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Effect of Different Scaling Methods and Materials on the Enamel Surface Topography: An *In Vitro* SEM Study

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Abstract

Aim: Scaling is important for maintenance of gingival and periodontal conditions. These procedures have a harmful effect on the dental hard tissues. The aim of this study was to investigate the effects of hand and ultrasonic instruments made of stainless and titanium on the surface properties of enamel. **Materials and Methods:** Forty extracted premolars were used in this *in vitro* study and were randomly divided into four groups ($n = 10$). Group I received ultrasonic scaling with stainless steel tip, group II received ultrasonic scaling with titanium tip, group III hand scaling with stainless steel tip, and group IV hand scaling with titanium tip. Scanning electron microscopy (SEM) was used to examine the enamel surface morphology. Surface roughness of enamel was measured at baseline and after the scaling simulation using atomic force microscopy (AFM). Differences between initial and final measurements of surface roughness (ΔRa) were analyzed using two-way analysis of variance (ANOVA) followed by *post hoc* pairwise comparisons between groups. **Results:** SEM revealed deeper scratches and more destructive changes on enamel surface in group IV, whereas other groups revealed less change. AFM revealed that a mean surface roughness difference (ΔRa) had the highest value with hand instruments using titanium curettes, whereas the lowest difference was found with ultrasonic tips using stainless-steel tips. Hand titanium curettes showed a statistically significant increase in ΔRa when compared to hand stainless steel curettes ($P = 0.02$) and ultrasonic titanium tips ($P = 0.01$). Hand stainless steel tips showed a statistically significant increase in ΔRa when compared to ultrasonic stainless steel tips ($P = 0.02$) and hand titanium curettes ($P = 0.02$). **Conclusion:** Scaling using ultrasonic stainless steel tips produce the least amount of surface roughness and damage to the tooth surface.

Keywords: Atomic Force Microscopy, Electron Microscopy, Enamel, Scaling, Surface Roughness

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INTRODUCTION

Bacterial plaque or biofilms are described as organized structures consisting of microcolonies of bacterial cells, distributed in a shaped matrix or glycocalyx.[1,2] In relation to the oral cavity, it is termed dental plaque and it subsequently mineralizes to form hard deposits termed calculus.[3] The majority of patients suffer from gingival inflammation in response to this plaque, which eventually progresses to periodontitis. Bone destruction and tooth loss are the main consequences following periodontitis which is considered one of the most common oral diseases.[4] Successful management of the periodontal diseases is of great significance in preventing irreversible bone destruction and tooth loss. This is based on regulating the dental plaque and restriction of further progression of the disease. Different treatment methods such as standard nonsurgical strategies, gingival curettage, laser treatment, and regenerative procedures can be used.[5-10]

American Academy of Periodontology proposed that any procedures to maintain the gingival and periodontal health should be performed with minimally invasive techniques.[11] These noninvasive treatment methods used to manage periodontal problems include scaling, root planning, and oral hygiene care and are extensively performed routinely in dental practice. The scaling procedure necessitates removal of bacterial plaque, hard calculus, and extrinsic stains from the surfaces of crown and root.[12] Although

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scaling is a very challenging procedure, its role in controlling gingivitis and periodontitis is well-documented.[13]

Scaling is carried out either with hand or ultrasonic scalers. The advantage of hand scaling involves superior management of the instruments and an improved tactile feedback to the operator. It is skill-dependent, time-consuming, and exhausting, whereas sonic and ultrasonic scalers allow access to the furcation and deep pockets and are more time efficient and less tiring to dental practitioners.[14,15]

The mechanism of ultrasonic scalers includes the vibrations that aids in biofilm removal and the acoustic effects of water lavage, and the mechanical chipping action of the oscillating scaler probe when in contact with the tooth surface which assists in the removal of calculus deposit.[16] However, it has been reported that these power-driven scalers can cause roughness of enamel surfaces, a procedure that can be affected by many factors such as procedure time, pressure, and angulation of the scaling tip.[17,18]

Different materials of hand instruments and ultrasonic tips such as stainless steel curettes, rubber cups, plastic curettes, titanium curettes, and air-power abrasive systems have been used in removing plaque from tooth surfaces as well as implants.[19] However, the scaling procedures with these materials can increase surface roughness of tooth surfaces and dental restorations, which will influence color stability and microbial colonization and induce plaque formation. A positive correlation between surface roughness and the rate of supragingival and subgingival plaque deposition has been reported.[20]

Stainless steel curettes are most commonly used for tooth scaling, whereas titanium-coated curettes are specifically made for dental implant debridement because they have a similar hardness to the titanium surface and will not scratch or mark the surface.[21] However, the effect of the use of titanium instruments for tooth scaling has not been investigated. The aim of this study was to investigate the effect of different types of hand and ultrasonic instruments used in scaling on surface properties of enamel.

