Clin Oral Invest (2008) 12:143–150
DOI 10.1007/s00784-007-0167-3

ORIGINAL ARTICLE

Comparative study on the effect of ultrasonic instruments on the root surface in vivo

Fábio André Santos · Márcia Thaís Pochapski · Paola Cristina Leal · Patrícia Panizzi Gimenes-Sakima · Elcio Marcantonio Jr.

Received: 12 June 2007 / Accepted: 12 November 2007 / Published online: 4 December 2007

Abstract The present study was designed to investigate the effectiveness of different ultrasonic instruments on the root surface. Fourteen patients with 35 single root teeth designated for extraction were recruited to the present study. Teeth were assigned to four experimental groups: group 1, piezoelectric ultrasonic device; group 2, magnetostrictive ultrasonic device; group 3, hand instrumentation; and group 4, untreated teeth (control). After instrumentation, the teeth were extracted and the presence of residual deposits (roughness and root surfaces characteristics) were analyzed. The results showed that residual deposits were similar in all tested groups: piezoelectric, 8.7%; magnetostrictive, 9.7%; hand instrumentation, 11.1% and control, 76.4%. There were statistically significant differences between control and all the experimental groups ($p<0.0001$). With respect to roughness parameters evaluation, R_a and R_z of the roots treated with the different instruments showed a similar pattern ($p>0.05$), but for R_t and R_y, a significant difference was observed ($p<0.05$) among hand instrumentation and ultrasonic devices. SEM analysis revealed a similar root surface pattern for the ultrasonic devices, but curettes showed many instrumental scratches, deep gouges, and a relatively large amount of dentin was removed. Within the limits of the study, although the instruments produced similar results, root surfaces instrumentated with curettes were rougher and had more root surface tissue removed than with the ultrasonic device.

Keywords Dental scaling · Root planning · Dental instruments · Dental calculus · Dental plaque

F. A. Santos (✉) · M. T. Pochapski
Department of Periodontics, School of Dentistry,
State University of Ponta Grossa,
Ponta Grossa, Paraná, Brazil
e-mail: fasantos11@gmail.com

F. A. Santos
Ave. Carlos Cavalcanti, n.4748,
CEP-84030-900 Uvaranas, Ponta Grossa, Paraná, Brazil

P. C. Leal · P. P. Gimenes-Sakima · E. Marcantonio Jr.
Department of Periodontics, School of Dentistry,
UNESP—São Paulo State University,
Araraquara, São Paulo, Brazil

Introduction

A major objective in the treatment of periodontitis is to reduce supra- and subgingival plaque, dental calculus, and prevent recolonization of periodontal pockets by pathogenic bacteria [2, 4, 12, 19, 25, 30]. Previous studies have reported beneficial results from scaling and root planning in both clinical and microbiological aspects [8, 16, 24–26, 33].

Machine-driven instruments (sonic and ultrasonic devices), curettes, laser, and rotating burs are currently used to remove dental plaque, calculus and contaminated root cementum [9, 13, 15, 18, 24]. Among the difficulties associated with calculus removal are limits of tactile sensitivity, uncertainty about the sharpness and effectiveness of hand instruments, uncontrolled damage to the root, and the amount of time needed to accomplish therapeutic goals [5, 6, 10, 14, 15, 20, 23, 29].

Ultrasonic instrumentation is as effective as hand scaling for plaque and calculus removal and the successful healing of diseased periodontal tissues [7, 10, 14, 23, 27–29]. It is established that ultrasonic scalers can remove dental plaque and calculus primarily by the mechanical chipping action of the scaler tip. There are two additional mechanisms that may aid in the removal of such deposits from the tooth surface. In the first, high energy shockwaves, which under cooling water supply, produce a phenomenon called cavitation (defined as the oscillation of air bubbles and the subsequent implosion in liquid medium). In the second mechanism, acoustic microstreaming patterns are formed close to the surface of the scaler tip. However, cavitation and acoustic microstreaming have only been found to contribute to the removal of dental plaque and calculus in vitro [13, 17, 21, 22, 27, 31–33].

Ultrasound can be produced by magnetostriction or piezoelectricity. It is questionable whether piezoelectric systems are superior to magnetostrictive systems. Direct comparisons of both types of devices (in vitro), regarding calculus removal and tooth surface roughness following instrumentation, have shown that the piezoelectric system removes calculus more efficiently, but leaves the instrumented tooth with a rougher surface topography. However, others studies reported that root surfaces subjected to the piezoelectric device were smoother than those following instrumentation with the magnetostrictive device [7, 11].

The surface roughness can influence the supragingival and subgengival plaque formation. Therefore, there is a the demand for smooth surfaces in order to minimize plaque formation, thereby reducing the occurrence of caries and periodontitis [24, 26].

The aim of this investigation was to compare root surfaces instrumented by piezoelectric and magnetostrictive ultrasonic devices in teeth exhibiting advanced periodontal disease.

Materials and methods

Sample

This study was approved by the Joint Research and Ethics Committee of the State University of Ponta Grossa (SUPG; Protocol: 1080/04). Fourteen patients, aged 35–69 years, with advanced chronic periodontal diseases, participated in this study. Each patient attended the Department of Periodontology at SUPG and had two or more teeth extracted for periodontal and prosthetic reasons. All participants signed a consent form, May 2004 through December 2004, after being informed of the nature of the study.

