamel with a scaler, so that only wear as it relates to bevel edge was evaluated. Neither the removal of dentin/cementum nor resultant surface roughness was assessed. In the work done by Bonini (2005), only bevel edge evaluation was undertaken.

The real surprise in the current study was the finding that the control instrument was not significantly less effective than the newer instruments with so-called edge retention technology on dentin removal over 1,010 strokes without sharpening. For decades it has been accepted knowledge that periodontal instruments must be re-sharpened frequently (Wilkins 1971, O'Leary & Kafrawy 1983, every five strokes; Tal et al. 1985, 15 strokes; Coldiron et al. 1990, every ten strokes; Zappa et al. 1991, every 40 strokes) to be effective. However, at least in the studies quoted here, sharpness (and its inferred efficacy) was determined by visual inspection of the cutting line angle and determination of the bevel width/deformities. Again, no attempt was undertaken to systematically quantify the amount of cementum or dentin removed using instruments that were not resharpened over hundreds or thousands of strokes. Only Coldiron et al. (1990) reported that while their protocol required resharpening after every ten strokes, they observed that their curettes were cutting smoothly and sounding sharp after 35 strokes. That leaves the question for how many strokes they might have continued to observe this phenomenon unanswered. Moreover, it suggests that depending upon the qualities of the alloy used in instrument production, the sharpness (or root planing capacity) may be retained for many more strokes than previously thought. Finally, it must be reminded that only dentin removal was undertaken with the instruments in this and the above-mentioned studies. Instruments that first are used for calculus removal before root planing, as is often the case clinically, may not well deliver the same results.

Conclusions

All three test instruments held their cutting capacity over an extended number of strokes under conditions of the present study. Instruments formerly thought to be ineffective after a limited number of strokes may retain their cutting efficacy much longer than visual analysis of the cutting angle would imply (as exemplified by the control curette). However, the sterilization process appears to have a negative impact on cutting edge retention of all the instruments studied. Since the sterilization process applied here had three parts (chemical and thermal disinfection followed by sterilization), further study is needed to determine if any one part is responsible for the loss of cutting efficacy and could be somehow adjusted to promote the instruments' innate cutting longevity.

Acknowledgements

The curettes used in this study were provided by: A Deppeler S.A., Rolle, Switzerland; American Eagle Instruments, Inc., Missoula, MT, USA; and Hu-Friedy Mfg. Co. Inc., Chicago, IL, USA.

Zusammenfassung

Diese Studie untersuchte die Abtragseffizienz dreier neuer Küretten mit sogenannter Schneidekanten-Erhaltungs-Technologie. Drei Testküretten wurden untersucht. Zwei verfügten über eine Titannitridbeschichtung, die andere war nicht beschichtet, wurde allerdings aus kryogen vergütetem Stahl gefertigt. Neun Küretten jeden Typs wurden dann auf jeweils einer planen Rinderdentinprobe angewendet, und das dabei entfernte Dentin wurde nach den ersten zehn Arbeitszügen (Root Planing) sowie nach 500–510 und 1000–1010 Zügen mit Atomabsorptionsspektrophotometrie (AAS) untersucht. Zusätzlich wurden die Instrumente noch einem wiederholten Desinfektions- und Sterilisationszyklus unterzogen und Schneideeffizienz, resp. der Dentinabtrag erneut nach weiteren zehn Arbeitszügen ermittelt. Eine Standarduniversalkürette wurde als Kontrolle gleichermassen verwendet. Sowohl Test- als auch Kontrollküretten zeigten nach 1010 Arbeitsbewegungen keine reduzierten und statistisch signifikant unterschiedlichen Abtragungswerte. Ebenso zeigte die Oberflächenrauigkeit keine signifikanten Unterschiede zwischen den Instrumenten. Allerdings beeinflussten die Desinfektions- und Sterilisationszyklen alle Instrumente gleichermassen negativ. Die Sterilisation scheint ein wichtiger Faktor für die Abstumpfung der Küretten zu sein, welche zwar die Dentinabtragseffizienz nachteilig beeinflusste, nicht aber die Oberflächenrauigkeit.

Résumé

Cette étude a examiné l'efficience de trois nouvelles curettes avec une soi-disant technologie de maintien de lisière de coupe. Trois curettes de test ont été examinées. Deux ont disposé d'un revêtement de nitrure de titane; l'autre était fabriquée en acier rémunéré cryogénique. Neuf curettes de chaque type ont été examinées respectivement sur un bloc de dentine bovine après les dix premières courses de travail ainsi qu'après 500–510 et 1000–1010 trains avec spectrophotométrie d'absorption atomique. En plus, les instruments ont été soumis encore à des cycles de stérilisation et de désinfection répétés et l'efficacité d'ablater la dentine après dix courses de travail a été déterminée de nouveau. Une curette universelle a été utilisée de la même manière comme contrôle. Toutes les curettes ont montré des valeurs comparables après 1010 courses de travail. De même, la rugosité de surface n'a pas montré de différences significatives entre les instruments. La stérilisation a toutefois influencé négativement de la même manière tous les instruments. La stérilisation semble être un facteur important pour émousser les curettes mais n'influence pas la rugosité de surface.

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