Clinical and Experimental
Health Sciences

In Vitro Evaluation of Root Surface Roughness in The Use of an Ultrasonic Device with Different Tips Having Different Mechanism of Action: A Profilometric Study

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Received: 18.10.2021 **Accepted:** 21.12.2021

ABSTRACT

Objective: The aim of this study was the profilometric evaluation of the changes in root surface roughness created by different types of ultrasonic tips and mechanism of action.

Methods: Thirty root dentine samples obtained from 15 maxillary premolars, extracted for orthodontic reasons, were included in the study. The sample surfaces were embedded into acrylic blocks, polished, and divided into 3 study groups as linear oscillating device (LOD) with straight tip (ST); LOD with perio-curette tip (PCT); conventional ultrasonic scaler tip (CUST). A calibrated clinician instrumented all surfaces in each group. The root surfaces were evaluated before and after instrumentations with a profilometer device.

Results: There were no statistical differences between the initial roughness values of the groups ($p<0.05$). Multiple comparisons of after-treatment values and differences before and after instrumentations revealed statistical significances ($p=0.041$; $p=0.016$, respectively). CUST group showed the highest surface roughness in comparison with the LOD groups. LOD with ST revealed the smoothest surface followed by LOD with PCT and CUST.

Conclusion: Within the limits of this study, it may be concluded that fine and delicate tips with linear oscillating movement may be considered as the choice of insert for subgingival instrumentation due to the gentler mechanism of action than the conventional ultrasonic scalers.

Keywords: in-vitro, profilometer, root debridement, surface roughness, ultrasonic device

1. INTRODUCTION

Periodontal diseases are multispecies microbial infections, characterized by continuous passage and thread of microorganisms from external environment into the periodontal tissues and the human body. Oral microorganisms are organised in the oral cavity as biofilms on desquamation free, non-shedding hard surfaces as the main etiological factor. The accumulation and attachment of microbial dental plaque biofilm are facilitated by retentive areas including rough root surfaces (1). The corner stone of anti-infective non-surgical approaches as the first phase of periodontal treatment protocol is the mechanical debridement for physical removal of biofilm and other disease mediating factors contaminating hard surfaces, namely the root surfaces (2, 3).

Sonic/ultrasonic devices, hand instruments (such as scalers and curettes), lasers and rotating burs are widely used to remove tooth-surface associated biofilm, calculus, and contaminated root cementum (4-6). Although hand instruments together with sufficient time/manual dexterity are accepted as the gold standard, ultrasonic devices with various tips are also considered as options during periodontal treatment (7,8). Power-driven ultrasonic scalers are mostly used in daily routine practice and have become increasingly popular for subgingival debridement due to less operator strain, similar effectiveness with hand tools, newly designed tips, and effective debridement (9, 10). Although periodontal therapy with power driven devices do indeed offer some clinical advantages to the clinician, there are still some conflicting results and issues to be solved. Different results have been shown in the literature regarding the physical effects of magnetostrictive and piezoelectric ultrasonic scaling devices on tooth surfaces (11,12).

The amount of removed root substance during subgingival instrumentation is as important as the removal of bacterial deposits (13), since the clinician may end up with excessive root surface roughness leading to increased sub-gingival plaque retention (13,14). Besides the aforementioned factors, the type, and the tips of the ultrasonic devices as well as the orientation, the distance, and the movement of the tip in relation to the root surface are of critical importance to avoid harmful effects.

DOI: 10.33808/clinexphealthsci.1010944

This is an open research area to overcome the limitations and disadvantages (7,14-16). Novel tools are continuously being designed and developed. A power-driven ultrasonic device presenting linear oscillating movement has been introduced in the market as a gentle and effective alternative tool for mechanical periodontal therapy. The tips of this new linear oscillating device (LOD) move linearly parallel to the root surface during instrumentation (17). In a limited number of studies, this device, avoiding horizontal vibrations, revealed better patient perception with less pain compared to other power-driven instruments (18,19) and caused less hypersensitivity compared to hand instruments (20,21). The unique vertical vibrational energy of the instrument is transmitted to the tooth and root surface as well as to the periodontal tissues in conjunction with or without a hydroxyapatite (HA) particle containing fluid. The use of the device with water or polishing fluid directed to the instrument tip helps to soft and hard debris removal occurring through hydrodynamic forces rather than by the chipping action of the conventional ultrasonic tips (22-24).

