

ORIGINAL ARTICLE

Micro-CT evaluation of the effect of various ScRp instrumentation methods on cement loss, porosity and micro-crack formation

Hasan Yıldız¹ | Nilsun Bagis¹ | Melike Camgoz² | Fatma Karacaoglu¹  | Mert Ocak³ | Kaan Orhan^{4,5}

¹Department of Periodontology, Faculty of Dentistry, Ankara University, Ankara, Turkey

²Faculty of Dentistry, Gazi University, Ankara, Turkey

³Department of Anatomy, Faculty of Dentistry, Ankara University, Ankara, Turkey

⁴Department of Oral and Maxillofacial Radiology, Faculty of Dentistry, Ankara University, Ankara, Turkey

⁵Ankara University Medical Design Application and Research Center (MEDITAM), Ankara, Turkey

Correspondence

Fatma Karacaoglu, Department of Periodontology, Faculty of Dentistry, Ankara University, Ankara, Turkey.
Email: fatmaboke@yahoo.com

Abstract

Objectives: The purpose of this study was to compare the effectiveness of three different instruments on cement loss, porosity and micro-crack formation, which was not evaluated before, following scaling and root planning (SRP) using micro-computed tomography (micro-CT).

Methods: In this experimental study, 30 single-rooted extracted human teeth were used and divided into three groups. All the teeth were scanned with micro-CT before and after SRP. Group 1: SRP was performed with Gracey curettes, Group 2: SRP was performed by using an ultrasonic device, and Group 3: SRP was performed by using diamond burs. Cement loss from the root surface, porosity, and micro-crack formation in the root dentine were analysed. Micro-CT is used for qualitative and quantitative analysis of samples. The obtained data were analysed statistically ($p < 0.05$).

Results: Minimum cement loss following SRP was detected with ultrasonic scaler (26.98 mm^3), whereas the highest was created by diamond burs (96.20 mm^3) ($p < 0.05$). The total porosity values after SRP were 0.278%, 0.334% and 0.252% for Groups 1, 2 and 3, respectively. Although Group 3 had the least porosity values, there was no statistically significant difference between the groups. The highest micro-crack formation was seen in Group 2 and the lowest was in Group 1 with a significant difference ($p < 0.05$).

Conclusions: More cement loss was observed with diamond burs. Ultrasonic devices appear to be a viable alternative to instrumentation with curettes. However, ultrasonic devices should be used carefully because of micro-crack formation since the micro-crack resulting from instrumentation with hand instruments is the least of all.

KEYWORDS

microcrack, microCT, scaling and root planning, porosity, surface roughness, Gracey curette, ultrasonic scaler

1 | INTRODUCTION

Periodontitis is a major health problem characterized by the destruction of supporting dental tissues. Dental plaque and calculus play an important role in the beginning and progression of this multifactorial inflammatory disease.¹ The main objective of periodontal treatment is to eliminate microbial dental plaque, calculus and debris on tooth surfaces, and to prevent the recolonization of periodontal pathogens in periodontal pockets, ensuring new attachment formation on biologically congruent root surfaces.²

After the professional removal of bacterial plaque and tartar, the patient is enabled to keep the surfaces free of new deposits with appropriate dental care aids.^{3,4} Surface qualities are not important for physiological tissue healing but is for regeneration.^{5,6} Many clinicians believe that a clean and hard tooth surface is the endpoint of mechanical scaling and root planning (SRP); but this may lead to pulpitis or hypersensitivity after extensive removal of hard tissues.⁷ So, it is recommended to remove as little tooth structure as possible to obtain a shapely surface.⁸ An ideal treatment should guarantee effective instrumentation and protection of dental structures.

Today, hand instruments, ultrasonic and sonic devices, rotating devices, and lasers are used in non-surgical periodontal treatment. The efficiency of these devices in eliminating calculus and plaque while preserving tooth material is still not clear.⁹

One of the many imaging models, micro-computed tomography (micro-CT) has revolutionized today's dentistry by expanding the field of research possibilities. Micro-CT provides high-resolution two- and three-dimensional images easy to interpret with a quick scan.¹⁰ Micro-CT is being used in many *in vitro* studies for evaluating root canal morphology, analysis of root canal preparation, surrounding tissues around roots and implants, enamel thickness measurement, determination of mineral concentrations of teeth.¹¹

Micro-crack formation on root dentine has long been evaluated in endodontics; however has not been studied yet in periodontics. This study aimed to evaluate the effects of 3 different instrumentation methods on root dentine and cementum by means of cement loss, porosity and micro-crack formation using micro-CT.