Inclusion criteria were single root teeth (incisors and canines) with evidence of chronic inflammatory periodontal disease and a 3–5 mm pocket, a clinical attachment loss of 8 to 12 mm (UNC 15 mm periodontal probe- Hu-Friedy do Brasil, Rio de Janeiro, RJ, Brazil), bone loss ≥ two-third of the root length (radiographical exam), presence of subgingival calculus detected with an explorer probe and mobility grade 2 and 3. Exclusion criteria were acute periodontal or endodontic infection, periodontal treatment on the last 5 years, root surface caries or any subgingivally placed restorations, and aggressive periodontitis.

Two root surfaces (buccal and lingual) of each tooth were subjected to debridement. Following the debridement, teeth were assigned to three experimental groups of ten teeth each and a control group consisting of five teeth: group 1—piezoelectric ultrasonic device (Jet-Sonic™ Gnatus, Ribeirão Preto, SP, Brazil) the vibrations are produced by oscillations using a quartz crystal handpiece, set at a frequency of approximately 29,000 Hz with a 10p tip; group 2—magnetostrictive ultrasonic device (Cavitron 3000™ Dentsply, York, PA, USA) the vibrations are produced by a resonating stack of metal strips, at a 25,000 Hz frequency with P-10 tip; group 3—hand instrumentation (Gracey curette #.5/6- Neumar Instrumentos Cirúrgicos Ltda, São Paulo - SP, Brazil); and group 4, untreated teeth (control), included only in planimetric analysis. The water-cooled ultrasonic devices were operated at medium power. The allocation process was randomized (tooth-based). Curettes were sharpened using an India medium stone before treatment.

Clinical procedures

Supra and subgingival instrumentation were performed by a single operator (general dental practitioner) with local anesthesia in one session. Scaling and root planning was judged to be complete when the #.17/23 explorer (Neumar Instrumentos Cirúrgicos Ltda, São Paulo - SP, Brazil) indicated a smooth hard surface. No splinting was made for instrumentation. No time limit was placed on the operator for the mechanical debridement.

Following instrumentation, a small diamond round burn (#.2) on a high-speed handpiece was used to mark the level of the free gingival margin, buccally and lingually. This groove provided a landmark for future evaluation and the tooth was extracted as atraumatically as possible, with the beak of the extraction forceps above the gingival margin. The tooth was washed in running water for 30 s to remove blood and debris and stored in a 10% buffered formalin solution.

Staining of teeth and photographs

The teeth were transferred to 1% methylene blue for 2 min to stain attached connective tissues and were then rinsed with running water for 2–3 min. The teeth were aligned parallel to the horizontal plane and photographed by digital camera (Sony Cybershot DSC 707, Sony Brasil Ltda, São Paulo—SP, Brazil) with 5.0 megapixels resolution. The image for each surface had a black background with a millimeter reference in focus below the tooth.

Evaluation of stained deposits

The presence of plaque and calculus on root surfaces was measured using a planimetric analysis tool (Image Tool™ software, UTHSC, San Antonio, TX, USA). The surface area under investigation was determined coronally by gingival groove (bur mark) and apically by border of connective tissue attachment. Laterally, the margins were set 0.5 mm apart from the line angle tooth (Fig. 1a). Within these boundaries, the root surface area covered by residual deposits was measured by a single trained examiner (mask manner).

The measurements for root deposits were repeated three times on different days (within 24 h) and the average was taken. Final measurements were obtained in square millimeters (mm^2) on total analyzed stained deposits.

Roughness parameters evaluation

After deposits analysis, all teeth were longitudinally sectioned, obtaining two surfaces for each tooth (Buccal and Lingual surface—total = 20 surfaces for group). There were 14 surfaces (7 buccal and 7 lingual) selected randomly per group and used for roughness evaluations. The roughness of the root surface was determined in micrometer (μm) using a surface profilometer (Surftest 301™, Mitutoyo Sul Americana, Suzano, SP, Brazil) and a sensor (831–798) with a Ø=2 μm. For this purpose, three lines were traced horizontally (mesio-distal) and vertically (coronal-apical), considering the center of the instrumented area (Fig. 1b). The measurement was performed with a 0.25-mm cutoff and 1.25-mm measurement length and used a 2CR filter (circuit with capacitors and resistors) to separate the components of a surface profile, high frequency corresponded with roughness and low frequency corresponded with radicular waviness. Surface profile was determined as average roughness (R_a), defined as the mean between peaks and valleys of the surface profile, total roughness (R_t) which means that the distance between maximum peak to valley height, R_y(DIN) is the largest roughness considered all the cutoffs (higher peak and higher valley) and R_z(DIN) is the mean of five peaks and five valley height in each cutoff. R_a and R_z are average roughness parameters and they are not enough to distinguish surfaces that differ in shape or spacing. Therefore, it is necessary to calculate other parameters for a surface that measure peaks and

