Root Surface Roughness after Treatment with Manual Curette and Er:YAG and Er,Cr:YSGG Lasers

Reza Amid [a], Seyed Masoud Mojahedi [b,c], Siamak Sabour [d], Azadeh Daniyalzadeh [e], Mahdi Kadkhodazadeh [f*]

[a] Department of Periodontics, School of Dentistry, Shahid Beheshti University of Medical Sciences, Tehran, Iran; [b] Laser Clinic, School of Dentistry, Shahid Beheshti University of Medical Sciences, Tehran, Iran; [c] Clinical Professor, Laser Clinic, School of Dentistry, Shahid Beheshti University of Medical Sciences, Tehran, Iran; [d] Department of Community Oral Health (COH) Clinical Epidemiology, Shahid Beheshti University of Medical Sciences, Tehran, Iran; [e] Private Practice, Tehran, Iran; [f] Dental Research Center, Shahid Beheshti University of Medical Sciences, Tehran, Iran

Corresponding author:** Mahdi Kadkhodazadeh, Dental Research Center, Shahid Beheshti University of Medical Sciences, Tehran, Iran. ***E-mail: Kadkhodazadehmahdi@yahoo.com; ***Tel***: +98-912 7608346

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Introduction: This study compared the root surface roughness following scaling and root planning with manual curettes and different powers of Er:YAG and Er,Cr:YSGG lasers using surface profilometry and scanning electron microscopy (SEM). **Materials and Methods:** In this *in vitro* experimental study, 50 extracted teeth were buccolingually sectioned into two halves. The obtained contaminated surfaces randomly received the following treatments: SRP with manual curettes (group I), Er:YAG laser irradiation (4 W) (group II), manual curette+Er: YAG laser (1W) (group III), manual curette+ Er,Cr:YSGG laser (150 mJ) (group IV) and Er,Cr:YSGG laser (250 mJ) (group V). Surface roughness (Ra), surface changes (Rz) and maximum roughness changes (Rmax) were calculated before and after treatment while the surface morphology was examined by SEM analysis. The differences in roughness parameters were statistically analyzed using Wilcoxon signed rank test for each modality. **Results:** Except for the manual curette group (I) in which the roughness parameters decreased significantly ($P<0.04$ for all), Ra, Rz and Rmax increased in the remaining groups. The reported increases in group II (4W Er:YAG)($P<0.005$, $P<0.007$ and $P<0.03$, respectively) and group V (250 mJ Er,Cr:YSGG) were statistically significant ($P<0.01$, $P<0.05$ and $P<0.05$). **Conclusion:** Within the limitations of this study, irradiation of Er:YAG and Er,Cr:YSGG lasers at both powers with and without using manual curettes increased surface roughness values compared to using manual curettes alone. Greater roughness values were obtained by increasing the power of lasers.

Keywords: Scaling, Surface Roughness; Manual Curettes; Laser

Introduction

Non-surgical, periodontal debridement treatments are performed with the aim of removing calculus and dental plaque without traumatizing the root surfaces. Scaling and root planning is the basis of all periodontal treatments; manual instruments and ultrasonic devices have long been used for this purpose (1). Manual instruments remove considerable amount of tissue from the root surfaces. However, some studies have reported more adverse effects due to the use of ultrasonic devices compared to hand instruments (2, 3). Root surface roughness after the application of manual and ultrasonic instruments has always been a subject of interest for clinicians (4).

Laser treatment of periodontal pockets has recently gained attention as an adjunct to scaling and root planning (SRP). There is a possibility that laser can smoothen the root surfaces and enhance subsequent fibroblast adhesion (5). However, one drawback of this method is the biological change that occurs in the root surfaces as the result of laser irradiation. Erbium lasers can particularly have physical and chemical effects on the root surfaces.

The energy of ER:YAG laser at a wavelength of 2,940 nm is largely absorbed by water. This energy is equal to the amount of energy absorbed by the hydroxyapatite (HA) crystals. Thus, ER:YAG laser is more efficient for removing dental hard tissue than other lasers (6, 7). Moreover, this can be done with minimal thermal damage to the tooth structure. That explains the popularity of Er:YAG laser in dentistry i.e. for caries removal and cavity preparation (8).

Er;Cr:YSGG laser, operating at a wavelength of 2,780 nm, is more absorbed by the OH^- ions rather than by water molecules and has been used to improve the efficacy of hard tissue ablation (9, 10). Er;Cr:YSGG laser uses an ablative hydrokinetic process that offers more efficient debridement and plaque removal from the tooth and implant surfaces (11, 12).

This study aimed to compare the root surface roughness following treatment with the manual curette and different powers of Er:YAG and Er,Cr:YSGG lasers.

Materials and Methods

This in-vitro, experimental study was conducted on 50 recently extracted maxillary and mandibular teeth of periodontal patients. The teeth were kept in saline solution. The root surfaces of teeth were thoroughly evaluated under 4X magnification to ensure absence of caries, fracture or cracks on the root surfaces. Next, the teeth were mounted in dental stone at the level of the cementoenamel junction (CEJ) and longitudinally sectioned into halves in the buccolingual dimension using a diamond saw (JOTA AG, Rüthi, Switzerland). The external root surface below the CEJ in each tooth half was horizontally divided into 2 segments that were subsequently coded. Fifty surfaces covered with calculus and debris were selected and the specimens were randomly assigned to 5 groups.