MATERIALS AND METHODS

Setting and design

This study was conducted to evaluate the effect of two different scaling mechanisms: hand scaling and ultrasonic scaling with scaling instrument material stainless steel and titanium on the surface roughness and surface anatomy of enamel by using atomic force microscopy (AFM) and scanning electron microscopy (SEM).

Sampling criteria

Forty extracted sound human premolars were collected from patients with an average age from 14 to 20 years undergoing extractions for orthodontic purposes. Immediately after extraction, the teeth were scraped of any residual tissue, washed under running tap water, and examined for the presence of cracks or carious lesions and were discarded if found any.

Study method

After removing the roots, the buccal surfaces were cleaned with prophylactic paste (Dharma FL USA 58-00030) to ensure removal of extrinsic stains. Gypsum blocks were used to mount the teeth by inserting the lingual half into the blocks with the highest area of the specimen being the middle third of the buccal aspect [Figure 1].

The specimens were equally (10 in each group) and randomly divided as follows:

Group I: Ultrasonic scaling with stainless steel tip

Group II: Ultrasonic scaling with titanium tip

Group III: Hand scaling with stainless steel tip

Group IV: Hand scaling with titanium tip

Instruments

Ultrasonic instruments: Stainless steel ultrasonic G1 Scaler tip (NSK, Japan).

Titanium nitride ultrasonic G1T Scaler Tip (Woodpecker, Guilin, Guangxi, China).

Hand instruments: Stainless steel curette: Gracey no. 7/8 Hu-Friedy, Chicago, Illinois.

Titanium curette: TI 23 AS2 A. Deppeler Sa, Rolle, Switzerland.

Scaling procedure

A customized apparatus was designed and fabricated to ensure proper standardization of the scaling method. This scaling apparatus consisted of a gearbox to control the speed of the motor. A crankshaft (two cycles/s) connecting rod which is fixed

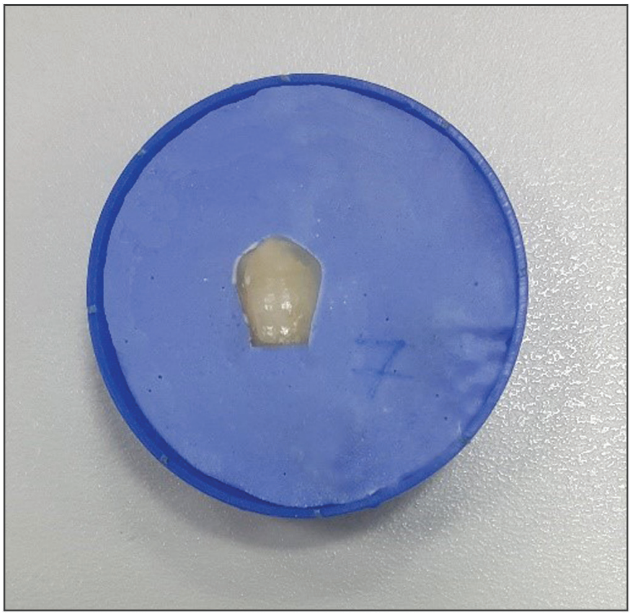

Figure 1: Gypsum blocks specimen

to a slider for changing the movement from rotation to linear movement to deliver a consistent 5mm horizontal movement, double-pane balance to simulate the forces used in manual, and ultrasonic scaling[22] [Figure 2].