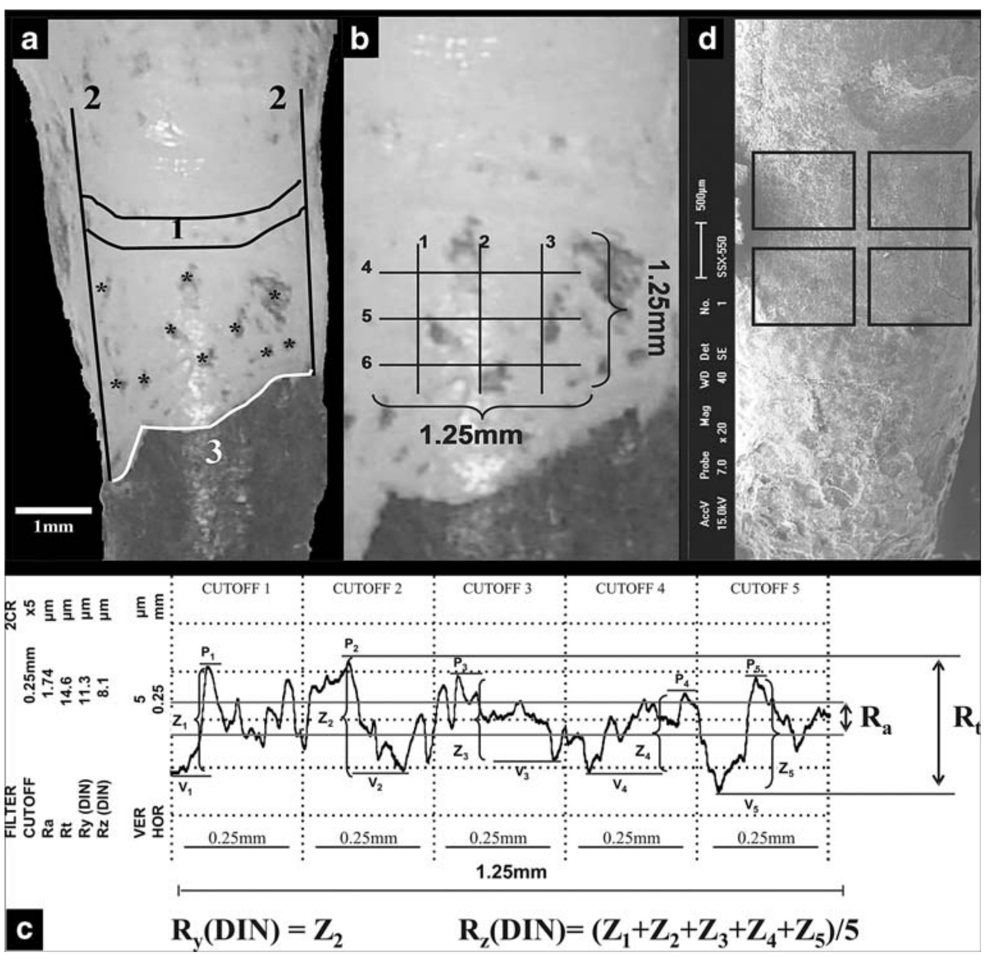

Fig. 1 a Root surface after subgingival instrumentation. Digital planimetric root surface analysis after staining with methylene blue. The area was determined by groove (gingival margin level) of the diamond bur (*1*), the lateral margins (*2*) and the border of the connective tissue attachment (*3*). Residual deposits (*asterisk*). **b** Analysis of radicular roughness. six measures, traced three horizontal and vertical lines. **c** Plot of roughness surface obtained with the surface profilometer: Parameters—R_a (average roughness) defined as the mean between peaks (*P*) and valleys (*V*) of the surface profile; R_t (total roughness) is the distance between maximum *P* to *V*; R_y (DIN) is the largest roughness considered all the cutoffs (higher peak and higher valley) and R_z (DIN) is the mean of five peaks and five valley height in each cutoff. **d** Four micrographs were taken from each specimen (×100) valleys (total roughness) such as R_y and R_t (Fig. 1c). Before the experiment, the surface profilometer was calibrated against a standard device. Data for the root surface roughness values were then plotted separately for R_a, R_t, R_y and R_z [1, 7, 11, 28].

Scanning electron microscopy

A total of 6 surfaces/group (3 Buccal and 3 Lingual) were evaluated by scanning electron microscopy (SEM). All specimens were prepared for critical point drying using a graded series of ethanol (25, 50, 75, 95, and 100%). After drying, each specimen was mounted on metal stubs, coated with 25 nm of gold. The scanning electron microscope (Shimadzu SSX 550™, Shimadzu do Brasil Comércio Ltda, São Paulo, SP, Brazil) was operated at 15 kV. Four standardized micrographs were taken of each specimen at ×100 magnification (Fig. 1d). The surfaces were examined for structure loss and amount of cementum present, damage, corrugated, scratches, and cracks.

Statistical analysis

Sample size was obtained by a previous pilot study (unpublished data) using a statistical program (nQuery Advisor™ version 4.0 for Windows, Statistical Solutions, Saugus, MA, USA).

Before the planimetric evaluation, the examiner was trained and calibrated in two phases: (1) measurements in five teeth to standardized area measured; (2) repeat measurements in 20 randomly surfaces at two different timepoints (within a 24 h interval). The intraexaminer repeatability was made by Bland and Altman procedure [3].

