International Journal of Dental Hygiene

Official Journal of the International Federation of Dental Hygienists

ORIGINAL ARTICLE

D Silva
O Martins
S Matos
P Lopes
T Rolo
I Baptista

Histological and profilometric evaluation of the root surface after instrumentation with a new piezoelectric device – *ex vivo* study

Authors' affiliations:
D Silva, O Martins, S Matos, T Rolo and I Baptista, Faculty of Medicine, Department of Dentistry, University of Coimbra, Coimbra, Portugal
P Lopes, Medical and Universitary Services, Social Services, University of Coimbra, Coimbra, Portugal

Correspondence to:
D. F. S. Silva
Av. Bissaya Barreto
Bloco de Celas 3000-075 Coimbra
Portugal
Tel.: +351 918 084 531
Fax: +351 239 402 910
E-mail: danielaf.santossilva@gmail.com

Abstract: *Objectives:* An *ex vivo* model was designed to profilometrically and histologically assess root changes resulting from scaling with a new ultrasonic device, designed for bone piezoelectric surgery, in comparison with curettes. *Methods:* Three groups of 10 periodontal hopeless teeth were each subjected to different root instrumentation: Gracey curettes (CUR); ultrasonic piezoelectric device, Perio 100% setting, level 8 (P100); and ultrasonic piezoelectric device Surg 50% setting, level 1 (S50). After extraction, all teeth were photographed to visually assess the presence of dental calculus. The treated root surfaces were profilometrically evaluated (Ra, Rz, Rmax). Undecalcified histological sections were prepared to assess qualitative changes in cementum thickness. Statistical analysis was carried out using one-way ANOVA test with a significance level of 95%. *Results:* Both instruments proved to be effective in the complete removal of calculus. The CUR group presented the lowest Ra [2.28 μm (±0.58)] and S50 the highest [3.01 μm (±0.61)]. No statistically significant differences were detected among the three groups, for Ra, Rz and Rmax. Histologically, there was a cementum thickness reduction in all groups, being higher and more irregular in S50 group. *Conclusions:* Within the limits of this study, there were no statistically significant differences in roughness parameters analyzed between curettes and the ultrasonic piezoelectric unit. This new instrument removes a smaller amount of cementum, mainly at the Perio 100% power setting, which appears to be the least damaging. The ultrasonic device is effective in calculus removal, proving to be as effective as curettes.

Key words: curettes; dental calculus; non-surgical periodontal debridement; periodontal hand instrumentation; piezoelectric instrumentation

Dates:
Accepted 30 May 2014

To cite this article:
Int J Dent Hygiene **13**, 2015; 138–144.
DOI: 10.1111/idh.12091
Silva D, Martins O, Matos S, Lopes P, Rolo T, Baptista I. Histological and profilometric evaluation of the root surface after instrumentation with a new piezoelectric device – *ex vivo* study.

Introduction

The primary aetiological factor of periodontal disease is the existence of specific bacterium associated with plaque (1, 2). Their metabolic components, antigenic compounds and endotoxins are responsible for gingival inflammation and eventual periodontal bone loss. Dental calculus is present in most adults, supra- and subgingivally (3, 4). Thus, despite the apical migration of the biofilm being the primary reason for periodontal destruction, calculus can create conditions to facilitate the destruction and add chronicity to periodontal lesions (5). The removal of the microbial biofilm and calculus from the root surface assumes crucial importance. This can be performed by scaling and root planning (SRP), the main component of non-surgical periodontal and supportive therapies (6–8). These therapies can be performed with a wide variety of instruments (9, 10), manual and ultrasonic, used alone or in combination with positive results demonstrated in several long-term clinical studies (6, 11, 12).

Manual instrumentation is considered the gold standard treatment (3, 6, 13–17). In recent years, ultrasonic instruments became widely accepted as an alternative to manual instrumentation, showing equal effectiveness in removing biofilm, subgingival calculus and endotoxins (13, 17–20). This is mainly due to its efficiency, simultaneous effect of irrigation, ease of use, minimal time consumption and a better access to the furcation area and deep pockets (10, 13–15, 18, 20–23). This facilitates the subgingival debridement, improving clinical and microbiological outcomes (24, 25).