Hand scaling

The samples were mounted onto one side of the double-pane balance and attached in place using screws. Each instrument was fixed in the arm using screws with the tip engaged at a 15° angle to the specimen. A constant force of 500 g was applied to the instrument by the vertical movement of counterweighted balance. Fifteen even strokes were made with the hand scaling instruments across the surface of each sample This representing 1 year scaling every 3 months (five times) three successive movements each.[23]

Ultrasonic scaling

The samples were mounted onto one side of the double-pane balance and attached in place using screws. An ultrasonic scaler handpiece was used intermediate power setting (level 5 of 14 grades). The scaling tips were angled 90° relative to the surface of sample. A constant force of 30 g was applied to the ultrasonic scalar tip by the vertical movement of a counterweighed balance.[24] A standardized 5 mm horizontal movement for 30 seconds was achieved. Thirty strokes were made with the ultrasonic handpiece at a speed of 2 Hz was achieved and operated by the control box.[17]

Scanning electron microscopy analysis

Specimens from each group were mounted on the SEM plate to examine their surfaces (Electron Microscopy Sciences, Hatfield, Pennsylvania) using the model Quanta FEG 250 (Field Emission Gun) with accelerating voltage 30 kV. All SEM images were randomized and each image was given a unique code to ensure that image analysis was performed blindly. Two research team members examined each image independently. Both examiners were initially calibrated by examining 10 SEM images (not included in the results) collaboratively to moderate and ensure consistency. The enamel surface morphology was examined on each SEM image for samples from each group after the simulated scaling procedure. Any abnormalities and/or surface defects that are not consistent with normal histological features. The intensity of surface defects was also described on each image as fine, moderate, or deep.

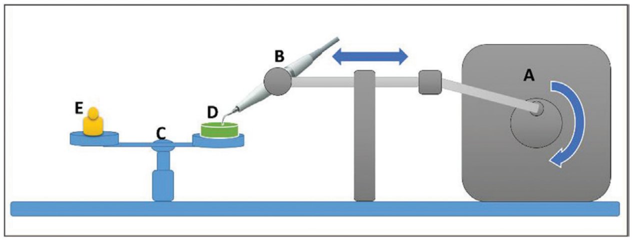

Figure 2: A schematic diagram showing the custom-made scaling and apparatus: (A) gear box, (B) instrument holder, (C) double-pane balance, (D) samples-holding pane, and (E) weight-holding pane

Surface roughness measurement

Initial surface roughness was measured using AFM Auto Probe CPResearch2 (Model: MLCT-MT-A) operated in contact mode using non-conductive silicon nitride probe, at scan area of 25 µm, scan rate of 1 Hz and number of data points 256 × 256 m^2 using proscan 1.8 software for controlling the scan parameters and IP 2.1 software for image analysis served as control. Surface roughness differences (ΔRa) were calculated after measuring the values after the scaling methods.

Statistical analysis

All data were analyzed using computer software SPSS version 21 (SPSS Armonk, New York). Two-way analysis of variance (ANOVA) followed by *post hoc* pairwise comparisons between groups were used to analyze surface roughness differences (ΔRa). A p-value less than or equal to 0.05 was considered statistically significant.

RESULTS

Scanning electron microscope examination

SEM of samples before scaling procedure revealed normal enamel surface with normal surface structures like perikymata and rod end. After scaling, group I teeth samples showed a relatively smooth enamel surface with little fine scratches. Group II showed similar surface morphology with greater change in enamel surface manifested as deep and multiple scratches on enamel surface in comparison to group I, whereas group III showed little scratches became more obvious and deeper than group I, also. Group IV samples revealed the most aggressive effect in regards to the morphology of the enamel surface in comparison to the other groups, scratches are the deepest and more destructive [Figure 3].

Surface roughness

Figure 4 shows the atomic force images before and after scaling procedures for each group.

Ultrasonic stainless steel tips clearly resulted in scraping of the enamel surfaces and loss of their original texture, leading to increased surface roughness. Its surface roughness was increased by 3.58 after scaling [Figure 4-I]. Ultrasonic titanium tips showed more aggressive and deeper scratches than the ultrasonic stainless steel tips. Its surface roughness was increased by 6.67 after scaling [Figure 4-II]. Manual stainless steel scaling showed more number of shallow irregularities than the ultrasonic stainless steel scaling. Its surface roughness was increased by 5.34 after scaling [Figure 4-III]. Manual titanium scaling caused the deepest scratches and highest change in surface roughness. Its surface roughness was increased by 8.97 after scaling [Figure 4-IV].

Two-way ANOVA revealed a statistically significant interaction in ΔRa among all groups ($P = 0.042$) [Table 1].

Comparisons between different experimental groups are summarized in Table 2.