Group 1. The root surfaces in this group were treated with manual curettes (7GE8, ADEp Gracey Curette, Swiss Made). The treatment was continued until reaching smooth surfaces. Smoothness of the surface was examined by a dental explorer using the tactile sense of the examiner.

Group 2. The root surfaces in this group were irradiated with Er:YAG laser (Smart 2940D, DEKA, Italy) with 4W power. The laser irradiation settings included 2,940 nm wavelength, 200mJ pulse energy, 20Hz pulse frequency for one minute, non-contact tip, very short pulse and 50% water 50% air.

Group 3. The root surfaces in this group were treated with manual curettes and then irradiated with Er:YAG laser (Smart 2940D, DEKA, Italy) with 1.0 Watt power (Figure 4). The laser irradiation settings included 2,940 nm wavelength, 200mJ pulse energy, 20Hz pulse frequency for one minute, non-contact tip, very short pulse and 50% water 50% air.

Group 4. The root surfaces in this group were treated with manual curettes and then irradiated with Er,Cr:YSGG laser (Biolaser, USA) with 150 mJ energy. The laser irradiation settings included 2,780 nm wavelength, one minute duration, 6mm G4 tip, very short pulse and 70% water 30% air.

Group 5. The root surfaces in this group were irradiated with Er,Cr:YSGG laser with 250mJ pulse energy for one minute with 6mm G4 tip and 70% water 30% air. All clinical phases (SRP) were performed by one clinician. All laser treatments were also carried out by one clinician (PhD in laser).

All specimens were evaluated by a profilometer (MahrSurf M300+RD18 C system, Germany) with a 2.5 µm-radius stylus tip. For SEM analysis, the specimens were cut into 2mm sections and the sections were immersed in 2.5% glutaraldehyde in phosphate buffer for 24h. The specimens were then washed, dehydrated, dried and gold-coated. The gold-coated specimens were evaluated under SEM (KYKY, EM3200). Micrographs were obtained from the root surfaces at different magnifications. The examiner, who evaluated the surface roughness using profilometer and SEM, was blinded to the type of treatment received by the specimens.

One-way ANOVA was used to assess the differences in surface roughness parameters among groups before and after treatment. Since the data did not have normal distribution and considering the sample, pairwise comparison of groups (where the results of one-way ANOVA were significant) was carried out using Mann Whitney U test. On the other hand, differences in Ra, Rz and Rmax parameters in each group before and after treatment were assessed using Wilcoxon signed rank test.

Results

One-way ANOVA revealed that the Ra parameter before treatment (P=0.65), the Rz before treatment (P=0.61) and the Rmax before (P=0.63) and after (P=0.41) treatment were not significantly different among the groups. However, the 5 groups had significant differences in the Ra parameter after treatment (P<0.05), the Rz after treatment (P<0.03), the Ra parameter before and after treatment (P<0.02) and the Rz (P<0.01).

The mean (±SD) Ra in the manual curette group (group I) was 3.96±1.93 µ before and 2.36±1.77 µ after treatment; these values indicated a significant reduction in the Ra parameter due to treatment (P<0.04). The mean (±SD) Rz in the manual curette group was 19.04±6.49 µ before and 11.06±6.76 µ after treatment; these values indicated a significant reduction in the Rz due to treatment (P<0.04). The Rmax values in this group were 31.67± 14.83 µ before and 17.24±11.34 µ after treatment indicating a significant reduction in this parameter (P<0.04).

The mean (±SD) Ra in the 4W power Er:YAG laser group (group II) was 5.34±7.9 µ before and 7.61±8.27 µ after treatment; which indicated a significant increase in this parameter (P<0.005). The mean (±SD) Rz in the 4W power Er:YAG group was 18.01±12.99 µ before and 23.23±14.44 µ after treatment; which indicated a significant increase in this parameter (P<0.007). The mean (±SD) Rmax in this group was 27.53±20.62 µ before and 34.02±22.72 µ after treatment; which indicated a significant increase in this parameter (P<0.03).

The mean (±SD) Ra in group III (manual curette+ 1.0 W Er:YAG laser) was 4.48±3.43 µ before and 5.78±2.01 µ after treatment; the change in Ra parameter was not significant (P=0.07). The mean (±SD) Rz in group III was 18.79±14.81 µ

Table 1. The changes in Ra parameter in different groups before and after the treatments (in μ)

Group	Mean (SD)	Minimum	Maximum	Median
Manual curette	-1.6 (2.65)	-7.76	2.27	-1.21
4W Er:YAG	2.27 (1.64)	0.04	5.63	2.38
Manual curette+ 1.0 W Er:YAG	1.29 (4.02)	-9.53	5.16	2.22
Manual curette+ 150 mJ Er,Cr:YSGG	0.83 (1.61)	-2.02	3.3	1.18
250 mJ Er,Cr:YSGG	1.16 (-0.81)	4.26	5.08	1.32

