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Profilometric and histological evaluation of the root surface after instrumentation in vitro with a fluorescence-controlled er: yag laser, hand instruments and an ultrasonic scaling device

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ABSTRACT

Objective: The present study is aimed to compare a fluorescence-controlled Er: YAG (erbium-doped yttrium aluminium garnet) laser with hand curettes and an ultrasonic scaling device regarding time taken, tooth root surface roughness, and cementum loss in an in vitro model.

Materials and the methods: 42 extracted single rooted human teeth with calculus on the root surface were randomly assigned to one of the following treatment groups (n=14): Gracey hand curettes (LM-Instruments Oy), an ultrasonic scaling device (KaVo PiezoLED) or a fluorescence-controlled Er: YAG laser (KaVo Keylaser 3+). Treatment time for each tooth was recorded. Root surface average roughness (Ra) for each sample was measured using optical profilometer. Loss of cementum was assessed by histological analysis of undecalcified sections.

Results: The results revealed that the mean time needed for instrumentation was significantly different ($p<0.05$) between treatment groups: hand curettes – median 158s, an ultrasonic scaling device – median 106s, a laser Er: YAG – median 245s. The lowest ($p<0.05$) mean Ra value was observed in hand curettes group – median 482 nm. Mean Ra difference between an ultrasonic scaling device – median 1029 nm and a laser Er: YAG – median 851 nm was not significant ($p>0.05$). There was no significant difference ($p>0.05$) regarding mean cementum loss between all groups: hand curettes – median 14 µm, an ultrasonic scaling device – median 16 µm and a laser Er: YAG – median 37 µm.

Conclusions: Within the limits of this in vitro study, a fluorescence-controlled Er: YAG laser was not superior to hand curettes and an ultrasonic scaling device in terms of treatment time, average surface roughness and cementum loss.

Keywords: Er: YAG laser, root debridement, subgingival calculus, roots cementum, scaling root planing, ultrasonic therapy.

Introduction

Primary aim of the non-surgical periodontal therapy is to remove plaque and calculus and create relatively smooth root surface. This can be achieved by maintaining good individual oral hygiene daily and periodically performing scaling and root planing. Mechanical debridement of calculus and root planing traditionally is done with hand curettes, ultrasonic scalers or combination of both. These two methods are time tested and widely accepted yet they have their own drawbacks.

Mechanical scaling and root planing may be difficult to achieve in furcation area, anatomical grooves of the root and deep periodontal pockets due to physical dimensions of instrument [1]. Moreover mechanical debridement removes part of root cementum or even dentin which may lead to excessive loss of tooth tissue. Therefore there are constant attempts to improve or invent new methods for non-surgical periodontal therapy.

Although the role of the cementum thickness in periodontal healing is unknown, yet extensive removal of tooth structure may lead to increased tooth sensitivity, susceptibility to caries or even endodontic pathology. Therefore excessive cementum loss is undesirable. In order to preserve cementum selective calculus removal idea has been introduced. One of the selective calculus removal systems is Er: YAG laser with an additional integrated InGaAsP (Indium gallium arsenide phosphide) infrared diode laser. The wavelength (2940 nm) of this laser is well absorbed by water molecules. Irradiated water molecules within hard tissues creates micro-explosions enabling thermomechanical ablation mechanism. This process consumes most the laser's energy and only a little portion of it emits to surrounding tissues, making Er: YAG laser safe tool in dental applications [1], [2]. This diagnostic diode laser induces fluorescence in plaque allowing calculus detection. The Er: YAG laser beam is activated only when fluorescence signal from root surface exceeds certain threshold level. This allows fluorescence-controlled calculus removal.

Fluorescence-controlled Er: YAG laser may preserve root cementum during periodontal therapy [3]. Yet trials, analyzing calculus removal with this device, are scarce and little is known about the impact of fluorescence-controlled laser's irradiation on the root surface. Hence the aim of the present experiment is to evaluate and compare surface roughness and cementum loss of teeth with calculus on root surface following fluorescence-controlled Er: YAG laser, hand curettes and ultrasonic scaler instrumentation. Additionally, treatment time with each of the methods should be assessed.