Besides plaque removal, an important consideration in periodontal therapy is the amount of root structure removed, as well as root surface roughness after treatment (26). An extensive removal of cementum can lead to an increased surface roughness, favouring plaque retention (26–29) and dentin hypersensitivity. Additionally, during periodontal maintenance, repeated instrumentation over a number of years may result in significant removal of tooth substance due to the cumulative effects of cementum removal (22).

In addition, the topography of the root surface plays an important role in cell adhesion. Several *in vivo* studies have revealed evidence of a positive correlation between the surface roughness and the rate of supragingival accumulation (1, 6, 9, 29–32). Although a higher surface roughness promotes plaque formation, its significance for periodontal healing has been a matter of controversy. Rough surfaces appear to facilitate periodontal ligament fibroblasts adhesion (33), favouring periodontal regeneration (30), while a smooth surface could lead to long junctional epithelium formation (1).

An ultrasonic surgical unit initially designed for piezoelectric bone surgery, recently appeared in the market, with several program settings and tips according to their application in different fields: bone surgery, endodontics and periodontology. This device has an application in periodontal therapy, with periodontal tips designed to SRP.

The aim of the present study is to evaluate, profilometrically and histologically, the root surface resulting from ultrasonic instrumentation, compared with periodontal Gracey curettes. The presence or absence of calculus after instrumentation was also considered.

Materials and methods

This *ex vivo* study included thirteen randomly selected patients of the department of dentistry (Faculty of Medicine, University of Coimbra, Portugal) aged between fifty-six and seventy years. The patients have previously been diagnosed with chronic periodontitis with one or more incisors, canines and first premolars scheduled for extraction due to hopeless periodontal prognosis. The ethic council of the stated above faculty approved this study. The selected patients signed an informed consent concerning the study nature, and the prosthetic rehabilitation of the resulting edentulous area was ensured.

The inclusion criteria were teeth with total absence of periodontal treatment by scaling and root planning (SRP); probing depth (PD) higher than 3 mm; bone level below one third of the root length; vertical and horizontal mobility; and presence of subgingival calculus detected with a periodontal probe (PUNC 15®, Hu-Friedy®, Chicago, IL, USA) and/or periapical radiograph. The exclusion criteria encompassed the presence of radicular caries, subgingival restorations and external root resorption. None of the teeth selected presented important anatomical variations, such as furcation or deep sulcus on interproximal surfaces.

Thirty teeth (n = 30) were equally and randomly assigned, throwing a die, to the following groups: CUR – manual SRP with Gracey® curettes (SG5/69®, Hu-Friedy); P100 – piezoelectric ultrasonic SRP with VarioSurg® (NSK, Kanuma, Japan) programmed on 'Periodontology mode' at 100% power setting, level 8; S50 – piezoelectric ultrasonic SRP with VarioSurg® programmed on 'Surgery mode' at 50% power setting, level 1. An external and blind subject made this allocation. A straight periodontal tip (P20-S®, NSK®) was used for both ultrasonic instrumentations.

For each tooth, the test proximal surface was the one with higher probing depth (PD) and the contra-lateral surface the non-instrumented control.

After local anaesthesia (Scandinibsa® 2% with epinephrine 1:100.000, Inibsa, Barcelona, Spain) and before instrumentation, the level of the free gingival margin was identified by a round bur notch. The periodontal pocket apical to this notch was submitted to instrumentation. The instrumentation was considered complete when no calculus was detected by the periodontal probe. All procedures were performed by the same experienced operator in a single session, with manual stabilization of the teeth, due to their mobility, and with no time limitations, providing enough time to the best possible instrumentation of the root surface. Operator was blind regarding the two settings of the ultrasonic unit. After instrumentation, extraction was atraumatically performed without touching the root surface. Teeth were washed in running water for 30 s and kept cold (6°C) in physiological serum.

Before further analysis, each interproximal surface was photographed (Canon EOS 600D, EF 100 mm f/2.8 Macro USM) on a millimetre scale paper and macroscopically observed for residual calculus.