2 | MATERIALS AND METHODS

This *in vitro* study was approved by the Clinical Research Ethics Committee of Ankara University, Faculty of Dentistry (Approval no.: 36290600/312021).

Thirty single-rooted human maxillary and mandibular incisors and canine teeth were used in this study. Before tooth extraction, detailed anamnesis including the presence of systemic conditions that may affect the cementum (hypothyroidism, vitamin deficiencies) was taken from the patients who had not received periodontal therapy for at least 1 year. The selection criteria were: absence

of dental caries; absence of root resorption; absence of any types of dental restorations and absence of systemic diseases affecting the cement. The extraction indication was extraction need from a periodontal disease. Extracted teeth were visually inspected for the evaluation of the root surface, and teeth with excessive calculus deposition were not included in the study. For disinfection, 5.25% NaOCl was used for 2 h, and then the teeth were stored in distilled water during the study. All samples were scanned with micro-CT before and after SRP.

The teeth were randomly divided into 3 groups ($n = 10$ teeth per group):

Group 1: SRP was performed by 15 strokes in an apico-coronal direction for each root surface using Gracey curette 3/4 alone (Nordent). Since the sharpness of the Gracey curettes may affect the substance loss, a new, never used before curette was utilized for each sample.

Group 2: An ultrasonic device; Woodpacker UDS-J with a scaler tip "P1" (Guilin Woodpecker Instrument Co.) was used SRP of the samples ($n = 10$) was done linearly 15 times with an intensity of 30 kHz, parallel to the tooth axis and from apical to coronal. The device was operated in its regular work state by spraying water on the specimens in order to maintain cooling.

Group 3: SRP was performed using diamond burs (40 μ m, Intensive Root Shape) in root surface treatment on the cementum layer from apical to coronal along with a washing and cooling procedure with 0.9% isotonic sodium chloride at 3000 rpm.¹² Since it was predicted that there would be a slight decrease in the sharpness of the diamond burs after their contact with the tooth surface, a new diamond bur was used each time to avoid differences between the samples.

The micro-CT was performed at Ankara University Faculty of Dentistry Research Lab. Sample collection, embedding in acrylic templates, and preparation for the procedure were completed by the same investigator (HY). The micro-CT shootings, superposing and analyses were performed by one investigator for standardization (MO). The randomized grouping before scaling and scaling and root planning was ensured by a third investigator (KO). After the creation of groups, all teeth were instrumented by the same operator (NB), who was a periodontologist with 18 years of experience at the time, according to periodontal treatment procedures as described by Zafar et al⁵ to provide the same working conditions and pressure. Instrumentation time was recorded. The work was carried out at the Periodontology Department of the same faculty.

After removing from distilled water, the teeth were dried and embedded into acrylic blocks with a 2 cm radius. To be able to proceed easily and for the superposition of micro-CT scans, the crowns were embedded and the roots were left out in the open. To standardize the before and after comparisons of micro-CT scans, grooves were prepared on the buccal sides of the teeth in each acrylic block (Figure 1).



FIGURE 1 Embedding of the samples into acrylic blocks.