Materials and methods

42 extracted single rooted human teeth with calculus on the root surface were held in formalin until the beginning of the experiment. Experimental zones were marked on the surface of the roots with periodontal mini sickle. 42 selected teeth were randomly distributed to three treatment groups (n=14): A, B or C. Gracey curettes (LM-Instruments Oy, Finland), were used for scaling and root planing in the A group. Calculus removal in the B group was done using PiezoLED (KaVo, Germany) piezoelectric device with periodontal tip No. 201, while cooling with water. Manipulations in A and B groups were considered done when the researcher and assistant clinician, using periodontal probe, did not detect any more calculus and the surface was plain enough. Er: YAG laser (KaVo Keylaser 3+, Germany) was used for calculus removal in the C group. Laser was set to 120mJ per pulse, 10 Hz, 1.20 W and periodontal tip No. 2061: Blue was chosen for the experiment. Fluorescence-controlled calculus detection feedback system (InGaAsP infrared diode laser) was enabled, set to threshold value 2 and calibrated accordingly to manufacturer's protocol. Water was used for cooling. Procedure was carried on until the feedback system detected no more calculus. All instrumentations were accomplished by the same researcher.

Procedures duration was not limited, yet the time spent removing calculus for each root surface was recorded.

All treated samples were examined with optic profilometer Sensofar PLu2300 (Sensofar, Spain). Objective-lens magnification x20, scanning area 636.61x477.25 μm^2, Z scanning ±300 µm mode with 1 µm step was chosen and Roughness Gaussian 0,08mm filter was set. Profiles mean Ra was recorded.

Undecalcified sections of 100 µm in thickness were prepared from each experimental tooth using microtome LEITZ Sägemikrotom 1600 (Wetzlar, Germany). Histological evaluation was done using optical microscope with photo camera attached MOTIC B3 Professional (Motic, Germany). Motic Imaged Plus 2.0ML software was used for measurements (Figure 1). The perimeter of each section of tooth was partitioned into 1mm length sections. The minimum thickness of cementum from granular dentin to the edge of tooth was measured in each section around the perimeter. Mean cementum thickness was calculated for treated zone and untreated zone, which served as control, for each tooth. The loss of cementum was calculated by the difference between mean cementum thickness in a control zone and in an experimental zone. The results were compared with the Kruskal-Wallis test. Differences were considered statistically significant at $p<0.05$.

Results

The treatment time was significantly different between all groups ($p<0.05$) (Table 1). The quickest procedure time was recorded in the B group (median 106s, interquartile rate (IQR) 68 - 160). Calculus removal in the A group took somewhat longer (median 158s, IQR 112 – 214). And the longest treatment time was in the C group (median 245s, IQR 178 – 437) (Figure 2).

The mean surface roughness (Ra) results are summarized in figure 3. Significantly the least Ra ($p<0.05$) was measured in the A group (median 482 nm, IQR 419 – 857). More than 2 times rougher root surface was recorded in the B group (median 1029nm, IQR 630 – 2630). Ra in the C group (median 851 nm, IQR 665 – 995) was a little bit lower than in the B group, yet this difference was not statistically significant ($p>0.05$) (Table 1).

The negative difference between cementum thickness in the control zone and in the experimental zone was calculated in 7 (18.9%) sections (30 % for A and B groups and 7.7% for) C group. The negative value was interpreted as zero i.e. no cementum loss. The mean cementum loss in the A group (median 14 µm, IQR 0.25 – 36.28) and B group (median 16 µm, IQR 0 – 28.75) was similar. C group showed a little bit more extensive cementum loss (median 37 µm, IQR 9 – 73) (Figure 4), yet statistical analysis showed no significant difference between all three groups ($p>0.05$) (Table 1).

