International Journal of Dental Hygiene

Official Journal of the International Federation of Dental Hygienists

ORIGINAL ARTICLE

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Dates:
Accepted 8 September 2016

To cite this article:
Int J Dent Hygiene **16**, 2018; 202–209
DOI: 10.1111/idh.12249
Bozbay E, Dominici F, Gokbuget AY, Cintan S, Guida L, Aydin MS, Mariotti A, Pilloni A. Preservation of root cementum: a comparative evaluation of power-driven versus hand instruments.

Preservation of root cementum: a comparative evaluation of power-driven versus hand instruments

Abstract: *Objectives:* The purpose of this study was to evaluate the effects of three distinct periodontal treatment methods in comparison with hand instrumentation on residual cementum of periodontal diseased teeth. Cementum can influence the activities of periodontal cells and may play an important regulatory role in periodontal treatment. The ideal method for periodontal therapy involves removal of biofilm, calculus and endotoxin while preserving root cementum. *Material and methods:* Forty-eight caries free, single-rooted teeth in patients diagnosed with severe chronic periodontitis were treated using four different methods prior to extraction. The teeth were instrumented subgingivally at one approximal site either by hand curettes (HC), piezoelectric ultrasonic scalers (U), piezoelectric ultrasonic scalers following air polishing (U + AP) or air polishing (AP) alone. Following extraction of teeth, instrumented and non-instrumented sites were analysed with a dissecting microscope and SEM for measurement of the amount of and surface characteristics of residual cementum. *Results:* The percentage of coronal cementum remaining following subgingival instrumentation was 84% for U, 80% for U + AP, 94% for AP and 65% for HC. Although subgingival instrumentation of apical portions of the cementum demonstrated 6% less retained cementum in comparison with coronal portions, the amount of retained cementum with AP was still significantly greater than with HC. SEM results found the smoothest root surfaces were produced by the HC followed by the AP, while root surfaces instrumented by U or U + AP presented grooves and scratches. *Conclusions:* This study demonstrated that AP was superior to U devices in preserving cementum, whereas HC were the most effective instruments in removing cementum.

Key words: air polishing with glycine; cementum removal; hand instrumentation; residual cementum; root surface instrumentation; ultrasonic scaling

Introduction

The major role of cementum is to serve as the site of attachment for principal collagen fibres (Sharpey's fibres). In particular, cementum, by virtue of its structural and dynamic qualities, provides tooth attachment and maintenance of occlusal relationships between the jaws. These multiple functions are fulfilled by the biological activity and reactivity of cementoblasts, which deposit two collagen-containing varieties of cementum with completely different properties (1). Periodontal disease may alter cementum resulting in the loss of connective tissue attachment to cementum. As the relationship between local bacteria and periodontal disease is widely recognized (2, 3), it is generally accepted that removal of pathogenic micro-organisms that form plaque and calculus on cementum is the major goal of periodontal treatment. This therapy currently consists of scaling and root planing, using mechanical instrumentation (4, 5).

Previously it was accepted that bacterial endotoxins or bacteria penetrate the cementum of periodontally diseased root surfaces. This concept resulted in the removal of the subgingival plaque and calculus deposits, and the removal of all or most of the cementum as a primary endpoint of periodontal healing (6, 7). More specifically, the goal of periodontal therapy was to obtain a treated root surface with smooth and hard surface characteristics that was free of endotoxins (6, 8).

In contrast, recent studies have reported that endotoxins were not located within cementum (9, 10) and removal of 'diseased' cementum was not necessary for a successful periodontal treatment (11). The preservation of cementum on the root surface was further supported by Saygin *et al.* (12) who reported that cementum was necessary for new attachment and as a source of growth factors (12,13). Furthermore, Grzesik *et al.* suggested that cementum plays an important regulatory role in periodontal regeneration (14). From these studies, it can be concluded that non-aggressive removal of cementum is necessary for optimal periodontal health as well as for periodontal regeneration.