Effect of materials used on ΔRa

For both ultrasonic scaling and hand methods, ΔRa of titanium curettes showed a statistically significant higher difference from that of stainless steel curettes ($P = 0.03$ and 0.02, respectively).

Effect of scaling methods used on ΔRa

For both stainless steel and titanium curettes, ΔRa of hand instruments showed a higher value and a statistically

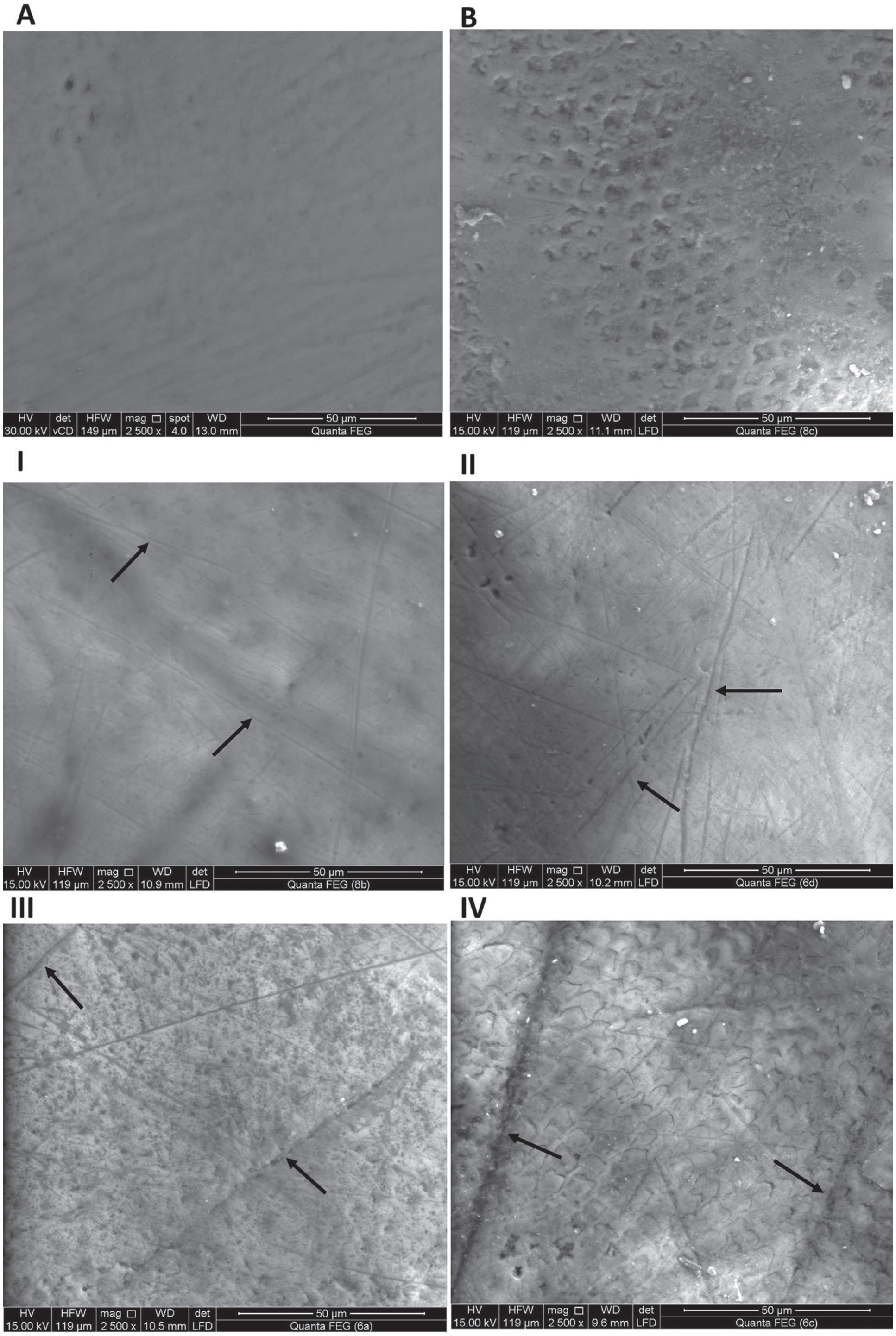

Figure 3: SEM micrographs of normal enamel surface before scaling (A) with normal structures like rod end (B). Experimental groups after the scaling procedure: group I showed smooth enamel surface with little fine scratches (arrows). Group II showed deep and multiple scratches on enamel surface (arrows), whereas group III little scratches became more obvious and deeper than group I, also. Group IV samples revealed that scratches are the deepest and more destructive (arrows). Magnification ×2500