Discussion

Classical conservative treatment methods of chronic periodontitis (curettes and ultrasound devices) have their own drawbacks. While searching for new calculus removal techniques the Er: YAG laser was proposed a few decades ago. Since then a lot of researches both in vitro and in vivo have been published, yet no consensus has been made about the efficiency of this device amongst scientists and clinicians. However nowadays laser technologies are moving forward with acceleration and one of the newer innovations of Er: YAG laser is calculus detection. This addition theoretically allows selective calculus removal and minimal cementum ablation, though there is a lack of experimental evidence. Other studies show that calculus removal on single root surface of the tooth in vitro with hand curettes takes ~30s [4], 108 ± 66s [5], 126,1± 38,2s [6], with ultrasonic device: ~50s [4], 72 ± 54s [5], 74 ± 28s [6], 60-97s [7]. Miremadi et al. [7] found out that calculus removal using Er: YAG laser in vitro took 52-112s (±21) depending on the laser output energy. However, it should be noted that Miremadi et al. used laser without calculus detection system. Unfortunately, experiments that recorded calculus removal duration using Er: YAG laser with feedback control in vitro were not available. Instrumentation time with hand curettes and ultrasonic device in the current experiment was similar to those reported by [5], [6], [7]. According to these results it may be implied that the calculus removal is done faster with the ultrasonic device than with hand curettes and Er: YAG laser. Nevertheless one should interpret treatment duration with caution because it is very sensitive to experience of the clinician, skill to use specific device, anatomical diversity of teeth and different quality of calculus. These confounding factors are barely controlled and it is very complicated to objectively measure durations of various treatment methods. One of the aims in treating marginal periodontitis is root planing. The smoother the root surface, the less plaque and bacterium adhere to it. Common conception is that Ra less than 0.2 μm has no influence on bacterium adhesion [8], [9]. However, there is no agreement between scientists whether smooth root surface facilitates periodontal healing because periodontal fibroblasts adhere to rougher surface better [10], [11]. This may accelerate epithelium junction formation. Yet optimal root surface roughness, that induces fibroblasts adhesion but at the same time does not encourage biofilm formation, is unknown. Studies analyzing root surface roughness after instrumentation report various Ra values. Root surface treated with hand curettes Ra is reported to be 0.35 ± 0.12μm [12], 0.95 ± 0.25 μm [13], 1.67 ± 0.56 [14], 1.88 μm [15], 2.28 ± 0.58 μm [16]. Treatment with ultrasonic device resulted in Ra 0.65 ± 0.34μm [12], 0.99 ± 0.43 μm [13], 1.43 ± 0.49 μm [14], 2.65 ± 0.73 μm [16], 2.8 μm [15].

Most of these studies show that a smoother surface is achieved with hand curettes than with ultrasonic device. Results for hand curettes (Ra = 0.482 μm) and ultrasonic device (Ra = 1.029 μm) of the current study are in agreement with previous statement. It is thought that laser treated root surface is relatively rough because no planing is done [13]. Few studies showed roughness to be 0.52 – 0.81 μm [17], 1.30 ± 0.42 μm [13] after treatment with Er: YAG laser without calculus detection system. Results of the current experiment are similar (Ra = 0.851 μm) despite fluorescence control used in this study. Yet the impact of calculus detection system on root surface roughness treated with Er: YAG laser is unknown.

It is clear that scaling and root planing is impossible without removing part of cementum. Due to extensive cementum removal during conservative periodontal treatment dentin tubules may be opened. This could lead to increased sensitivity of teeth, root caries or even endodontic pathology [18]. Along with calculus cementum could be ablated due to excessive pressure of hand instruments, repetitious scaling root planing procedures. Several studies have shown that the loss of tooth structure depends on Er: YAG laser output energy [7], [19], [20]. Miremadi et al. [7] showed that Er: YAG laser set on 160mJ per pulse or more, 10 Hz without calculus detection system is significantly more aggressive than ultrasonic device. Miremadi suggests safe laser energy 100mJ per pulse and even more if the calculus detection system is applied. In order to preserve cementum as much as possible calculus detection systems should be applied. However there are no defined parameters of the Er: YAG laser established which would allow effective calculus removal and minimal cementum loss. Laser parameters in the current experiment were chosen according to manufacturer's recommendations: 120mJ per pulse, 10Hz. Only calculus detection system's threshold value was set according to Krause et al. [3] study to value 2 which reduce residual calculus amount without meaningful alterations to cementum. In order to assess cementum loss after calculus removal and root planing histological examination of root sections is done. Yet such experiments are sparse. Almedi et al. [1] found out that Er: YAG laser without calculus detection system (51.6± 25.8 μm) removed more cementum than ultrasonic scaler (33.0±12.4 μm). Using calculus detection system cementum loss was reduced as showed Krasue et al. [3], Schwarz et al. [19] and Herrero et al. [20].