Subgingival instrumentation during periodontal therapy results in the removal of root cementum, which can eventually lead to exposure of dentinal tubules, pulp injury and dentin hypersensitivity (15). The *in vitro* studies, including establishing *in vitro* experimental models under standardized experimental conditions, evaluated the amount of cementum with various instruments or force combinations (16–25). Several studies that have shown the effects of different instruments on root surfaces emphasized that periodontal treatment can be performed less aggressively with respect to the removal of cementum (16, 17, 22–28).

There has been a previous report that the teeth treated by hand curettes (HC) and piezoelectric ultrasonic scalers (U) can produce a root surface without cementum and with open dentinal tubules (26). More specifically, root surfaces treated by U exhibited a scaly and rough topography, whereas the teeth treated with HC presented smooth surfaces. Kawashima et al. compared two different U (Vector™ and Enac^{R} scaler) with HC and found that both U groups had significantly more remaining cementum than the HC group (27). In addition, they observed some areas with thin or absent cementum in the HC group. Ruhling *et al.* compared the effects of various ultrasonic scalers, sonic scalers (SS) and HC and found that HC and SS groups caused greater removal of cementum (28). In fact, nearly all cementum was removed in 25% of the samples treated with HC.

Tomasi *et al.* reported that biofilm and calculus certainly should be removed, but also they questioned the requirement for removal of 'contaminated' root cementum by root planning (29). U with new shaped tips and subgingival air polishing (AP) devices have been developed for removal of root accretions with minimal root damage. In recent years, newly developed instruments have provided clinically positive results in the treatment of chronic periodontitis with minimal cementum removal. As AP has been suggested as a treatment modality for root debridement (30), recent studies (31, 32) using this technique have revealed probing depth reductions and removal of subgingival biofilm. Currently, there is no scientific evidence showing the loss of root substance or surface roughness by AP or U instrumentation with AP (33).

The aim of the present clinical study was to evaluate how much cementum could be retained as well as the surface characteristics of the retained cementum following *in vivo* root instrumentation. More specifically, a new U instrument with or without AP with glycine powder was compared to HC on cementum removal on diseased root surfaces that had never been periodontally treated.

Materials and methods

Selection criteria

Twenty-seven patients (aged >18) with teeth diagnosed with severe chronic periodontitis and scheduled for extraction were included in this study. The inclusion criteria included participants who were systemically healthy, were non-smokers, had single-rooted teeth or molars with fused roots and had bleeding on probing. The patients participated on the basis of a periodontal probing depth (PPD) ≥5 mm in at least two sites per tooth with radiographical bone loss for more than two-thirds of root length and having hopeless single-rooted teeth for periodontal treatment. Exclusion criteria for subjects included subjects who were pregnant, breastfeeding, had been treated for periodontal disease (either non-surgical or surgical), had dental caries or restorations on the mesial or distal tooth surfaces or had class III dental mobility. The study protocol was approved by the Sapienza, University of Rome Ethical Committee (Resolution 2821 from the National Health Council, Health Ministry, Italy, 26/09/2013; ClinicalTrials.gov Identifier: NCT02205619 with the Protocol Record ABT-1233-RV), the participants volunteered for the study after receiving verbal and written information and a signed informed consent approved by the Sapienza, University of Rome Ethical Committee in accordance with the Declaration of Helsinki. The patients selected had periodontal pocketing with radiographic bone loss of more than two-thirds of the root length with a hopeless tooth prognosis.

Clinical procedures

All the subjects of the study received a supragingival tooth cleaning 1 week prior to the measurements with the use of ultrasonic scaler (Air-Flow Master Piezon®, Instrument Tip A; EMS SA, Nyon, Swiss) and glycine-based air polishing

(Air-Flow® Powder SOFT; EMS SA). Probing depths (PD) and clinical attachment levels (CAL) were measured by a calibrated investigator (DDS) prior to instrumentation. The measurements were carried out on all teeth, at six locations per tooth to nearest 1 mm using a standardized periodontal probe (PCPUNC 15, University of North Carolina, Hu-Friedy, Chicago, IL, USA).