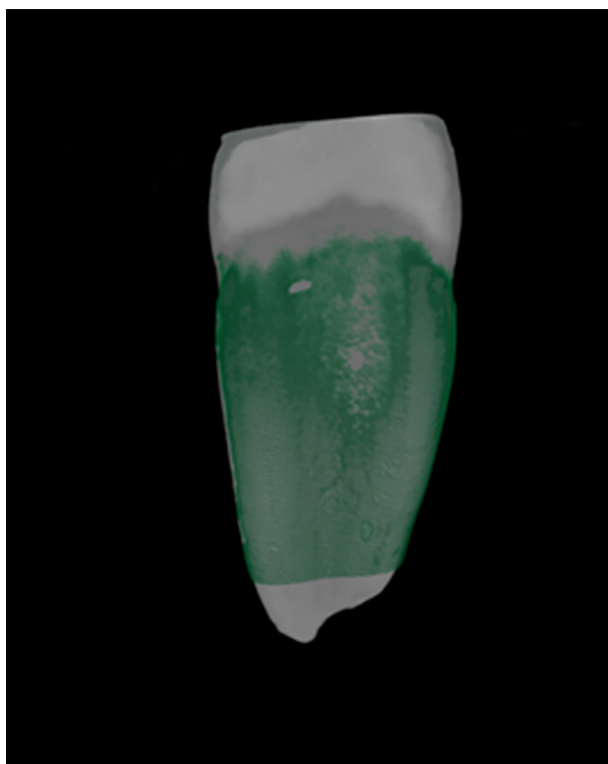


FIGURE 2 Superposing of micro-CT scan images obtained before and after periodontal procedure.

2.1 | Micro-CT scans before scaling and root planning

The embedded teeth were scanned with a high-resolution, desktop micro-CT system before SRP (BrukerSkyscan 1275). Technically; scans were made according to the irradiation parameters with a

0.5 mm Al/Cu filter at 100 kVp, a pixel size of 10.2 μ m at 100 mA, and a rotation speed of 0.5° in the BrukerSkyscan 1275 device. Air calibration of the detector was performed before each scan to minimize ring artefacts. Each sample was rotated 360° within an integration time of 5 min. The mean scanning time was 2 h for each sample. Optimum contrast limits were entered according to the manufacturer's instructions based on beam hardening correction, pre-scanning, and reconstructing of teeth. To ensure the standardization of the study with the same scanning parameters, each tooth was scanned twice before performing root surface treatment procedures.

2.2 | Calculation of volumetric difference by superposing the micro-CT images

NRecon software (version 1.6.10.4, Skyscan) and CTAn (version 1.17.7.2) were used to visualize the micro-CT scanned samples and make the quantitative measurements. A total of 30 images were analysed. The instructions by SKYSCAN were followed when corrections were needed. First, reformed images were superposed using the DataViewer software (version 1.5.6.2, SKYSCAN). The cavities formed on the acrylic blocks and the corners of teeth were chosen as reference points so that the teeth could be superposed. The image of the tooth before (reference) and after (target) the SRP procedure were superposed to obtain a subtraction image giving the volume of the cement deformed due to scaling and root planning (Figure 2). CTAn software was used for three-dimensional volumetric visualization, analysis and volume measurement. Likewise, in the superposed images obtained with the DataViewer program, the pore structure, that is, the space that does not exist before and the porosity that appears afterward in the channel space, was calculated in three dimensions with the CTAn software.

2.3 | Dentinal micro-fracture detection by superposing the micro-CT images

Before, after and superimposed images were evaluated and counted for micro-crack formation. To define crack formation, two different categories were established (i.e., "no crack" and "crack") to avoid confusing descriptions of root cracks. "No crack" was defined as root dentin without cracks or craze lines either at the internal surface of the root canal wall or the external surface of the root. "Crack" was defined as all lines observed on the slice that either extended from the root canal lumen to the dentine or from the outer root surface to the dentine (Figure 3).

2.4 | Statistical analysis

Mean standard deviation, median, minimum and maximum values were given in descriptive statistics for continuous data.