Krause [3] showed that loss of cementum after treatment with Er: YAG laser with calculus detection system was about 10 μm. On the other hand, classical studies show that hand curettes might remove up to 343 μm tooth structure in thickness depending on strokes count and pressing force [21], [22], while ultrasonic device up to 107 μm [23], [24]. Schwarz et al. [19] demonstrated that root surface treated with hand curettes had grooves in depth up to 51.6 μm, whereas root surface treated with Er: YAG laser with calculus detection system had craters 5.6 – 6.5 μm in depth. Histological measurements in the current experiment showed that laser removed up to 37 μm, curettes – up to 14 μm and ultrasonic scaler – up to 16 μm of cementum in thickness. These results are contradictory to selective calculus removal idea. However statistical analysis revealed that the cementum loss difference was not significant in the current experiment. The differences in the amount of calculus on each root surface, as well as the various composition of the calculus itself have limited the ideally equal conditions for an in vitro experiment, which may have veiled real differences of these treatment methods.

Figure 1. Histological tooth root section, magnification x100. C – cementum, D – dentin, GD – granular dentin.

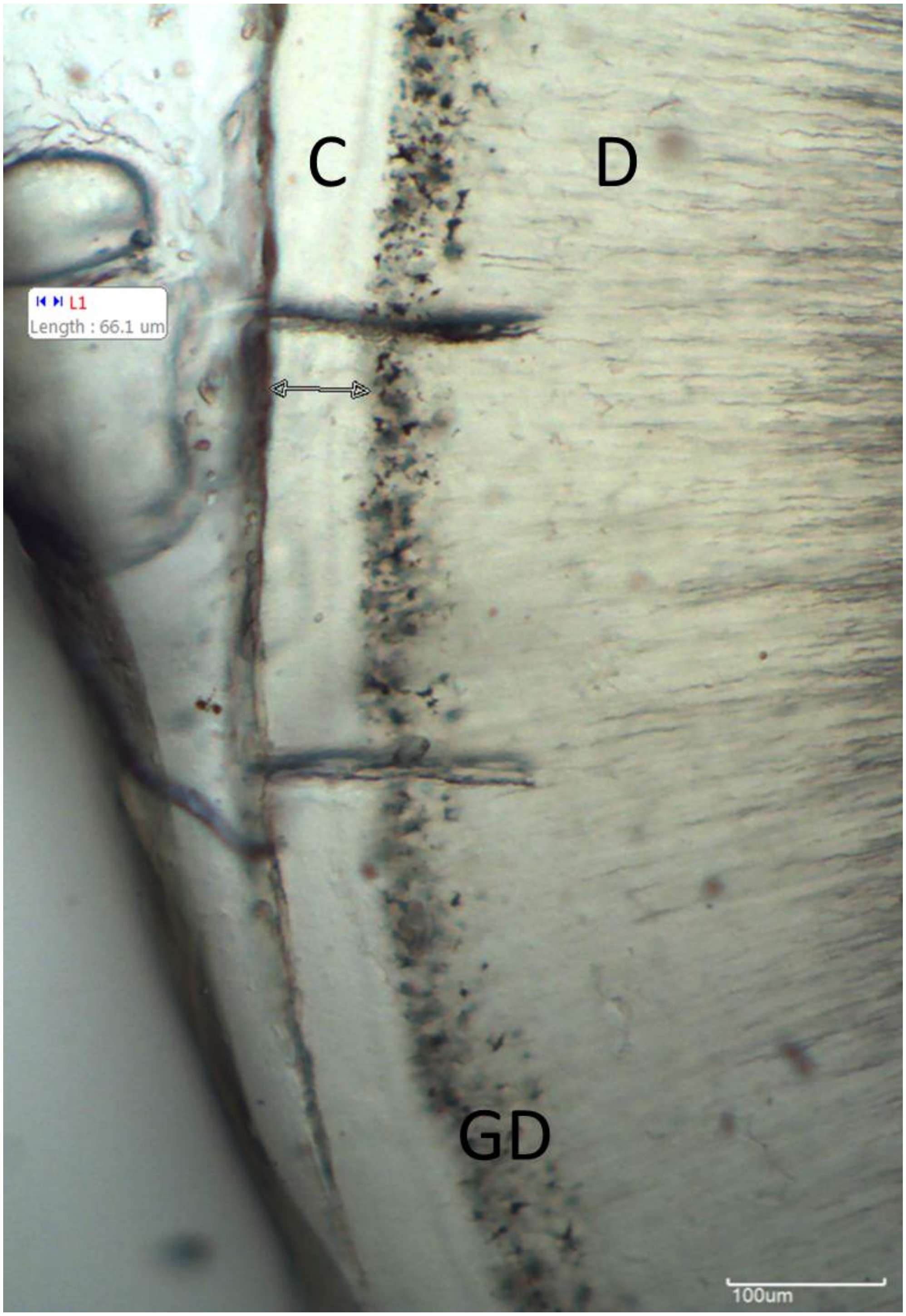


Table 1. Instrumentation time, sourface roughness (Ra) and cementum loss comparison between groups using Kruskal-Wallis test with a significance level of 95%. A – hand curretes, B – ultrasonic scaler, C – Er:YAG laser.

	Group		p
Time	A	B	**0,020**
	A	C	**0,006**
	B	C	**0,000**
Ra	A	B	**0,003**
	A	C	**0,019**
	B	C	0,168
Cement loss	A	B	0,907
	A	C	0,102
	B	C	0,090

Figure 2. Instrumentation time median, first quartile, thrid quartile, lowest and highest value in seconds. A – hand curretes, B – ultrasonic scaler, C – Er:YAG laser.