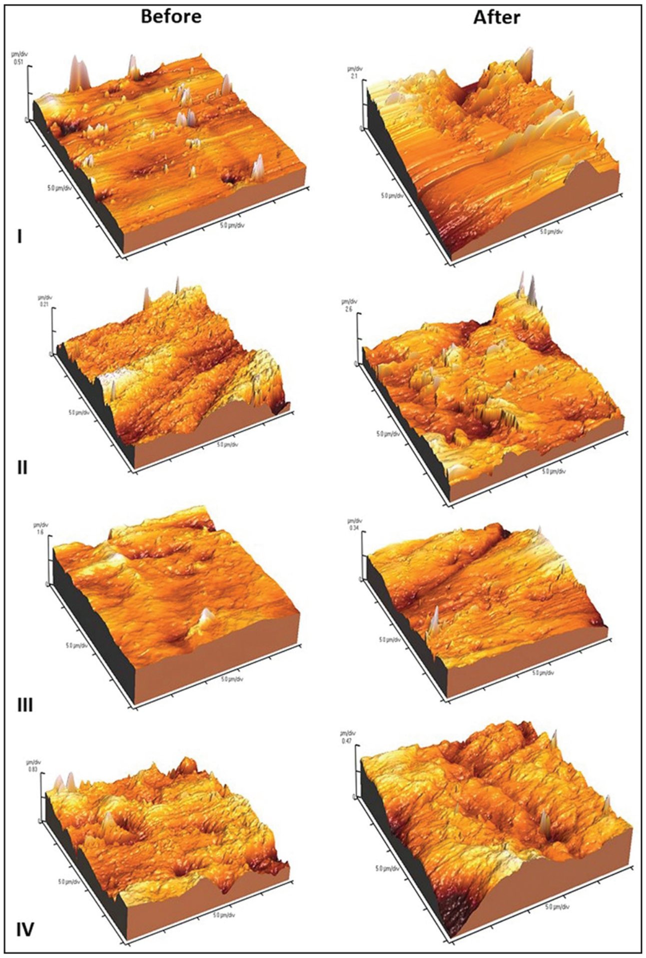

Figure 4: Atomic force images of all groups before and after scaling procedure

significant difference from that of ultrasonic tips ($P = 0.02$ and 0.01), respectively.

DISCUSSION

Scaling is a vital part of professional dental cleaning that is practiced by dentists and oral hygienist on a daily basis.[25,26] It is executed using hand and power-driven ultrasonic instruments.[27] Casarin *et al.*[28] reported that ultrasonic scalers can cause roughness of tooth surfaces, a process that can be affected by working factors such as procedure time, pressure, and angulation of the scaling tip. Oral bacterial adhesion and retention is affected by the surface roughness of any hard surfaces in the oral cavity and has a significant outcome on the formation and progression of dental plaque as well as influencing discoloration of esthetic restorations..[29-31] Consequently, this *in vitro* study has been performed to detect the effect of routine scaling using hand or ultrasonic tips on the enamel surface roughness (Ra).

Instrumentation of the tooth, until it is clean, is highly operator-dependent and many operating parameters such as load and contact angle might affect the outcome.[32] In this study, instrumentation was performed using a specially designed apparatus to control all variables (time, pressure, and tip angulation), whereas testing other factors which are the material and method of scaling procedure.

The use of SEM for evaluating surface topography and assessing the state of dental tissues surfaces has been widely used in previous studies.[21,32-35] For, high-resolution surface investigation, AFM was used. AFM analysis was proposed to provide qualitative and quantitative data on the detailed description of various dental materials.[36] AFM recreate a 3-dimensional image of the surface topography in real time. Analysis of these data sets can be used with specific software to obtain all the relevant data related to the examined surface in a quantitative form. Moreover, another important feature of AFM is that it allows the surface features to be visualized in an enhanced with better details.[36]