Prior to extraction, the teeth (n = 48) were randomly divided into these four treatment groups: (i) piezoelectric ultrasonic scaler (U) (Air-Flow Master Piezon®, Instrument Tip PS; EMS SA); (ii) U (Air-Flow Master Piezon®; EMS SA) followed by air polishing with the glycine powder (Air-Flow® Powder Perio, Perio-Flow Nozzles; EMS SA) (U + AP); (iii) air polishing with the glycine powder (Air-Flow® Powder Perio, Perio-Flow Nozzles; EMS SA) (AP); and (iv) hand instruments (HC) (Gracey curettes 5/6, 11/12, 13/14 American Eagle, Missoula, MT, USA). Treatment options were randomly assigned to the operator immediately prior to treatment. Instrumentations with air polishing and U devices were performed with medium power settings and with the use of water cooling (as instructed by the manufacturer). One approximal root surface (distal or mesial) of each tooth was randomly subjected to debridement, and the other approximal surface was used as control. All the measurements and instrumentations of teeth were performed by a single operator (DDS). The criteria for adequate treatment were smooth, hard root surfaces, with no clinical evidence of calculus. The cleanliness and smoothness of the root surface were checked using a fine dental explorer (Hu-Friedy 3A Explorer, Chicago, IL, USA). The instrumentations were carried out under local anaesthesia. The length of time required for scaling, air polishing and root planing with each instrument was recorded in seconds (s). The mesial and distal locations of the gingival margin that were marked on the root surface were determined and marked with shallow 'V'-shaped notches by a diamond flame bur. Following instrumentation, the teeth were immediately extracted atraumatically and wiped with wet gauze to remove debris. The teeth were stored in numbered and labelled jars in a solution of 0.9% w/v of NaCl (about 300 mOsm/l) for a maximum 30 days.

SEM procedures

Before sectioning, the root surface characteristics of 20 randomly selected teeth were analysed using a scanning electron microscopy (LEO, EO 435 VP, Marvell Nanofabrication, Berkeley, CA, USA). The roots were gold-sputtered with a sputtering device (Agar Sputter Coater, 108 Supply 230, Frequency 50, Essex, UK). Micrographs were taken at magnifications from ×48 to ×210. Remaining Calculus Index (RCI) and Roughness Loss of Tooth Substance Index (RLTSI) were calculated to determine remaining calculus, root surface roughness and loss of root substance. However, calculus appearance was provided with qualitative information on the mineral and organic composition of the root surface. Additionally, scratches, gouges, cracks, cementum presence and any other changes in the cementum were noted.

Specimen preparation

The teeth were rinsed in NaOCl for 2 min to remove deposits and periodontal fibres before sectioning. The gingival margin on the mesial and distal root surfaces were identified from previous markings (while teeth were *in situ*), and a line was drawn at the level of the marked area with a permanent marker (edding, 780 gloss paint marker 0.8 mm, Ahrensburg, Germany) to ensure evaluation of subgingival root surfaces. Subsequent to the identification of the subgingival root surface, crowns were removed, teeth were cut into mesial and distal sections and the roots were stored in a decalcification solution (Osteomoll® rapid decalcifier, Merck Millipore, Darmstadt, Germany) for 24 h. After decalcification, the roots were immersed in a tissue processor (Leica ASP300S, Wetzlar, Germany) for approximately 24 h and embedded into paraffin blocks. The teeth were sectioned perpendicularly to the root axis with a microtome (Leica, RM2245, Wetzlar, Germany) between 10 and 15 μm thickness and stained with haematoxylin and eosin. Two horizontal root sections of each tooth were taken from the coronal and apical portion of the instrumented root for a total 96 histologic specimens. Coronal sections were taken 1 mm apically from the gingival margin, whereas apical sections were taken 1 mm coronally from the notched root surface (i.e. endpoint of periodontal pocket).

Measurement process

Both histologic and SEM measurements were carried out by blinded examiners. The teeth were examined by an optic microscope (Nikon Eclipse i5, Tokyo, Japan) connected to a camera (Nikon, DS-Filc, Tokyo, Japan) and a dedicated computer. The thickness of the cementum was measured by specific software (Nikon, NIS Elements 4.0, Tokyo, Japan). As shown in Fig. 1, six components, including the mesial and distal areas of each tooth, were analysed and each measure was reported as a mean value of five quantifications (Fig. 3a).