The results of the planimetric and roughness parameters (R_a, R_t, R_y and R_z) were computed as means and standard error (SE). Statistically significant differences among groups (planimetric and roughness parameters) were evaluated by one way ANOVA with Tukey's post hoc test. To fit the requirements for this method (normal distribution and equal variances), the raw data were logarithmically transformed (only planimetric evaluation). The normal distribution of data was tested by the Shapiro-Wilks test and the homogeneity of variances was tested using Levene's test. The relationship between radicular stained deposits and surface roughness parameters was obtained using the Pearson correlation test. The significance levels were set at α=5% ($p \leq 0.05$). The analyses were performed using a statistical program (SPSS™ version 11.5.1 for Windows, SPSS do Brasil, São Paulo, SP, Brazil). The SEM evaluation was done qualitatively.

Results

Intraexaminer repeatability (stained deposits measurements) was in the limits of agreement (Bland and Altman plot—Fig. 2).

There were 35 teeth included for evaluation, providing 70 root surfaces for the analysis. The data of the total area and stained deposits showed normality distributed and equality variances ($p > 0.05$).

Evaluation of stained deposits

The total area analyzed was not significantly different (p= 0.135, ANOVA; Power test = 77%) among the groups: group1 (Piezoelectric, 22.16±3.36 mm^2), group 2 (magnectoestrictive, 18.01±1.94 mm^2), group 3 (Curette, 17.42± 2.04 mm^2) and group 4 (control untreated, 21.38± 3.70 mm^2).

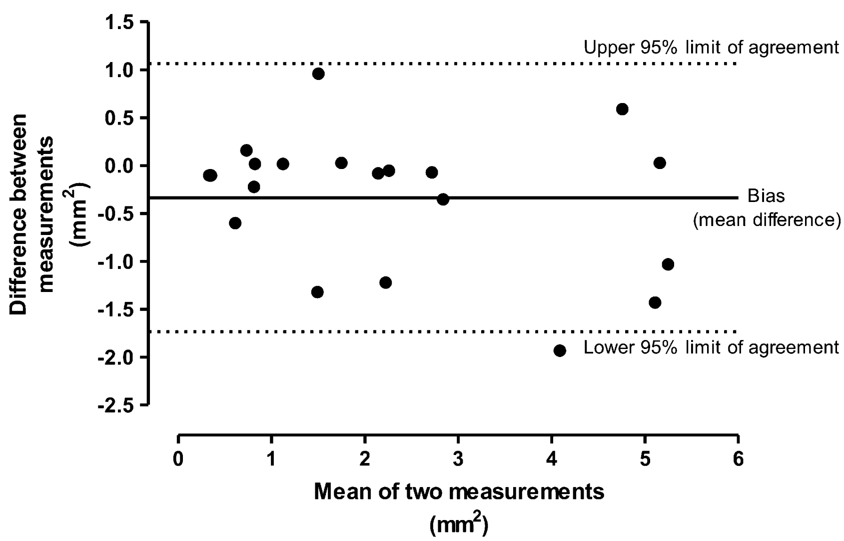

Fig. 2 Intraexaminer repeatability. Bland-Altman plot of the data obtained by repeat measurements in two different timepoints. One point is superposed

The remaining identifiable stained deposits were similar in all experimental groups. For all the analyzed teeth, the mean percent for stained deposits was: group 1, piezoelectric 8.7% (1.94±0.27 mm^2); group 2, magnetostrictive 9.7% (1.73±0.36 mm^2); group 3, curette 11.1% (2.24± 0.46 mm^2) and control 76.4% (17.36±3.59 mm^2). There were statistically significant differences ($p<0.0001$, Tukey's post hoc test) between the control group and all the experimental groups (Fig. 3).

Roughness parameters evaluation

The roughness values, R_a and R_z, of the roots treated showed a similar pattern among the groups ($p>0.05$—ANOVA, not statistically significant difference, Power test = 63 and 55%, respectively). The mean and standard deviation for the groups were: group 1 (R_a=4.1±1.3 µm and R_z=14.4± 4.3 µm), group 2 (R_a=4.4±1.4 µm and R_z=13.8±4.2 µm) and group 3 (R_a=5.2±1.7 µm and R_z=16.3±4.6 µm). However, significant differences for R_t and R_y were observed ($p<0.05$, ANOVA) among curette (R_t=38.4±10.0 µm and R_y=34.3±9;4 µm) and ultrasonic instruments (piezoelectric, R_t=29.4±9.6 µm and R_y=25.6±7.8 µm; magnetostrictive, R_t=30.2±6.1 µm and R_y=26.4±6.4 µm). These findings showed that curettes produced deepest gouges (Fig. 4). In the group 4 (untreated teeth) roughness parameters were not evaluated because surface profilometer sensor was out of the reading range (irregular radicular surface due to the presence of heavy calculus deposits).

The relationship between roughness parameters and radicular deposits (mm^2) were not significant ($p>0.05$, Pearson correlation; Fig. 5).

Scanning electron microscopy

In group 1 (piezoelectric), in all subjects, cementum was present and the radicular surface appeared irregular with few corrugations. A reduced number of instrumental scratches and gouges were observed. Few dentine substance was lost. Cracks were presented in this group (Fig. 6a).