Within the ten teeth of each group, six, with higher PD, were selected for profilometric evaluation (Perthometer S4P®, Göttingen, Germany). The analysed area length was 4 mm, and three linear readings spaced by 0.1 mm were performed, using a 0.8-mm filter. For each test tooth root surface, the average of the measurements determined the value of the accessed parameters: average roughness (Ra – arithmetic mean deviation of a profile), three-dimensional roughness (Rz – average of the five lowest valleys and the five highest peaks within a profile) and maximum roughness (Rmax – the maximum peak to valley of a profile) (34).

Regarding the histological procedures, two longitudinal sections including the test and control surfaces of each of the ten teeth, prepared according to a protocol for undecalcified sections (Exakt Band System 300 CL/CP, Hamburg, Germany). Final samples were mounted on acrylic slides and polished (Micro Grinding System Exakt 400 CS, Hamburg, Germany), obtaining a total of 60 μm of histological sample thickness. The histological preparation was finished by the coloration of the samples, with a toluidine blue dye. Histological evaluation was performed using an optical microscope (OM) (Eclipe 600, Nikon®, Tokyo, Japan) at ×20 and ×40 magnifications, for qualitative evaluation of the remaining cementum and calculus.

External concealed examiners made all measurements and qualitative evaluations.

Statistical analysis was carried out with the program SPSS® v17 (SPSS Inc. SPSS Statistics 17.0.1 – December 2008. Chicago). Normal distribution of each variable, per group, was identified by the Kolmogorov–Smirnov test. Intergroups analysis was performed w*ith* one-way ANOVA with a significance level of 95%.

Results

Sixteen incisors, five canines and nine first premolars were included. PD ranged between 4 mm and 11 mm (Table 1).

Macroscopic evaluation

Apically to the radicular notch, all the test surfaces from the three experimental groups (CUR; P100; and S50) had a total absence of calculus even in teeth with higher PD. Still, calculus was present in all control surfaces.

Table 1. **Distribution of the included teeth per group (CUR; P100; S50) and initial probing depth (PD)**

	PD (mm)	Incisors	Canines	First premolars
Upper	4			S50 (1)
	5			
	6			
	7	S50 (3) P100 (1)	CUR (1)	S50 (1) P100 (2)
	8	P100 (4)		
	9		CUR (1) P100 (1)	
	10			
	11	CUR (1)	S50 (1)	
Lower	4	CUR (2)		
	5	S50 (2) P100 (1)		CUR (2) S50 (1)
	6	CUR (2)		
	7			
	8		CUR (1)	S50 (1)
	9			P100 (1)
	10			
	11			
Total		16	5	9

Profilometric evaluation

CUR group presented the lowest mean Ra [2.28 μm (±0.58)] and S50 group the highest [3.01 μm (±0.61)]. No statistically significant differences were detected among the three groups, for Ra values. The other two parameters (Rz and Rmax) had the same distribution pattern. Rmax for S50 presented two outliers (statistically aberrant values). (Table 2).

Histological evaluation

Fourteen of the twenty histological samples from CUR presented a maintenance or slight removal of cementum with no dentin exposure (Fig. 1). In the remaining histological samples, it could be observed some dentin exposure.

In the P100 group, all of the twenty histological samples showed a maintenance or slight decrease in cementum thickness with no dentin exposure (Fig. 2).

In sixteen of the twenty histological samples from S50 group, a slight decrease in cementum thickness could be observed. However, the remaining samples presented a pronounced loss of tooth tissues, with a total cementum removal and a considerable reduction of dentin thickness (Fig. 3).

Discussion

The *ex vivo* character of this experimental study allowed us to have a more realistic perception of the tested devices, as the operator had no limits, particularly with respect to the pressure used, the angle of tip application or time spent. The experimental protocol was performed in a clinical environment.

To minimize the clinical variables, only anterior teeth with no interproximal deep grooves and single-root first premolars were selected.

A proximal surface was instrumented and the contra-lateral used as control. This method has already been described in previous studies (2, 16, 19, 32). Besides providing information about the cementum thickness of each tooth, this method allowed a direct and qualitative comparison between both surfaces, allowing for the evaluation of the amount of cementum removed. In a particular tooth, the thickness of cementum may not be exactly the same at both interproximal surfaces. As a result, the thickness measurement of the remaining cementum thickness was not performed.