Statistical analysis

Statistical analyses were performed with SPSS software (SPSS 21.0, IBM® Corp, Armonk, New York, USA). Paired t-tests were used to evaluate the differences between the thickness of instrumented and non-instrumented surfaces for each group. The amount of cementum in instrumented and non-instrumented surfaces was calculated, and one-way analysis of variance (ANOVA) test was used for comparisons between the differences of four instrumentation groups. Tukey's HSD and Bonferroni tests were performed to compare multiple comparisons between instrumentation groups. P values <0.05 were considered as statistically significant.

Results

Ninety-six sections of 48 teeth were processed for histologic examination. The mean age of patients (14 females and 13

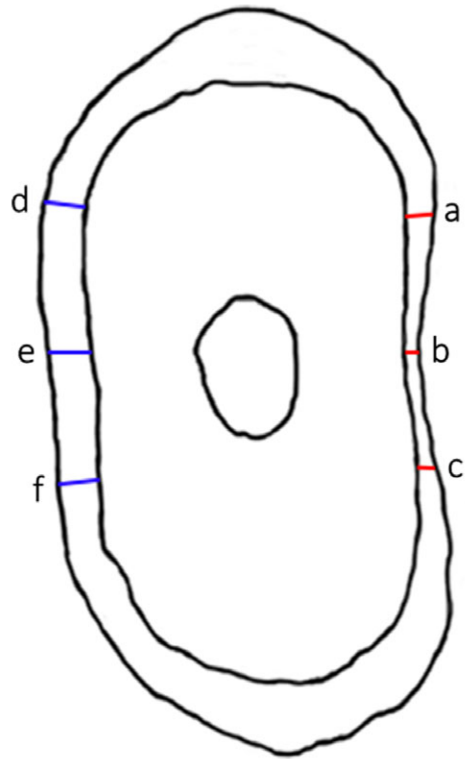

Fig. 1. Schematic drawing of the measurement method.

males) was 42.5 years. The mean values of PD and CAL for all teeth were 5.08 ± 1.64 mm and 7.77 ± 2.10 mm, respectively.

Regardless of the type of subgingival instrumentation, a statistically significant amount of cementum was removed in both coronal and apical surfaces of the root (Table 1). Despite the consistent removal of cementum, there were differences between the treatment modalities in regard to the amounts of cementum retained following the subgingival instrumentation. The percentages of coronal cementum retained were 84% with U, 80% with U + AP and 94% with AP, whereas HC only retained 65% of the cementum. In the apical sections, cementum loss was 84% with U, 83% with U + AP, 88% with AP and 70% with HC. When comparing the cementum retention for coronal and apical sections, only AP had a statistically significant effect on reducing the amount of remaining cementum in apical sites when compared to coronal sites ($P = 0.027$).

Overall, power-driven instruments were statistically more efficient at retaining cementum when compared to hand instruments. More specifically, HC and U + AP produced significantly greater cementum removal than AP in coronal sections ($P = 0.002$, $P = 0.004$, respectively); HC caused significantly greater removal of cementum than AP in apical sections ($P = 0.016$). It should be noted that in both the coronal and apical sections, AP produced the least amount of cementum loss and therefore the greatest retention of residual cementum.

Table 1. **A–B: Mean cementum thickness and standard deviation (±SD), in micrometres, for each coronal and apical cut section. C: Mean loss of cementum thicknesses and standard deviation (±SD), in micrometres, for each coronal and apical cut section, *: considered as statistically significant ($P < 0.05$)**

(A)	Coronal sections				
	Non-instrumented		Instrumented		Paired *t*-test
Instrumentation	Mean	±SD	Mean	±SD	
Piezoelectric (U)	77.11	32.65	64.04	33.84	$P < 0.001$
U + AP (Piezo + air polish)	103.37	49.70	82.57	44.19	$P < 0.001$
AP (air polishing)	70.53	46.13	65.60	45.48	$P = 0.008$
Hand curettes (HC)	62.77	21.64	40.49	12.39	$P < 0.001$