In group 2 (magnetostrictive), the majority of the samples had all the cementum removed and the radicular surfaces appeared irregular with few corrugations. Decreased number of instrumental scratches and gouges were observed. Dentine substance was lost to a greater extent than that observed in group 1. A few cracks were observed in this group (Fig. 6b).

In group 3 (hand instrumentation, Curette), cementum was observed in few points and the radicular surface appeared regular with few corrugations. Many instrumental scratches and deep gouges were observed. A significant amount of the dentine layer was removed. Surface cracks were absent (Fig. 6c).

After instrumentation, all groups were covered by smear layer, which made difficult to distinguish cementum from dentine. Gouges, probably corresponding to the instruments tips, were found on all surfaces. Magnetostrictive ultrasonic manipulation resulted in a smooth root surface with small pits. Under high magnification (×100), the surfaces alternated between smooth patches and those that were pitted and irregular. In these samples, the cementum was better conserved. In piezoelectric group, the root surfaces appeared less smooth and more irregular than magnetostrictive device. A greater number of gouges or depressions were observed. More cementum seemed to be removed in group 2.

Discussion

Many studies have demonstrated the effectiveness of basic periodontal therapy procedures for the resolution of clinical signs of periodontal diseases. A therapy consisting of oral hygiene instruction and supra and subgingival debridement

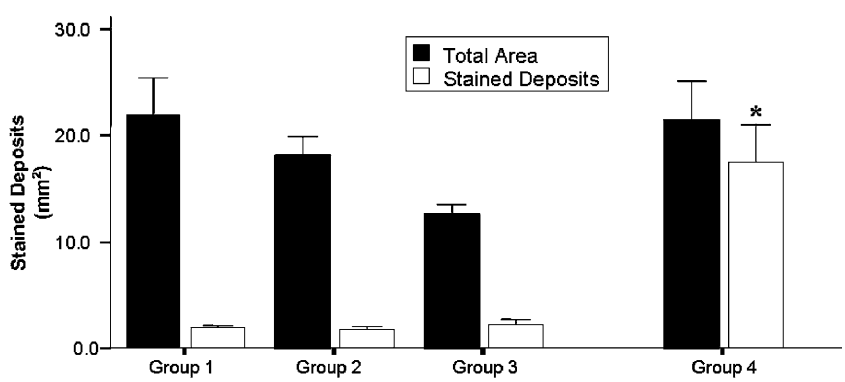

Fig. 3 Mean and standard error of planimetric root surface following treatment with different instruments: group 1, piezoelectric ultrasonic; group 2, magnetostrictive ultrasonic; group 3, hand instrumentation (Gracey curette); group 4- control (untreated teeth). The graph shows the total area analyzed and stained deposits (calculus and dental plaque) in mm^2. Total area analyzed—not significantly different—p=0.135. Stained deposits—significantly different—*asterisk*, "versus" all the experimental groups—$p<0.0001$. ANOVA and Tukey's post hoc test

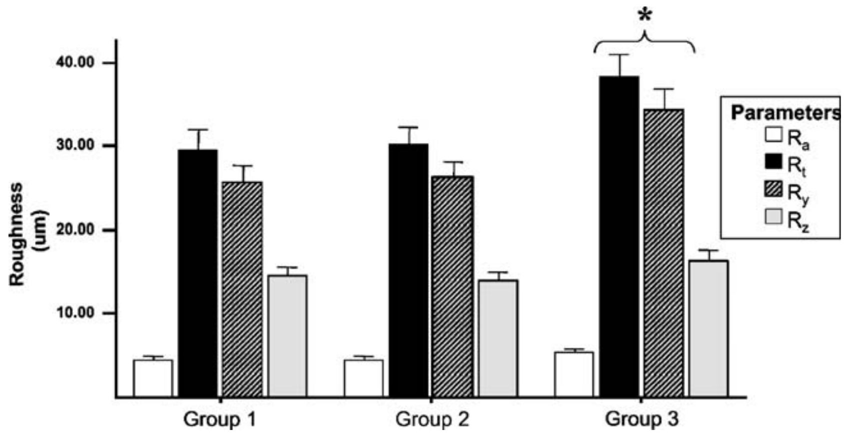

Fig. 4 Mean and standard error of average parameters (R_a, R_t, R_y and R_z) following treatment of the root surface with different instruments: group 1, piezoelectric ultrasonic; group 2, magnetostrictive ultrasonic; group 3, hand instrumentation (Gracey curette). R_a and R_z were not significantly different—$p>0.05$. R_t and R_y, *asterisk*, "versus" Piezoelectric and Magnetostrictive—significantly different—$p<0.05$. ANOVA and Tukey's post hoc test

can effectively improve periodontal conditions [2, 10, 12, 25, 30].

The removal of supra and subgingival plaque and calculus is a prerequisite for successful periodontal treatment. Root surfaces free of plaque and calculus can be created using many different instruments such as curettes, sonic, ultrasonic, laser and rotary instruments [6, 8, 9, 15, 24, 26, 27]. The present clinical study evaluated different ultrasonic instruments and hand instrumentation (curette) with respect to stained deposits, surface roughness, and SEM analysis.