Therefore, the aim of this study was to evaluate the effects of two subgingival tips of the LOD in comparison to a scaler tip of the conventional ultrasonic system on the roughness of the root surfaces following non-surgical periodontal instrumentation in vitro.

2. METHODS

The present study was approved by Yeditepe University, Dentistry Faculty Scientific committee and Ethical Board of Yeditepe University (number:37068.608.6100-15-2228/13.10.2021). The sample calculation was carried out with another vitro research (25): a:0.05, power (β) of 80%, d effect size of 1.365 for the mean surface roughness (Ra) parameter and SD of 1.5. The sample number was calculated to be minimum of 10 in each group.

Fifteen human maxillary premolar teeth, freshly extracted for orthodontic reasons, were used. Teeth with cracks, large carious lesions, or restorations were excluded. Care was taken to keep the root surfaces intact during extraction. Immediately after extraction of the teeth, they were rinsed in running tap water for approximately 20 seconds to remove the surface debris or blood. Afterwards stored in 4°C distilled water with thymol as a preservative to inhibit microbial growth until their use (26).

2.1. Sample Preparation

Dentine specimens obtained from 15 teeth were prepared as described in a previous study (27). After preparation procedures, 30 dentin samples with a thickness of 5 mm were randomly divided into 3 groups through a randomization table (randomlists.com). To avoid the inclusion of the two pieces of the same teeth in the same group, the halves were coded as a and b and then distributed. The prepared dentine specimens were mounted in a specially designed rectangular cast filled with acrylic resin keeping either of the two surfaces (buccal/palatal) exposed without any visible surface irregularities. The specimen surfaces were wet-polished with a sequence of silicone carbide papers 320.600.1200-and 2000 grit). All specimens were rinsed with sterile water solution and air dried.

2.2. Application Groups

Straight Tip Group (ST) (n=10).

Perio Curette Tip Group (PCT) (n=10).

Conventional Ultrasonic Scaler Tip Group (CUST) (n=10).

2.3. Application Procedures

In a previous study (27), an experienced periodontist (OLT) was educated and calibrated to operate with stable lateral forces for both power-driven and hand instruments according to calibration methodology (1,8,28,29). The pressure was aimed to 40 g for power-driven instruments.

All tips were used in connection with the same ultrasonic device (Vector® Paro Pro, Dürr Dental, Bietigheim-Bissingen, Germany), consisted of two different handpieces, one specially designed for linear oscillating movement (Vector Paro Handpiece, 25-35 kHz operating frequency) and the other with conventional scaler handpiece generating a spatial vibration (Vector Scaler Handpiece, 25-35 kHz operating frequency) (Figure 1).

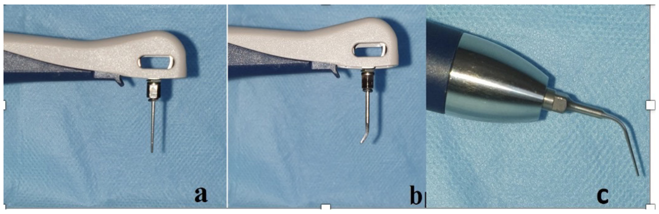

Figure 1. *Vector® Paro and Vector® Conventional Ultasonic tips used in treatment groups a) straight tip, b) perio-curette tip c) ultrasonic scaler tip*

ST, like a periodontal probe in shape and PCT, like a periodontal curette, were used only with water according to the setting instructions given by the manufacturer (70% power setting), while CUST (P1) was used through conventional piezoelectric ultrasonic handpiece and settings for the instrumentation of the specimen surfaces.