(B)	Apical sections				
	Non-instrumented		Instrumented		Paired *t*-test
Instrumentation	Mean	±SD	Mean	±SD	
Piezoelectric (U)	89.23	47.93	74.73	43.65	$P < 0.001$
U + AP (Piezo + air polish)	100.49	40.38	82.93	35.92	$P = 0.001$
AP (air polishing)	74.28	29.12	64.81	30.46	$P = 0.003$
Hand curettes (HC)	76.74	18.00	53.07	13.03	$P < 0.001$

(C)	Coronal sections		Apical sections		Paired *t*-test
Instrumentation	Mean	±SD	Mean	±SD	
Piezoelectric (U)	13.08	7.59	14.50	79.479	$P = 0.734$
U + AP (Piezo + air polish)	20.80	12.10	17.56	13.6348	$P = 0.571$
AP (air polishing)	4.93	5.24	9.47	8.5204	$P = 0.027$
Hand curettes (HC)	22.28	15.22	23.67	13.1199	$P = 0.762$
One-way ANOVA	($P = 0.001$)		($P = 0.025$)		

Table 2. **Mean instrumentation time and standard deviation (±SD), in seconds, for each treatment group, *: considered as statistically significant (P < 0.05)**

Instrumentation	Mean	±SD	Tukey' s HSD test
Piezoelectric (U)	103.50	43.83	$P > 0.05$
U + AP (Piezo + air polish)	149.42	52.94	$P > 0.05$
AP (air polishing)*	70.75	30.37	$P < 0.05$*
Hand curettes (HC)	139.00	54.23	$P > 0.05$

In regard to mean time to complete root instrumentation, the shortest mean time was using AP and the longest mean time was U + AP. In comparison with HC, AP required 31% less time for root preparation, whereas U + AP required 30% more time (Table 2).

SEM results

The teeth instrumented with HC exhibited smooth surfaces, while the cementum appeared completely removed in one micrograph (as showed in the Fig. 2b); whereas in other micrographs, a few areas without cementum could be noticed. Root surfaces instrumented with U (Fig. 2a) presented with grooves and scratches as did roots instrumented with U + AP (Fig. 2c). Large areas without remaining calculus and with a relatively smooth and intact surface occurred following the use of all the instruments tested, although the use of AP (Fig. 2d) left the surface more intact and inadequate on removal of calculus than the other groups.

Discussion

This study was initiated to assess the *in vivo* removal of root cementum following different traditional periodontal treatment methods. Once these different clinical instrumentation techniques were applied, *in vitro* histologic measurements were used to evaluate cementum removal following teeth extractions. There are few *in vivo* studies that have compared root surface characteristics following periodontal instrumentation (26–28, 34, 35), and this study investigates the effects of various types of *in situ* instrumentation on cementum removal in periodontal patients. More specifically, this is the first study to histologically determine, using multiple replicate measures, the effects of a clinician in achieving both debridement and preservation of a diseased root surface on never-instrumented teeth.

The *in vitro* evaluation of substance loss of dental tissue has been described by various investigators using different periodontal treatment methods (16–25, 36–38). All of the periodontal treatment methods used in this study have demonstrated the removal of cementum, although AP alone eliminated less cementum than HC or U. The histologic sections of the present study indicated that cementum was generally present on the root surfaces after experimental instrumentation; only in the three sections of the HC group was the cementum totally absent and the dentin layer exposed (Fig. 3b) and was thinner on the instrumented areas (Fig. 3c). Because diseased root cementum is thinner than healthy cementum (39, 40), one can hypothesize that during