A single operator instrumented all surfaces eliminating inter-operators variables, such as differences in the applied pressure, which could bias the results. The instrumentation was made until the operator felt a smooth surface, as in daily clinical practice. The number of strokes or time needed to complete instrumentation was not assessed or processed, as it was not the purpose of the present study.

Despite the fact that we did not know the initial amount of calculus present at each surface, at the end of instrumentation,

Table 2. **Ra, Rz and Rmax, per group (Mean ± Standard deviation). Maximum and minimum values of variables, per group. Inter-groups analysis (one-way ANOVA with a significance level of 95%)**

		Ra		Rz		Rmax		ANOVA
	n	Mean Ra ± standard deviation (μm)	95% confidence interval	Mean Rz ± standard deviation (μm)	95% confidence interval	Mean Rmax ± standard deviation (μm)	95% confidence interval	*P*-value
CUR	6	2.28 ± 0.58	3.19–1.71	15.34 ± 3.33	20.53–11.98	20.70 ± 6.42	31.18–14.91	0.19
P100	6	2.65 ± 0.73	3.22–1.51	17.94 ± 4.04	21.65–11.99	25.14 ± 5.23	31.65–18.08	0.13
S50	6	3.01 ± 0.61	3.92–2.18	19.79 ± 3.35	14.64–24.16	27.19 ± 5.58	36.03–19.05	0.17

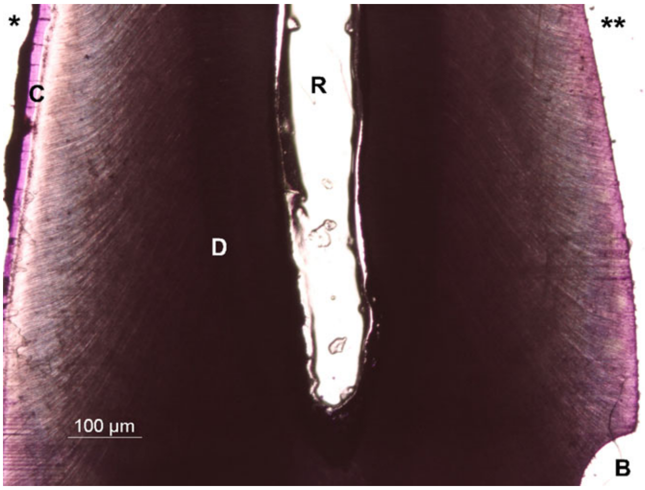

Fig. 1. Histological image obtained by OM (×20) of a CUR-group sample, stained with toluidine blue dye (C - Cement, D - Dentin, R - Root canal, B - Bur notch, * - Control surface, ** - Test surface).

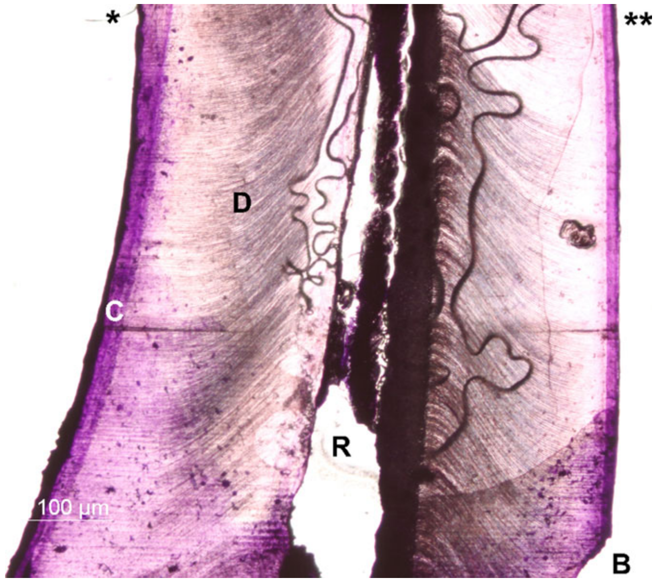

Fig. 2. Histological image obtained by OM (×20) of a P100-group sample, stained with toluidine blue dye (C - Cement, D - Dentin, R - Root canal, B - Bur notch, * - Control surface, ** - Test surface).

no calculus was detected. All instruments were equally effective in removing calculus. Initial PD did not influence the results in terms of efficacy in removing calculus. It should be noted that we used anterior and single-root teeth with good accessibility, so that PD could display only a limited influence on the results, when compared with posterior teeth (17).