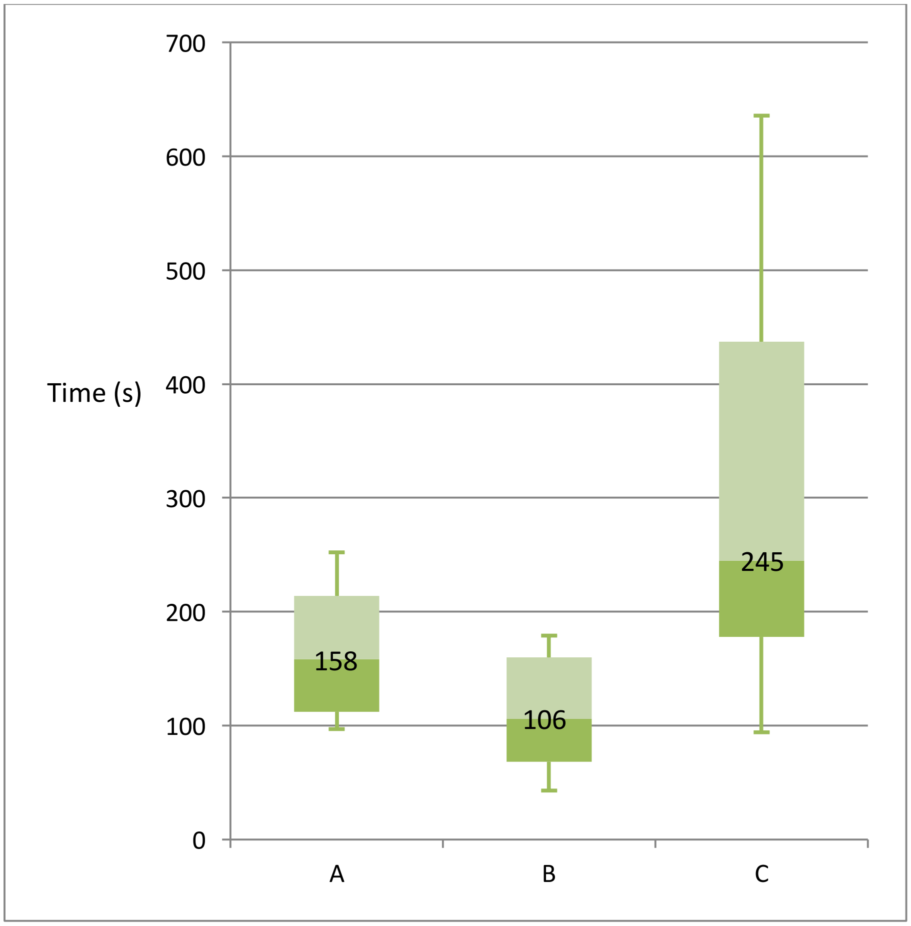


Figure 3. Mean surface roughness (Ra) median, first quartile, thrid quartile, lowest and highest value in nm. A – hand curretes, B – ultrasonic scaler, C – Er:YAG laser