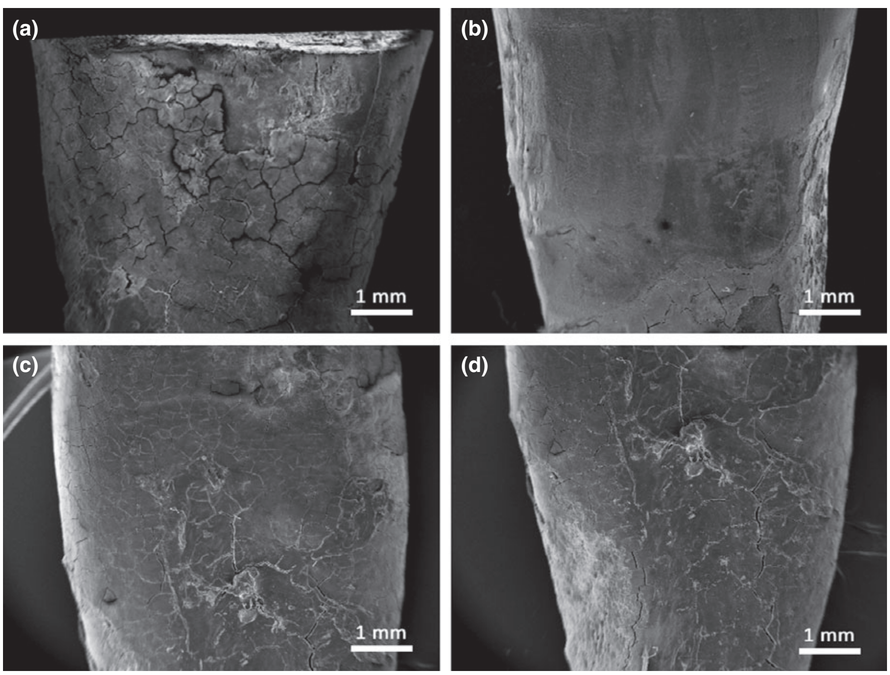

Fig. 2. Representative 48× photomicrographs of the four instrumentation groups. (a) Instrumented root with U. Cementum is absent coronally. Cementum has irregularities, scratches and gouges. (b) Instrumented root with HC. There is no cementum in the instrumentation area, surface clean and smooth. (c) Instrumented root with U + AP. Most of the cementum is intact, groove present with irregularities and debris. (d) Instrumented root with AP: cementum is present.

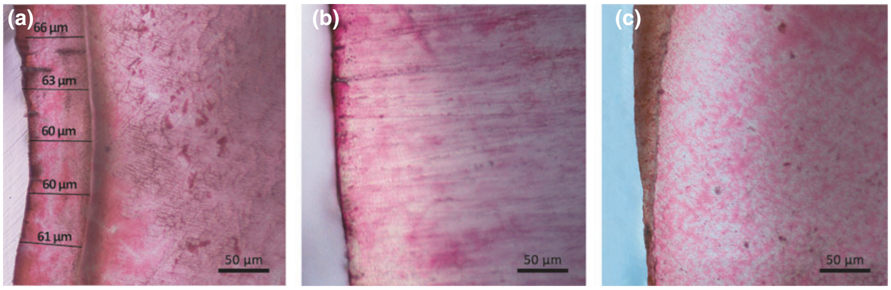

Fig. 3. Haematoxylin and eosin histologic root sections (magnification ×400). (a) Instrumentation of root surface: evaluation of cementum thickness is a mean value of five measurements at each point. (b) Instrumentation of root surface with HC. The surface is without cementum, exposed dentin present. (c) Instrumentation of root surface with HC. The cementum thickness is thinner on the middle of the approximal surface.

instrumentation of the diseased root, a portion of the dentin structure may also be removed with the cementum.

An *in vitro* study (34) comparing the depth of root surface removal by hand curettes with different stroke numbers has shown that hand curettes removed cementum completely with a minimum of 20 strokes. However, they used periodontally healthy teeth including impacted third molars and bicuspids. To replicate routine clinical treatment procedures, only periodontally diseased teeth were selected for the present study. Ritz *et al.* (36) reported that the debridement of the root surface should preserve the root material. This being the case, this study demonstrates how much root cementum can be retained after power-driven or hand instrumentation of root surfaces.