In this study, surface roughness increased in all specimens after scaling procedure. Group IV (hand scaling using titanium curettes) showed the highest mean surface roughness difference (ΔRa), whereas group I (ultrasonic scaling using stainless steel tips) showed the least ΔRa. Regarding the effect of the material of instrument on the surface roughness (ΔRa) readings; titanium instruments caused a statistically significant increase in mean surface roughness than the stainless steel instruments in both hand ($P = 0.02$) and ultrasonic ($P = 0.03$) groups. This was qualitatively confirmed by SEM analysis which showed enamel specimens of the titanium groups to have deep surface scratches and grooves. This may be attributed to the increased hardness of the titanium instruments (~751.9 MPa) compared to the stainless-steel instruments (~591.6 MPa)[37] which in return causes more deleterious effect on enamel. Tamura *et al*.[38] reported that the Vickers hardness of titanium nitride was 1300. This was in contradiction to Vigolo *et al.*[39] who recorded equal increase in the median surface roughness profile value for both steel curette and titanium curette.

As for the effect of scaling method, this study revealed that hand scaling method caused more increase in enamel roughness and more harmful changes to enamel surface than that of ultrasonic scaling method. The increase in mean surface roughness was statistically significant for the titanium instruments and for the stainless steel instruments. SEM analysis revealed larger scratches on the enamel surface of specimens of the hand instruments groups. This difference might hereby be explained by the higher pressure usually used for hand instrumentation[40] than that used for ultrasonic scaling,[41] to simulate the clinical situation. This results in deep scratches as well as striae in the hand group. Coinciding results were found in previous investigations.[42,43] Graetz *et al.*,[33] in a comparative assessment of the possible efficacy, benefits and harms of newly developed double gracey curettes (GRA) and sonic (AIR) and ultrasonic instruments (TIG)

Table 1: Mean and standard deviation of surface roughness before and after scaling and the mean difference (ΔRa) of all groups

Scaling method	Material	Mean ΔRa	SD	df			95% Confidence interval for mean		ANOVA *P* Value
				Between groups	Within groups	Total	Lower Bound	Upper Bound	
Ultrasonic	Stainless steel	3.58	0.3	3	36	39	3.31	3.84	0.042*
	Titanium	6.67	0.25				6.36	6.97	
Hand	Stainless steel	5.34	0.42				5.01	5.66	
	Titanium	8.97	0.76				8.70	9.23	

*Significant at $P < 0.05$

Table 2: Mean ΔRa and *P* values comparing different experimental groups

Group	Mean difference	*P* Value
Group I vs. Group II	–3.09	$P = 0.03$*
Group I vs. Group III	–1.76	$P = 0.02$*
Group I vs. Group IV	–5.39	$P = 0.01$*
Group II vs. Group III	1.33	$P = 0.42$
Group II vs. Group IV	–2.30	$P = 0.01$*
Group III vs. Group IV	–3.63	$P = 0.02$*

*Significant at $P < 0.05$

where the surface roughness was higher with GRA than the AIR and TIG. This increase in surface roughness was attributed to the repetitive overlapping working strokes, which can cause irregular patterns and deep scratches on the surface. Also Mittal *et al.*[44] in a comparison of the effectiveness of different ultrasonic (a piezoelectric device and a magnetostrictive ultrasonic device) and a periodontal curette on calculus removal and surface roughness where the curette produced the rougher surfaces than ultrasonic devices, many instrument scratches, and deep gouges were observed and a significant amount of the dentine layer was removed, the surface cracks were maximum in this group.

The results of this study suggest changes in the enamel surface topography and roughness after using titanium and stainless steel instruments for prophylactic periodontal treatment. Moreover, different methods of scaling, hand, and ultrasonic, resulted in changes in the morphology and roughness of enamel surface. Therefore titanium curettes and tips are not suitable for the use in scaling procedures on enamel surface.

Further studies, including clinical trials, of the effects of novel periodontal instruments onto hard dental tissues topography and into the most desirable approach for intraoral debridement would be desirable to clarify the significance of the observations made in this *in vitro* study.

Conclusion

Scaling using ultrasonic stainless steel tips produced the least amount of surface roughness and damage, whereas titanium curettes and tips produced more aggressive changes on the enamel surface *in vitro*.

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Not applicable.

Conflicts of interest

There are no conflicts of interest.

Ethical policy and Institutional Review board statement

Ethical approval was obtained from the Research Ethics Committee at Suez Canal University (Suez- REC 54/2018).

Data availability statement

The data that support the findings of this study are available from the corresponding author, on reasonable request.

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