Even though we have verified the existence of a similar *ex vivo* study by Santos *et al.* (9) which compared a piezoelectric ultrasonic unit, a magnetostrictive ultrasonic unit and hand instrumentation, the use of a different profilometer introduces an element of bias. Profilometric analysis with different equipments originates non-comparable results because the roughness values obtained with a laser pickup, as ours, are generally higher than those obtained using a mechanical stylus, as used by Santos *et al.* (9, 35) Even if a single device is used in several studies, the achieved absolute values may still not be comparable because of the use of different filters and different analysed area lengths (9, 32, 34).

Referring to *in vitro* studies, Folwaczny *et al.* (1) compared different Er:YAG laser energies and curette instrumentations using a similar profilometer (Perthometer® Perten GmbH, Göttingen, Germany). Following the hand instrumentation with curettes, the Ra value was 0.53 μm (±0.15) and the Rmax was 5.08 μm (±4.98). Due to the *in vitro* design of the refereed study and the fact of the analysed area length is not mentioned, as well as the filter used, the results cannot be compared with the present study. Additionally, Vastardis *et al.* (26) analysed the root roughness originated by a plain ultrasonic insert, mounted at a magnetostrictive ultrasonic unit, an ultrasonic insert with a fine grit diamond coating and Gracey curettes, but did not mention the profilometer used, which invalidates any comparison with other results. Busslinger *et al.* (12) compared a magnetostrictive ultrasonic scaling instrument with a piezoelectric ultrasonic scaling instrument and a hand curette, analysing 3-mm-length area of silicone replicas. The use of silicone replicas could introduce an element of bias as they may not accurately replicate the root surface roughness. The accuracy of the measurement depends on the replica material, the presence of air bubbles and the surface preparation.(35) Nevertheless, these authors (12) concluded that the piezoelectric ultrasonic scaler was more efficient in removing calculus than the magnetostrictive, which is in disagreement with our study, as all the analysed instruments were equally effective on calculus removal.

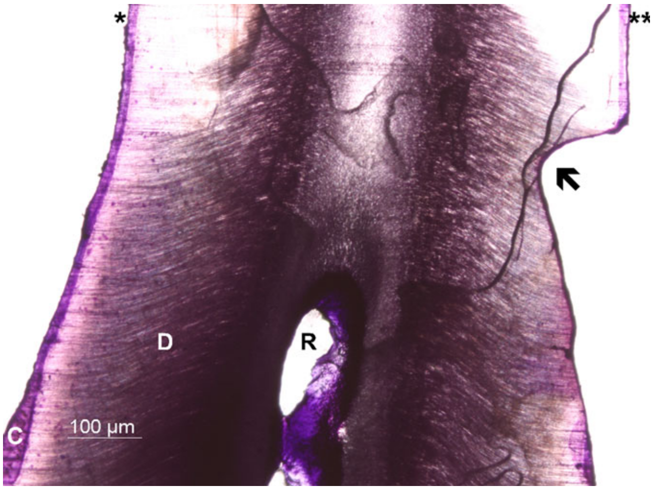

Fig. 3. Histological image obtained by OM (×20) of a S50-group sample, stained with toluidine blue dye (C - Cement, D - Dentin, R - Root canal, * - Control surface, ** - Test surface, - Abrupt decrease in cementum thickness).

Concerning the surface roughness, our results are in accordance with Busslinger *et al.* (12), as piezoelectric resulted in higher surface roughness than curettes. Moreno *et al.* (36) performed an *in vitro* study which analysed by confocal microscopy and scanning electron microscopy the root surface roughness after using Gracey curettes, termination diamond burs (40 μm), a piezoceramic ultrasonic scaler and a piezosurgery ultrasonic scaler using confocal microscopy and scanning electron microscopy. These authors (36) concluded that the piezosurgery ultrasonic scaler created the smoothest surface, with a statistically significant difference in roughness after a non-surgical periodontal treatment. These results are not consistent with ours, but we should consider that different methodologies, as profilometry, confocal microscopy and scanning electron microscopy, hinder such a comparison (36).