Regardless of the amount of cementum removed, patches of dental calculus could be observed, from SEM micrographs, on the root surfaces in U or AP instrumentation groups. These findings are consistent with those of Crespi *et al.* (26) who found both ultrasonic devices and hand curettes were not capable of removing all residual plaque and calculus deposits present on root surfaces. Although single instrumentation procedures were not able to remove all calculus, this study found that a combination of instrumentation (e.g. U + AP) was able to remove all residual calculus deposits present on root surfaces. Therefore, U devices in conjunction with AP seem to be more efficient for the removal of hard or soft deposits.

In regard to root roughness, the present findings seem to be consistent with Schimidlin and co-workers who found that roots instrumented with hand curettes produced the smoothest surfaces if compared to the surfaces instrumented with the ultrasonic or sonic scalers (19). Similarly, Bless *et al.* (25) found that rougher surfaces occurred after treatment with ultrasonic scalers when compared to treatment with hand curettes. The SEM results of this study have shown that smoother root surfaces can be obtained with HC when compared to U.

The time necessary to complete a procedure can also play an important role in what type of instrumentation a dentist will use. The time required to complete root surface preparation in this study varied depending on the type of subgingival instrumentation. The average time for HC was 115.33 s per site. Although the time of use of U (107.83 s) was similar to HC, the use of U + AP was significantly longer than HC (34.75 s) and U was significantly shorter (36.5 s) than HC.

The thickness of cementum can be affected by various factors (41), and a limitation of this study was the assumption that the thickness of the cementum on the mesial and distal surfaces was similar. Bellucci and Perrini (41) measured the thickness of radicular dentine and cementum of 220 single-rooted incisors, canines and premolars from adult subjects aged between 35 and 55 years and revealed differences between mesial and distal thicknesses were not statistically significant. In contrast, Dastmalchi *et al.* (42) reported markedly thicker cementum on the distal root surfaces of eight human premolars and three molars and speculated that this was due to tensile forces after mesial drift. Furthermore, Stamfelj *et al.* (43) have shown that distal and oral root surfaces exhibit thicker cementum than corresponding mesial and vestibular surfaces of multirooted teeth. Although similarity between mesial and distal cementum thickness may be controversial, data from the above-mentioned studies do not confirm differences in cementum thicknesses between mesial and distal sides of the tooth.

From a biological perspective, the periodontium has been shown to contain biologically active mediators (12, 44–46) and these molecules are elevated in alveolar bone and cementum (47–50). Periodic professional cleaning may lead to major losses of root cementum, leading to a loss of growth factor reservoirs in the cementum. For this reason, it is strongly suggested that the root surface debridement should aim on preserving root substance to improve healing following non-surgical or surgical therapy. The study design of this work seems to help in showing how the efforts of a clinician, in achieving both debridement and preservation of a diseased root, can be measured, the former using never-instrumented-diseased root surfaces and the latter by obtaining replicable thicknesses of cementum with the use of averages of the entire perimeter of the tested root in one specific site.

Clinical relevance

Scientific rationale for the study

Cementum is a key component of periodontal tissues, and its preservation is of paramount importance for the quality of healing at completion of periodontal both non-surgical and surgical treatment modalities. Periodontal reattachment or new attachment as end result of therapy strongly relies on the presence of cementum after root instrumentation. Improper or aggressive mechanical instrumentation may reduce the thickness or eventually remove all the cementum over the root surface. This study investigates the effects of various types of *in situ* instrumentation on cementum removal in periodontal patients. More specifically, this is the first study to histologically determine, using multiple replicate measures, the effects of a clinician in achieving both debridement and preservation of a diseased root surface on never-instrumented teeth.

Principle findings

AP was significantly more effective on preserving cementum. Use of HC resulted more removal of cementum than those of US and AP.

Practical implications

Clinicians seek for more conservative or minimally aggressive means for root debridement as it may offer better chance for cementum preservation. Clinical methods aiming at the regeneration of inserted and functionally oriented new fibres may benefit from this type of approach for proper preparation of the previously diseased root surfaces.

Acknowledgements

The authors thank Professor Antonella Polimeni from Sapienza, University of Rome, Italy, for the knowledgeable contribution to the protocol of this study. The authors wish to thank Dr. Sevda Ozel from Istanbul University for the statistical analyses.

Source of support

Research Fund of Istanbul University.

Conflict of Interest

None.

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