Significant variation in the appearance of stained areas was observed on all teeth surfaces. The results showed similar quantified stained deposits in all groups. All instruments significantly reduced the amount of stained deposits on the root surface. For all the analyzed teeth, the mean percentages were: piezoelectric (8.7%), magnetostrictive (9.7%), and hand instrumentation (11.1%). These results were higher than those obtained by Bussilinger et al. [7]: piezoelectric (1.13%), magnetostrictive (0.21%) and curette (0.62%). For hand instrumentation, Kocher et al. [20], Hurzerler et al. [16], and Eberhard et al. [13] showed 2.5, 4.2, and 6.1% (residual deposits), respectively. Our results were similar to that of Yukna et al. [33] (hand instrumentation, 7.6±7.5%; magnetostrictive, 5.6±5.6%) and Kocher et al. [20] (magnetostrictive, 8.0%). The reasons for these differences are probable due to differences in methodology such as an in vitro study with modified tips and instrumentation with mucoperiosteal flap [7, 16]. Several potential factors were responsible for the less favorable

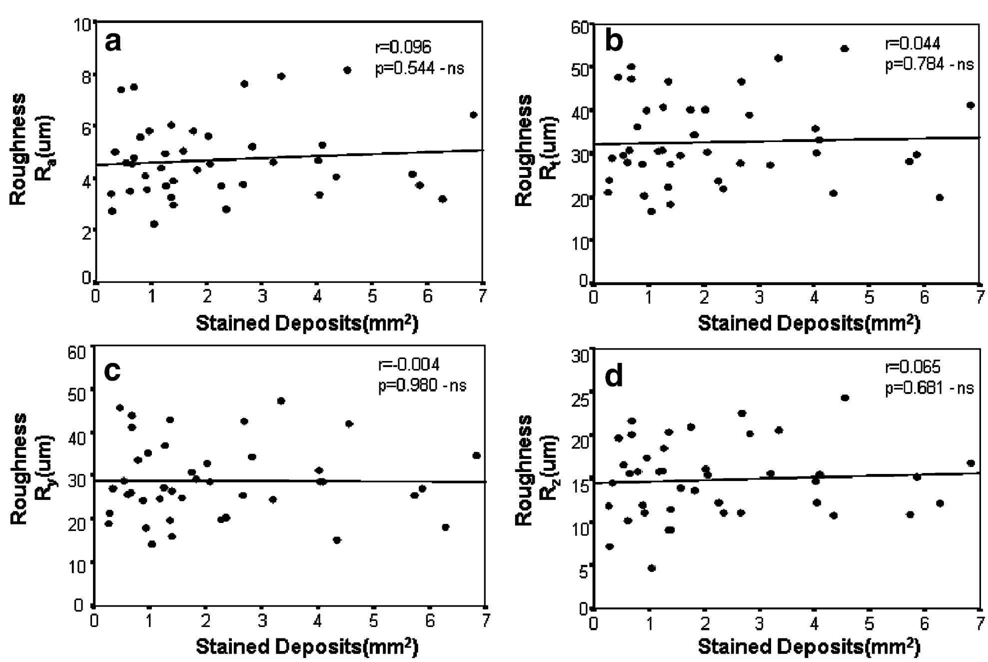

Fig. 5 Pearson correlation test among surface roughness parameters and radicular stained deposits (independent of the treatment). *ns*, not significantly different. **a** R_a, **b** R_t, **c** R_y and **d** R_z

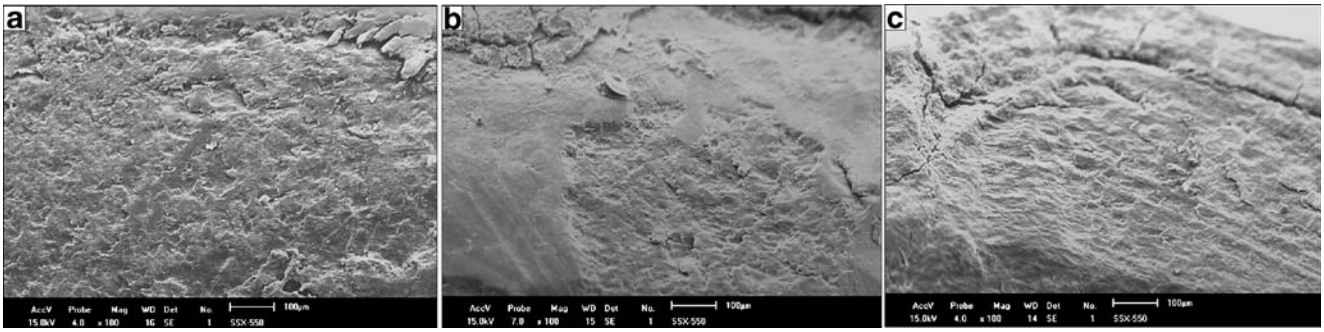

Fig. 6 Radicular surface after treatments. **a** Group 1, piezoelectric—cementum was presented, a little dentine substance was lost. **b** Group 2, magnetoestrictive—dentine substance was lost, more than group 1 and several cracks were present. **c** Group 3, hand instrumentation (Gracey curette)—cementum was observed in few points and many instrumental scratches and deep gouges were observed. Large dentine layers were removed. SEM, magnification ×100

results reported in this study with curette instrumentation. These include teeth conditions, great mobility (grade 2 and 3), decreased precision with curette movement, and lack of experience (the operator who conducted teeth debridement was a general dental practitioner).