In the present study, root surface treatment with the new piezoelectric unit leads to a mean (Ra), three-dimensional (RZ) and maximum (Rmax) roughness within the same range as that of samples which have been treated with curettes. There were no statistically significant differences for Ra, Rz and Rmax between the three experimental groups. However, given the value of *n* for each group and the high degree of dispersion of values around the means, it would be advisable, in future studies, to increase the sample size to confirm, or not, the achieved results. Thus, taking into account the constraints provided by the reduced number of samples, as well as the fact that there is an absence of previous studies about this specific device, we should look at this experimental *ex vivo* study as a preliminary one. The two Rmax outliers identified for S50 can be justified by the fact that the 'Surgery' program used in this group was designed for bone surgery with a burst vibration mode, unlike 'Perio' program which has a continuous vibration mode.

Concerning the histological analysis of this *ex vivo* study, curettes resulted mainly in a maintenance or slight removal of cementum. These results are not consistent with an *in situ* study by Eberhard *et al.* (37) and an *in vivo* study by Schwarz *et al.* (27). The first authors compared Er:YAG irradiation with curettes instrumentation and found in their histological analysis an extensive reduction of cementum caused by curettes and consequent exposure of dentin, while only a minimal reduction was apparent after laser irradiation (37). Schwarz and colleagues compared different Er:YAG laser energies, the Vector® ultrasonic system and hand instrumentation, concluding that all root surfaces subjected to SRP with manual instruments had notable conspicuous root surface damage, located mainly in cementum, occasionally resulting in dentin exposure (27).

Regarding the histological findings after instrumentation with VarioSurg®, it should be noted that there are, to date, no published studies assessing cementum changes caused by this device.

According to the manufacturer information about the 'Surg' program burst mode, S50-group and P100-group settings provide different intensity of vibrations with a higher vibration during S50. These different intensity vibrations might explain the sharp decreases in the thickness of cementum and dentin observed (Fig. 3). Additionally, the time spent to achieve a smooth surface was greater for P100 than for S50. However, as the amount of calculus in each tooth surface before instrumentation was not calibrated, the length of instrumentation was registered but not processed,

The height-descriptive two-dimensional parameters (Ra, Rz and Rmax) are the most commonly used. Sometimes, their three-dimensional counterparts, like the average surface roughness (Sa - arithmetic mean deviation of a surface), are also included. Height parameters alone are by far the most quoted parameters, but a proper description of a surface minimally needs to include one height as well as, at least, one spacial or hybrid parameter. In a future study, (Sa) (38) should be established as a complement of the average roughness (Ra) performed in the present study.

Conclusion

Within the limits of this *ex vivo* study, the piezoelectric surgical unit programmed at 'Perio' and 'Surg' was as effective as Gracey curettes on calculus removal. There were no statistically significant differences in root roughness. Compared with Gracey curettes, this new device removes a smaller amount of cementum, mainly at the 'Perio' program, 100% power, which appears to be the less damaging, regarding the root structure removal. 'Surg' program, 50% power had the most heterogeneous results, concerning the removal of root cementum and dentin.

Conflict of interest and funding

The authors declare that they have no conflict of interests. There is no funding source. Ultrasonic device and curettes belong to the Department of Dentistry of the University of Coimbra. Histological and profilometric analyses were performed at Hard Tissue Laboratory of the same institution, with no charges.

Clinical Relevance

Scientific rationale for study

To the best of our knowledge, there is no previous study concerning the effects on the root surface and the efficacy of a new piezoelectric surgical unit.

Principal findings

Root roughness profilometry showed no differences compared to gracey curettes. 'Perio' setting has no major effect on cementum removal and root roughness, even at 100% power. 'Surg' setting appears to be more aggressive, causing severe changes on root surface, even at 50% power. Efficacy on calculus removal was similar among tested instruments.

Practical implications

This piezoelectric unit could be advised to nonsurgical and supportive periodontal therapies, using 'Perio' setting.

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