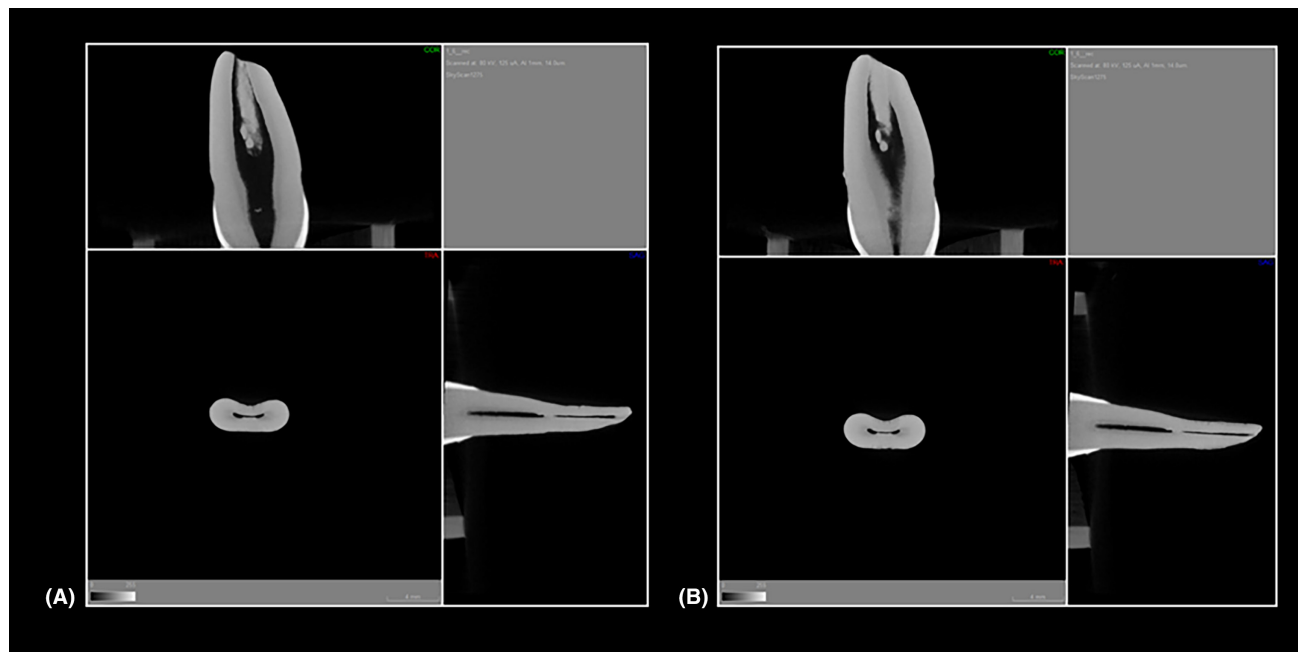


FIGURE 3 (A) Evaluation of dentinal micro-fractures before root planning with micro-CT scan. (B) Evaluation of dentinal micro-fractures after root planning with micro-CT.

The Kruskal–Wallis Variance was used for comparisons of volume and time between groups. The differences found as a result of the Kruskal–Wallis Variance Analysis were investigated with Kruskal–Wallis multiple comparison test in order to uncover from which groups the differences in variables were raised.

IBM SPSS Statistics 20 was used for evaluation and the level of significance was taken as $p < 0.05$.

3 | RESULTS

Table 1 presents the volumetric loss, dentinal micro-fracture, porosity values and scaling time of teeth treated by 3 different instrumentation methods. The minimum loss was detected in the ultrasonic device group (Group 2) ($26.98 \pm 20.37 \mu$), whereas the maximum volume loss was seen in the diamond bur group (Group 3) ($96.20 \pm 24.14 \mu$). A statistically significant difference was found between the amount of volume loss between the diamond bur group and the ultrasonic device group ($p < 0.001$), and a statistically significant difference was found between the diamond bur group and the Gracey curette group (Group 1) ($p = 0.051$). There was no significant difference in volume loss between Groups 1 and 2.

The treatment time in Group 3 was statistically significantly higher than in Groups 1 and 2 ($p < 0.05$; $p < 0.001$). No statistically significant difference was observed between Groups 1 and 2 (Table 1). The number of dentinal micro-fractures caused by different instrumentation techniques was determined as a percentage rate (Table 1). The micro-crack values in teeth that were treated with Gracey curettes (Group 1) were statistically significantly lower than that of Groups 2 and 3. There were no statistically significant

differences between the micro-crack values of Groups 2 and 3 ($p > 0.05$).

The porosity that occurred on tooth surfaces was $0.278 \pm 0.186\%$ in Group 1, $0.344 \pm 0.218\%$ in Group 2, and $0.252 \pm 0.179\%$ in Group 3. There were no statistically significant differences between groups ($p > 0.05$) (Table 1).

4 | DISCUSSION

This in vitro study was designed to compare the substance loss resulting from root surface treatment using Gracey curettes, ultrasonic scalers and diamond burs; evaluate the porosity occurring on root surfaces following treatment, and determine the micro-crack in the dentine layer caused by instrumentation.

Our study has shown that the change in cementum volume caused by hand tools was less than that of diamond burs; but more than that of instrumentation with ultrasonic scalers. Although this difference was not statistically significant, there was a statistically significant difference between the volume values of the teeth treated with Gracey curettes compared to the instrumentation performed with diamond burs ($p = 0.051$). The reason why there is no statistical difference may be the small number of our samples. On the contrary, the damage in dentine and micro-crack resulting from instrumentation with hand instruments were statistically lower than other methods ($p < 0.001$). This outcome supports the opinion that hand tools are more controlled.