All groups had similar amounts of residual stained deposits after scaling. Although the computer planimetric analysis reduces errors associated with measuring the area of stained deposits inherent in the manual planimetric methods, problems still exist. The examiner could not consistently identify lightly stained deposits, since it is difficult for the investigator to obtain reproducible results due to the fact that the intensity of the deposits may not be readily visible.

With regard to the roughness parameters after instrumentation, R_a and R_z values showed a similar pattern. However, R_t and R_y had higher values for hand instrumentation and similar values for ultrasonic devices. For instance, curette debridement produced channels or grooves running along the tooth's long axis. However, a relationship between the roughness parameters and radicular deposits could be observed. Thus, deep grooves were created when a curette skidded or when the ultrasonic device was applied at the wrong angle. In this study, we observed values much larger than those of other investigations [7, 15, 16, 18, 19, 28]. The results were similar to Cross-Poline et al. [11] The main reasons for the difference are the methodology used such as in vitro study, different tips, power setting, intrumentation's time and load. Schlageter et al. [28] used open debridement and roughness was analyzed by profilometer. Huerzeler et al. [16] in their study performed mucoperiosteal flap and roughness analyses used an optical surface sensor system. In the current study, it was necessary to use a relatively short measuring distance to measure surface roughness with surface profilometer, since the sample was not completely flat. Cross-Poline et al. [11] found similar results (R_a and R_t) with ultrasonic and hand instruments, but the curette produced the smoothest surfaces. In our study, it was necessary to consider teeth curvature. On the other hand, we used a filter (2CR) to separate short waves (roughness) from long waves. The filtering could also introduce some bias.

Our results with SEM in piezoelectric and magnetostrictive were similar. The root surfaces appeared irregular with occasional gouges or depressions, but greater loses of dentine substance were observed with magnetostrictive than with piezoelectric devices. After hand instrumentation, we observed instrumental scratches, deep gouges and large dentine layers were removed. The results were different than those obtained by Busslinger et al. [7] in that the magnetostrictive instrument produced a better surface finish than piezoelectric manipulation, with the curette revealing gouges that likely correspond to the curette tip. From our study, it can be concluded that all three scaling instruments tested can produce a calculus free root surface when correctly applied and hand curettes did not produce a smooth surface after instrumentation. Hurzeler et al. [16] and Eberhard et al. [13] showed a smooth and homogeneous surface with traces and scratches after hand instrumentation. Kishida et al. [18] observed a smear layer on root surfaces treated with a Gracey scaler. In an in vitro study, Lee et al. [23] observed that curettes and a magnetostrictive device caused some degree of roughness and loss of tooth substance. Additionally, all instruments produced localized spalling indentations and occasionally some ridging of cementum. Hand and ultrasonic instrumentation, however, considerably produced scratch marks on the root surfaces. Caution should be used when interpreting the studies too strictly as only a limited number of surfaces were examined and the interpretations were purely subjective.

Important factors can be responsible for variations among several studies. Trenter et al. [31] observed displacement amplitude and showed variation not only between tips of different designs but also between those of the same design made by the same manufacturer. In our study, we used five tips for each ultrasonic unit. Jepsen et al. [17], demonstrated that the aggressiveness of magneto-estrictive and piezoelectric ultrasonic device to root substances was significantly influenced by the scaler tip designs. Lea et al. [22] showed that the tip displacement amplitude can vary dramatically between not only the generator type and tip design, but also between tips of the same type used with the same generator.

In conclusion, within the limits of this study, all the three instruments tested could not produce a completely deposit-free surface. Curettes produced deep radicular sulci and the ultrasonic devices produced a smooth root surface.