For Paro handpiece, HA particle containing fluid was intentionally not used during the application to avoid the possibility of jeopardizing the profilometer readings of roughness, since it provides a polished surface after usage. The water was not in spray aerosol form but held hydrodynamically on the instrument by the linear ultrasonic movement (21).

The tips were guided by a parallel position (0°) hold onto the specimen surfaces in contact mode and applied in an imbricate sweeping movement without pressure during surface scanning of 30 sec.

2.4. Profilometer Roughness Calculation

Surface roughness of all dentin specimens were evaluated before and after instrumentation procedures with a profilometer (Perthometer M1 Mahr, Göttingen, Germany) as described in a previous research (27). For each specimen, 5 measurements were recorded at different locations and in different directions (blinded, EÖK). Ra (µm) was taken as the average value of these five readings. The surface-roughness tester was used during the whole evaluation to periodically calibrate the profilometer (Mahr GmbH, Göttingen, Germany).

2.5. Statistical Analysis

Surface Ra was chosen as the primary outcome variable. IBM SPSS Statistics 22 Program (SPSS IBM, Turkey) was used for statistical analysis. Kolmogorov-Smirnov and Shapiro Wilks tests were used to evaluate the normal distribution of the data. Owing the fact that parameters did not show a normal distribution, Kruskal Wallis test was used for comparing the parameters between the groups, whereas Dunn's test was used for the paired evaluation when a significant difference was detected in multiple comparison. Wilcoxon sign test was used for intra-group comparisons. Significance was set at $p < 0.05$.

3. RESULTS

All groups showed Ra increases in intra-group comparisons (p=0.028). No significant difference was detected between the initial roughness of the groups before instrumentation (Table 1). Multiple comparisons of after-treatment values and differences before and after instrumentations revealed statistical significances (p=0.041; p=0.016, respectively). When after-treatment mean values and mean differences between the groups were evaluated in pairs, statistical significances were detected between the groups of (ST and CUST) (p= 0.031; after-treatment) (p=0.035; mean difference), (PCT and CUST) (p= 0.027; after-treatment) (p=0.017; mean difference) (Figure 2).

***Table1. Roughness** values of the groups*

	ST	PCT	CUST	
Roughness (µm)	Mean±SD (median)	Ort Mean±SD (median)	Mean±SD (median)	[1]p
Before	0.17±0.03 (0.17)	0.15±0.06 (0.13)	0.16±0.04 (0.14)	0.523
After	0.27±0.02 (0.26)	0.24±0.12 (0.22)	0.46±0.25 (0.38)	0.041*
[2]p	0.028*	0.028*	0.028*	
Difference	0.10±0.04 (0.1)	0.09±0.09 (0.05)	0.30±0.21 (0.23)	0.016*

*[1]Kruskal Wallis Test [2]Wilcoxon sign test [*a] significant difference (p<0.05).*
ST: Scaler tip, PCT: Perio-curette tip, CUST: Conventional ultrasonic scaler tip

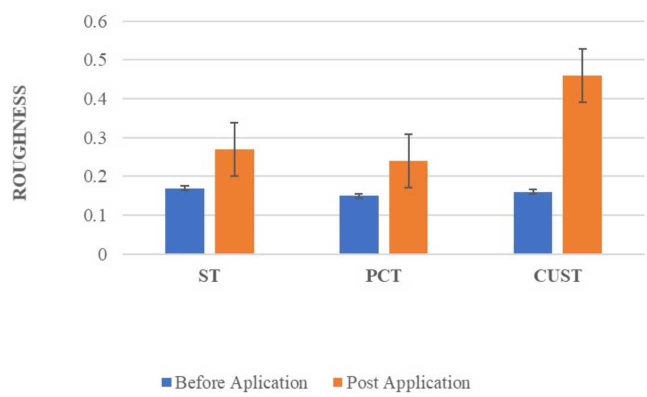

***Figure 2.** Diagram of roughness changes after surface instrumentations with straight, perio-curette and conventional ultrasonic scaler tip*