It is recommended to remove as little tooth structure as possible while obtaining a clean and smooth surface for successful periodontal treatment in long term.¹³ The substance loss caused

TABLE 1 The comparison of volumetric loss, dentinal micro-fracture, porosity values and scaling time of teeth treated with Gracey curettes, ultrasonic device and diamond burs.

Group	Volume			Time			Micro-fracture			Porosity			p*
	Mean ± SD	Median (Min-Max)	Post Hoc test	Mean ± SD	Median (Min-Max)	Post Hoc test	Mean ± SD	Median (Min-Max)	Post Hoc test	Mean ± SD	Median (Min-Max)		
1. Gracey Curette ^a	55.66 ± 26.91	57.55 (11.94–103.26)	a-b p=0.191	46.50 ± 4.83	45.5 (40–55)	a-b p=0.311	3.20 ± 0.78	3 (2–4)	a-b *	0.278 ± 0.186	0.192 (0.095–0.613)	0.475	
2. Ultrasonic scaler ^b	26.98 ± 20.37	22.13 (4–68.79)	a-c p=0.051	37.60 ± 8.27	34 (27–50)	a-c p=0.019	8.60 ± 3.06	8 (5–14)	a-c p=0.004	0.344 ± 0.218	0.279 (0.121–0.846)		
3. Diamond bur ^c	96.20 ± 24.14	93.59 (58.91–150.26)	b-c *, p<0.001	57.80 ± 5.47	58.5 (50–65)	b-c *, p<0.001	6.5 ± 1.35	6.5 (4–8)	b-c p=0.882	0.252 ± 0.179	0.169 (0.091–0.571)		

Abbreviations: SD, Standard deviation.

* $p<0.001$, The Kruskal–Wallis Variance Analysis.

a: Group1–Gracey curette; b: Group2–Ultrasonic scaler; c: Group3–Diamond bur.

by recurrent SRP over the years can cause complications with a cumulative effect such as hypersensitivity and may even become a serious problem affecting the survival of the tooth.¹⁴ Kim et al.¹⁵ indicated that determining the location of calculus before periodontal treatment and avoiding unnecessary instrumentation may be beneficial because of the micro-fractures, defects and substance loss occurring on teeth.

Arefnia et al. observed more than 40 microns of substance loss with hand tools and more than 20 microns with ultrasonic devices following scaling and root planning.¹⁶ In another study examining the effects of piezo-electric, ultrasonic devices, and hand tools on the cement layer with micro-CT, it was reported that substance loss with Gracey curettes was 134.16 microns, 59.44 microns with an ultrasonic device, and 47.15 microns piezo-electric device.¹⁷ The results revealed that Gracey curettes caused more substance loss than ultrasonic scalers. This data supports the information that we obtained as a result of our current study, that the loss of substance after root surface treatment with ultrasonic devices is less than the substance loss after treatment with hand tools. The power level of ultrasonic devices is important during root surface treatment. The amount of substance loss increases with the increase in the power of the ultrasonic device. However, in studies conducted by different researchers at the same power level, different values were reported in terms of substance loss.^{18,19} In our study, we determined that regardless of the difference in the power level of the ultrasonic device, the material loss caused by the instrumentation at a constant power level is less compared with Gracey curettes and diamond burs. This difference is not statistically significant in comparison with Gracey curettes ($p=0.191$). On the contrary, the difference between ultrasonic devices and diamond burs was statistically significant ($p<0.001$). Our results indicated that instrumentation with ultrasonic devices leads to minimal loss when compared with other techniques.

The amount of pressure applied to the cementum layer by the instruments during root surface treatment is another factor that may alter substance loss. Ritz et al. reported a directly proportional inclination in substance loss with raise in pressure application of ultrasonic devices, curettes and diamond burs.⁸ This result showed that not only the type of tool used or the shape of the cutting tip but also the force applied during the treatment was effective. In our study, no extra pressure standardization was made, and all root surface treatments aimed at providing a certain standard were performed by a single researcher. We believe the wide value range between the minimum and maximum values is due to that.

Zappa et al. reported an increase with the rise in the number of hits to the root surface with handpieces.²⁰ The application procedure was standardized according to the suggestions of Zafar⁵ in the present study. Thus, differences between samples due to the number of hits were eliminated.