References

1. Al-Omari WM, Mitchell CA, Cunningham JL (2001) Surface roughness and wettability of enamel and dentine surfaces prepared with different dental burs. J Oral Rehabil 28:645–650
2. Badersten A, Nilveus R, Egelberg J (1981) Effect of non-surgical periodontal therapy. (I). Moderately advanced periodontitis. J Clin Periodontol 8:57–72
3. Bland JM, Altman DG (1999) Measuring agreement in method comparison studies. Stat Methods Med Res 8:135–160
4. Braum A, Krause F, Frentzen M, Jepsen S (2005) Efficiency of subgingival calculus removal with the Vector™- system compared to ultrasonic scaling and hand instrumentation in vitro. J Periodontol Res 40:48–52
5. Brayer WK, Mellonig JT, Dunlap RM, Marinak KW, Carson RE (1989) Scaling and root planing effectiveness: the effect of root surface access and operator experience. J Periodontol 60:67–72
6. Buchanan SA, Robertson PB (1987) Calculus removal by scaling/root planning with and without surgical access. J Periodontol 58:159–163
7. Busslinger A, Lampe K, Beuchat M, Lehmann B (2001) A comparative in vitro study of a magnetostrictive and a piezoelectric ultrasonic scaling instrument. J Clin Periodontol 28:642–649
8. Caffesse RG, Sweeney PL, Smith BA (1986) Scaling and root planning with and without periodontal flap surgery. J Clin Periodontol 13:205–210
9. Chan YK, Needleman IG, Clifford L (2000) Comparison of four methods do assessing root surface debridement. J Periodontol 71:385–393
10. Copulos TA, Low SB, Walker CB, Trebilcock YY, Hefti AF (1993) Comparative analysis between a modified ultrasonic tip and hand instruments on clinical parameters of periodontal diseases. J Periodontol 64:694–700
11. Cross-Poline GN, Stach DJ, Newman SM (1995) Effects of curet and ultrasonics on root surfaces. Am J Dent 8:131–133
12. Dragoo MR (1992) A clinical evaluation of hand and ultrasonic instruments on subgingival debridement. Part I. With unmodified and modified ultrasonic inserts. Int J Periodont Rest Dent 12:311–323
13. Eberhard J, Ehlers H, Falk W, Açil Y, Albers H-K, Jepsen S (2003) Efficacy of subgingival calculus removal with Er:YAG laser compared to mechanical debridement: an in situ study. J Clin Periodontol 30:511–518
14. Fleischer HC, Mellonig JT, Brayer WK, Gray JL, Barnett JD (1989) Scaling and root planing efficacy in multirooted teeth. J Periodontol 60:402–409
15. Folwaczny M, Merkel U, Mehl A, Hickel R (2004) Influence of parameters on root surface roughness following treatment with a magnetostrictive ultrasonic scaler: an in vitro study. J Periodontol 75:1221–1226
16. Huerzeler MB, Einsele FT, Leupolz M, Kerkhecker U, Strub JR (1998) The effectiveness of different root debridement modalities in open flap surgery. J Clin Periodontol 25:202–208
17. Jepsen S, Ayna M, Hedderich J, Eberhard J (2004) Significant influence of scaler tip design on root substance loss resulting form ultrasonic scaling a laserprofilometric in vitro study. J Clin Periodontol 31:1003–1006
18. Kishida M, Sato S, Ito K (2004) Comparison of the effects of various periodontal rotary instruments on surface characteristics of root surface. J Oral Sci 46:1–8
19. Kocher T, Langenbeck N, Rühling A, Plagmann H-C (2000) Subgengival polishing with a Teflon-coated sonic scaler insert in comparison to conventional instruments as assessed on extracted teeth: (I). Residual deposits. J Clin Periodontol 27:243–249
20. Kocher T, Rosin M, Langenbeck N, Bernhardt O (2001) Subgengival polishing with a Teflon-coated sonic scaler insert in comparison to conventional instruments as assessed on extracted teeth: (II). Subgengival roughness. J Clin Periodontol 28:723–729
21. Lea SC, Landini G, Walmsley AD (2002) Vibration characteristics of ultrasonic scalers assessed with scanning laser vibrometry. J Dent 30:147–151
22. Lea SC, Landini G, Walmsley AD (2003) Displacement amplitude of ultrasonic scaler inserts. J Clin Periodontol 30:505–510
23. Lee A, Heasman PA, Kelly PJ (1996) An in vitro comparative study of a reciprocating scaler for root surface debridement. J Dent 24:81–86
24. Leknes KN, Lie T, Wikesjö UME, Bogle GC, Selvig KA (1994) Influence of tooth instrumentation roughness on subgingival microbial colonization. J Periodontol 65:303–308
25. Loos B, Kiger R, Egelberg J (1987) An evaluation of basic periodontal therapy using sonic and ultrasonic scalers. J Clin Periodontol 14:29–33
26. Quirynen M, Marechal M, Busscher HJ, Weerkamp AH, Darius PL, Van Steenberghe D (1990) The influence of surface free energy and surface roughness on early plaque formation. An in vivo study in man. J Clin Periodontol 17:138–144
27. Schenk G, Flemmig TF, Lob S, Ruckdeschel G, Hinckel R (2000) Lack of antimicrobial effect on periodontopathic bacteria by ultrasonic and sonic scalers in vitro. J Clin Periodontol 27:116–119
28. Schlageter L, Rateitschak-Plüs EM, Schwarz J-P (1996) Root smoothness or roughness following open debridement. An in vivo study. J Clin Periodontol 23:460–464
29. Schwarz J-P, Guggenheim R, Düggelin M, Hefti AF, Rateitschak-Plüss EM, Rateitschak KH (1989) The effectiveness of root debridement in open flap procedures by means of comparison between hand instruments and diamond burs. A SEM study. J Clin Periodontol 16:510–518
30. Sherman PR, Hutchens LH Jr, Jewson LG, Moriarty JM, Greco GW, McFall WT Jr (1990) The effectiveness of subgingival scaling and root planning I. Clinical detection of residual calculus. J Periodontol 61:3–8
31. Trenter SC, Landini G, Walmsley AD (2003) Effect of loading no vibration characterist of thin magnetostrictive ultrasonic scaler inserts. J Periodontol 74:1308–1315
32. Walmsley AD, Walsh TF, Laird WRE Williams AR (1990) Effects of cavitational activity on the root surface of teeth during ultrasonic scaler. J Clin Periodontol 17:306–312
33. Yukna RA, Scott JB, Aichelmann-Reidy ME, LeBlanc DM, Mayer ET (1997) Clinical evaluation of the speed and effectiveness of subgingival calculus removal on single-rooted teeth with diamond-coated ultrasonic tips. J Periodontol 68:436–442