5. DISCUSSION

The main goal of nonsurgical periodontal therapy is to reduce or to eliminate the amount of tooth associated biofilms and their biological products, such as bacterial endotoxins, antigens, enzymes and other tissue-irritating substances on root surfaces (30). Nominately both primary etiologic factor as supra/subgingival plaque biofilm and other disease contributing factors on the root surfaces should be removed during nonsurgical periodontal therapy. These can be achieved through especially changing the subgingival environment by root debridement procedures. Instruments that are used for root debridement include hand instruments, ultrasonic devices, air-powder abrasive systems, and lasers etc.

The root surface roughness influence the supragingival and subgingival plaque biofilm formation (31). Conventional root instrumentation with curettes removes root irregularities that harbor plaque and calculus, and renders the diseased root surfaces free of detectable endotoxins (32-34). Therefore, there is a demand for smoothness on after-treatment surfaces in order to minimize plaque formation, thereby reducing periodontal or restorative needs. The roughness of the root surface after debridement is a factor to consider for maintenance, because it has been shown that bacterial plaque biofilm adheres easily onto rough root surfaces (35) and initial bacterial adhesion always occurs on surface irregularities (31).

According to the literature, ultrasonic devices are less time consuming but leave more rough surfaces after instrumentation compared to hand instruments (36). However, it has been found that new age ultrasonic systems are described as delicate but also effective in removing plaque and calculus (24). The results of our present study showed that the LOD application with oscillating vertical movements on root surfaces seemed to be gentler with regards to roughness parameters than the conventional ultrasonic scaler. It has been proposed that Ra value of 0.2 µm was the threshold of initial bacterial adhesion on root surfaces

(31). Ra for both the ST (0.27±0.02 µm) and PCT (0.24±0.12 µm) was close to this threshold value even without using the polishing liquid of the LOD system containing HA particles, expected to smoothen the surface. On the other hand, Ra value in the literature for various sonic or ultrasonic devices varies within a range from 0.6 to 1.8 µm (37,38). The CUST result of this present study (0.46±0.25 µm) was found below this range, but greater than ST and PCT Ra values. In this study LOD tips caused the least amount of roughness increase and the results are compatible with the findings in the literature as above.

The used new generation LOD instrument with two different fine tips comprises a ring-shaped resonant body vibrated by an ultrasonic drive (at 25kHz), which is attached to the working end at an angle of 90°. This configuration eliminates ellipsoid vibrations of the tips moving in a plane parallel to the tooth surface, contrary to the horizontal vibrations in conventional ultrasonic scalers (17). As a result, the tips move parallel along the axis of the special handpiece presenting an obvious difference mechanism of action. One of the limitation of this in vitro study maybe the performance of the tested instrument are expected to be higher due to lack of one-to-one stimulation of the oral conditions.

6. CONCLUSION

In conclusion, the root surface roughness with the investigated ultrasonic system significantly depends on the selection of handpieces and tips. Within the limits of this study, fine and delicate tips with linear oscillating movement may be considered as the choice of insert for subgingival instrumentation due to the gentler mechanism of action than the conventional ultrasonic scalers.

Disclosure Statement

The authors do not have any financial interest in the companies whose materials are included in this article.

Acknowledgement

The authors would like to express their sincere gratitude to Prof. Dr. Bahar KURU for her guidance and contributions to their research.

Conflict of Interest

The authors declare that they have no conflict of interest.

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How to cite this article: Ozkan Karaca E, Tunar OL. In Vitro Evaluation of Root Surface Roughness in The Use of an Ultrasonic Device with Different Tips Having Different Mechanism of Action: A Profilometric Study. Clin Exp Health Sci 2022; 12: 310-314. DOI: 10.33808/clinexphealthsci.1010944