One of the biggest problems in an efficient periodontal treatment is the difficulty in being able to reach altered root morphology. Although many clinicians prefer hand tools for difficult areas, the

shape of diamond-coated periodontal burs has changed and been made to fit root morphology. Sonic, ultrasonic and rotary systems have disadvantages such as sensitivity, uncontrolled damage and inadequate adaptation to root surfaces. Rotary instruments form a thick smear over the root surface and remove a greater amount of tooth substance than scraping.²¹ This result supports our findings about the amount of material removed after the root surface treatment with diamond burs is higher than that of hand tools and ultrasonic tools.

The remaining root topography following instrumentation significantly affects the success of periodontal therapy. Clean root surfaces have the clinical importance of minimalizing bacterial plaque accumulation, therefore preventing calculus,³ and easing the reattachment of fibrous tissue of the gingival.^{6,22} Some studies on plaque accumulation showed a positive relation between root surface roughness and plaque growth.²³ However, the surface roughness effect of the instruments used is still not clear. Yildirim et al.²⁴ and Arefnia et al.¹⁶ suggested that the use of ultrasonic scalers may cause more surface roughness than hand tools. On the contrary, Haroon et al.⁴ reported that instrumentation with Gracey curettes causes less roughness than conventional piezoelectric devices. The 3 instrumentation methods used in the present study indicated similar results regarding porosity ($p=0.475$). The results of our study comply with Karacaoglu and Orhan.¹⁷ Consequently, it may be said that obtaining a clean root surface is independent of the instrumentation method. Therefore, regarding the success of periodontal therapy, it may be stated that while trying to obtain a biocompatible surface, the damage caused by the applied instrumentation and substance loss should be taken into consideration.

Santos et al. observed scratches, deep cavities, and large dentine layers removed from cement surfaces following instrumentation with hand tools in 2008.²⁵ Lee et al. found that curettes and ultrasonic scalers result in some porosity and substance loss. In addition to that, they observed localized indentations caused by all instruments; sometimes some scratches were formed on the cement, and that hand and ultrasonic instrumentation produced significant scratch marks on root surfaces.²⁶ Since these scratch marks and pits are not regular, it could be considered that the volume loss may be irregular within and between groups. The wide range of the data in each group between the minimum and maximum values in our study may be due to the irregularity of these scratches and pits.

In our study, unlike previous studies, micro-fractures created by instrumentation methods in the dentine tissue were analysed. There is not a study in the literature that investigates the effect of scaling and root planning procedures on dentine. Dentine is a light but very strong tooth tissue that protects the teeth from deterioration and resorbs an important amount of mechanical energy. The micro-cracks are caused by excessive forces applied to teeth that have a negative effect on occlusal forces and prepare the ground for root fracture formation.²⁷ Many studies showed that micro-fractures may occur following endodontic procedures.^{28,29} These defects are regarded as stress areas.³⁰

Studies conducted on dentine micro-cracks are limited to the effect of the methods used during root canal preparation and

endodontic treatment on micro-fractures.^{27,31} It was stated that micro-fractures would negatively affect the resistance against masticatory forces and increase the risk of vertical fractures. A fracture of the tooth may affect the prognosis of the tooth negatively and may result in tooth loss.³²