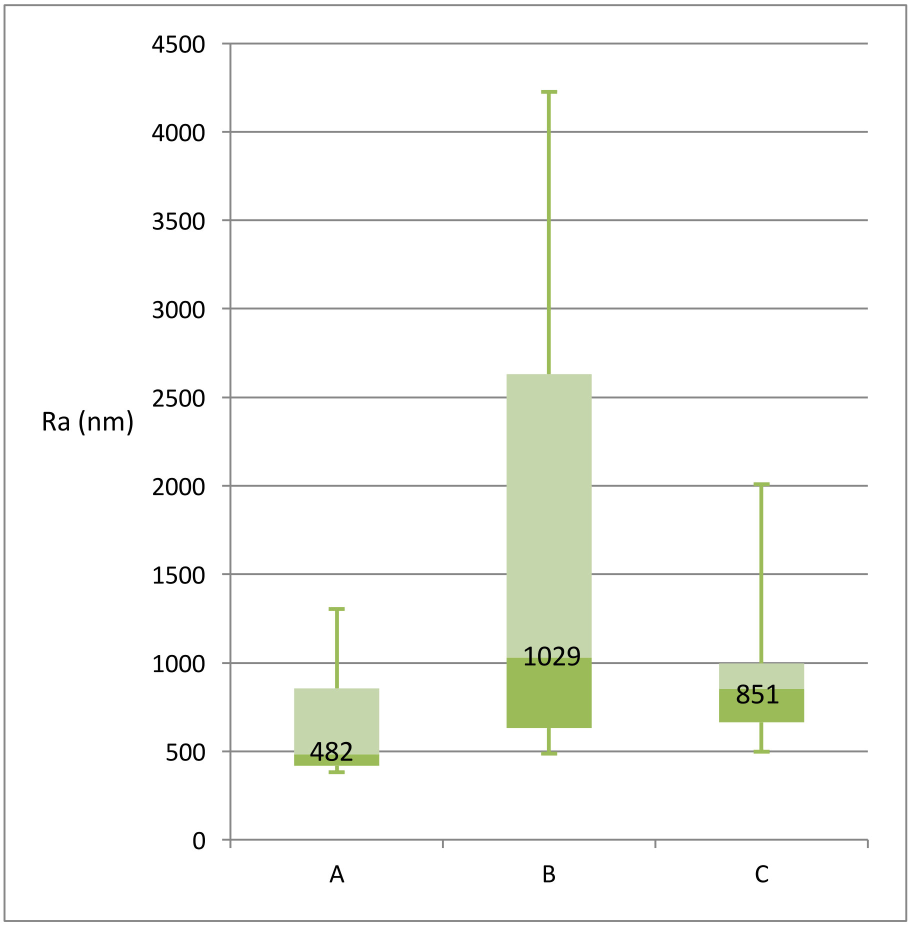
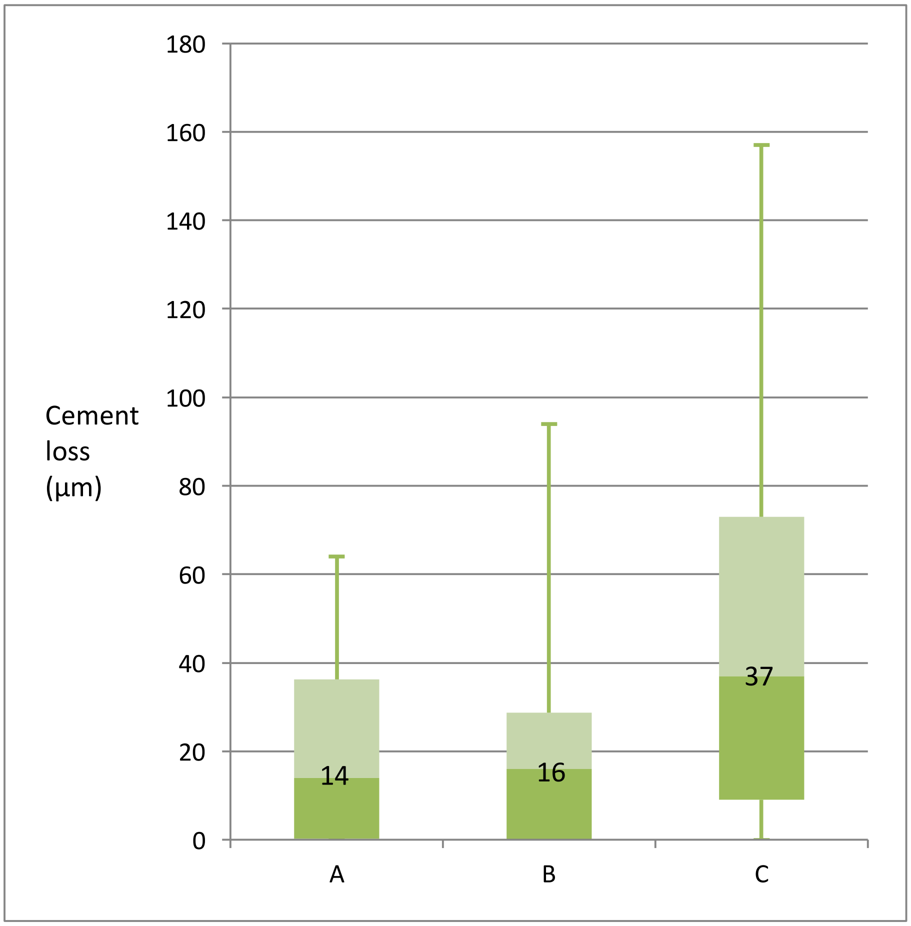


Figure 4. Cementum loss median, first quartile, thrid quartile, lowest and highest value in µm. A – hand curretes, B – ultrasonic scaler, C – Er:YAG laser.



Conclusions

Within the limitations of this in vitro experiment hand curettes and ultrasonic scaler were superior to Er: YAG laser with calculus detection system in terms of treatment duration. As it was expected Er: YAG laser treated root surface was rougher than after treatment with hand curettes. Yet ultrasonic scaler was not superior to laser in terms of surface roughness. Also Er: YAG laser with calculus detection system was not superior to hand curettes and ultrasonic scaler in preserving cementum.

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Principal findings

Current in vitro study implies that fluorescence-controlled Er: YAG laser does not surpass conventional conservative periodontitis treatment instruments. Hand curettes are superior to ultrasonic scaler and laser in terms of root planing. Cementum preservation may not necessary be achieved using selective calculus removal with Er: YAG laser.

Practical implications

In order to achieve as smooth as possible root surface one should consider finishing treatment by planing roots with hand curettes.

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