Although it has been considered that dentinal defects are generally caused by endodontic procedures, it is presented for the first time in this study that SRP procedures may also result in micro-cracks in dentine. The micro-cracks are commonly studied in endodontics as previously mentioned; however, since our study is the first to evaluate the effects of SRP on dentine defects, we were not able to compare or discuss our results. According to the findings of our study, a difference was found between the dentinal micro-crack values in teeth using Gracey curettes and the values in teeth using ultrasonic scalers and diamond burs. Moreover, the dentinal micro-crack values in teeth using Gracey curettes were significantly higher than the values using both ultrasonic devices and diamond burs. A literature search indicates that when the cracking potentials of the different methods used during root canal preparations were compared, it was seen that generally hand instrumentation causes fewer micro-cracks.^{33,34} The common result from these studies is; that although it prolongs the working time, manual instrumentation reduces the formation of micro-cracks and is more controlled and reliable. Just like during root canal preparation, it was shown in this study that root surface planning protocols can also create micro-cracks in dentine depending on the application force, the vibration effect applied with ultrasonic or rotary instruments and the frequency of repetition on the tooth surface. The less amount of micro-fracture formation caused by Gracey curettes complies with those studies and may be explained by controlled pressure application though it results in less cementum loss than ultrasonic devices. The cementum removed during SRP is a less mineralized tissue than dentine. Our results demonstrated that scaling with hand tools can remove cementum more easily; however, the vibration power of ultrasonic or rotary devices causes more damage to dentine which is a more calcified tissue. Kim et al.¹⁵ evaluated the micro-cracks created by ultrasonic instrumentation on the enamel surface and restorative materials in the enamel with a scanning electron microscope (SEM) and emphasized that the instrumentation with ultrasonic scalers caused enamel defects and cracks at different levels, and this situation may result in caries formation in the future. They suggested that the localization of calculus should be detected well before scaling with ultrasonic devices and unnecessary instrumentation should be avoided. According to our study results, we can say that repetitive instrumentation should be avoided to prevent dentine damage that may occur similarly, or using a combination of ultrasonic/rotary instruments and manual application in recurrent instrumentation may be more reliable in terms of dentine damage.

SEM,³⁵ profilometry,^{36,37} electron probe made with a micro-analysis device,³⁸ confocal laser microscope,³⁹ light microscope,⁴⁰ three-dimensional laser printer⁴¹ were used in studies that evaluated changes on tooth surface following periodontal treatment. A literature search showed a limited number of studies present that

investigated the effect of instruments used in root surface treatment on dentine and cementum by using a three-dimensional imaging technique with a micro-CT device.^{17,42}

The cement surface is very thin and requires sensitivity while analysing. Being able to prepare appropriate sections for analysis with SEM requires extra preparation. In addition, this method with sectioning is inadequate. The advantage of micro-CT is the fact that there is no need for any preliminary or preparation of the teeth and thus data loss is eliminated.

5 | CONCLUSION

Within the limitations of this in vitro study, it may be concluded that ultrasonic scalers cause less cementum loss than Gracey curettes following SRP. Treatment with diamond burs causes most cementum loss. This indicates the fact that they should be used much more carefully in root surface treatment. However, instrumentation with manual tools has the potential of causing fewer fractures/cracks in dentine when compared to other instruments. Therefore, recurrent instrumentation should be avoided to prevent dentine damage which can be interpreted as safe approach for tooth prognosis to combine ultrasonic and/or rotary devices with hand tools in repetitive instrumentations. This pioneering study will hopefully lead to more research with large sample sizes.

6 | CLINICAL RELEVANCE

6.1 | Scientific role

Although various instruments have been used for SRP, it is still unclear which instrument is the most effective in terms of roughness values and the loss of tooth substances. And, clinicians should evaluate and follow up the clinical effects of different instruments used with current methods. The aim of this pioneering study is to examine the effects of different instruments on the root surface morphology using micro-CT.

6.2 | Principle findings

In this study, it was observed that the minimum cement loss on the root surface was observed in the ultrasonic scaler group. Although minimal cement loss was observed on the root surface in the ultrasonic scaler group, maximum micro-crack formation was also seen in this group. The lowest micro-crack was constituted in the Gracey curette group with a significant difference.

6.3 | Practical implication

In this study, where we compared the effects of ultrasonic devices, curettes and diamond burs on the root surface, it was determined

that there was more cement loss with diamond burs. On the other hand, ultrasonic devices seem to be a viable alternative to manual instrumentation. However, ultrasonic devices should be used with caution due to the formation of micro-cracks.

AUTHOR CONTRIBUTIONS

HY: Conceived the ideas, study design and, interpretation of data and drafting of the article.

NB: Conceived the ideas, study design, instrumentation of teeth, interpretation of data and drafting of the article.

MC: Study design, interpretation of data and drafting of the article.

FK: Conceived the ideas, study design, interpretation of data and drafting of the article.

MO: Micro-CT analysis of samples, interpretation of data.

KO: Micro-CT analysis of samples, interpretation of data and revision of the article.

All the authors contributed written and approved the final draft of the article.

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CONFLICT OF INTEREST STATEMENT

The authors declare that they have no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are openly available in [repository name] at [DOI], reference number [reference number].

ORCID

Fatma Karacaoglu  <https://orcid.org/0000-0003-0122-2038>

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