Table 2. The changes in Rz parameter in different groups before and after the treatments (in μ)

Group	Mean (SD)	Minimum	Maximum	Median
Manual curette	-7.98 (9.98)	-24.82	8.81	-7.91
4W Er:YAG	5.22 (4.94)	-0.29	16.5	3.68
Manual curette+1.0 W Er:YAG	1.78 (13.84)	-36.61	12.12	4.13
Manual curette+150 mJ Er,Cr:YSGG	2.23 (5.12)	-7.01	10.24	2.52
250 mJ Er,Cr:YSGG	3.49 (4.97)	-3.72	14.43	2.95

Table 3. The changes of Rz parameter in different groups before and after the treatments (in μ)

Group	Mean (SD)	Minimum	Maximum	Median
Manual curette	-14.43 (21.65)	-64.57	14.15	-13.54
4W Er:YAG	6.49 (6.85)	-6.36	15.36	6.88
Manual curette+1.0 W Er:YAG	316.05 (995.03)	-41.4	3147.52	10.14
Manual curette+150 mJ Er,Cr:YSGG	5.55 (7.69)	-4.09	17.04	5.36
250 mJ Er,Cr:YSGG	5.46 (7.8)	-4.36	21.1	3.24

before and 20.57±8.75 μ after treatment; despite a slight increase in the Rz after treatment, this increase was not statistically significant (P=0.07). The mean (±SD) Rmax in group III was 26.34±22.74 μ before and 39.34±99.11 μ after treatment; despite the considerable increase in Rmax after treatment, this increase was not statistically significant (P=0.29).

The mean (±SD) Ra in group IV (manual curette+150mJ power Er,Cr:YSGG laser) was 2.64±1.39 μ before and 3.48±1.29 μ after treatment; which showed no significant change (P=0.14). The mean (±SD) Rz in group III was 12.25±6.75 μ before and 14.47±5.13 μ after treatment; despite a slight increase in the Rz after treatment, this increase was not statistically significant (P=0.2). The mean (±SD) Rmax in group III was 19.5±9.51 μ before and 25.05±6.24 μ after treatment; despite a slight increase in the Rmax after treatment, this increase was not statistically significant (P=0.07).

The mean (±SD) Ra in group V (250mJ power Er,Cr:YSGG laser) was 3.41±2.36 μ before and 4.57±1.79 μ after treatment; which indicated a significant increase in this parameter (P<0.01). The mean (±SD) Rz parameter in group V was 16.02±10.18 μ before and 19.51±7.67 μ after treatment; which indicated a significant increase in this parameter (P<0.05). The mean (±SD) Rmax in group V was 23.55±18.44 μ before and 29.01± 14.35 μ after treatment; which indicated a significant increase in this parameter (P<0.05).

The mean changes of Ra parameter was -1.6± 2.65 (median of changes: -1.21) in group I (manual curette), 2.27±1.64 (median of changes: 2.38) in group I (4W Er:YAG), 1.29±4.02 (median of changes: 2.22) in group III (manual curette+1.0 W Er:YAG), 0.83± 1.61 (median of changes: 1.18) in group IV (manual curette+ 150mJ Er,Cr:YSGG) and 1.16± 1.41 (median of changes: 1.32) in group V (250 mJ Er,Cr:YSGG) (Table 1).

The changes in Rz parameter was -7.98± 9.98 (median of changes: -7.91) in group I (manual curette), 5.22±4.94 (median of changes: 3.68) in group II (4W Er: YAG), 1.78±13.84 (median of changes: 4.13) in group III (manual curette+ 1.0 W Er:YAG), 2.23± 5.12 (median of changes: 2.52) in group IV (manual curette+150mJ Er,Cr:YSGG) and 3.49± 4.97 (median of changes: 2.95) in group V (250 mJ Er,Cr:YSGG) (Table 2).

The mean (±SD) changes of Rmax was -14.43± 21.65 (median of changes: -13.54) in group I (manual curette), 6.49±6.85 (median of changes: 6.88) in group II (4W Er:YAG), 316.05±995.03 (median of changes: 10.14) in group III (manual curette+ 1.0 W Er:YAG), 5.55±7.69 (median of changes: 5.36) in group IV (manual curette+150mJ Er,Cr:YSGG) and 5.46±3.27 (median of changes: 3.27) in group V (250 mJ Er,Cr:YSGG) (Table 3).

The results of Mann Whitney U test revealed significant differences between groups I (manual curette) and II (4W Er: YAG laser) in terms of Ra parameter after treatment (P<0.04). No other significant differences were found by pairwise comparison of groups in this respect.

Significant differences were also found between groups I (manual curette) and II (4W Er: YAG laser) in terms of Rz parameter after treatment (*P*<0.04). No other significant differences were found by pairwise comparison of groups in this regard.

The differences in Ra before and after treatment between the two groups of I (manual curette) and II (4W Er: YAG laser) were statistically significant as well (*P*<0.009). No other significant differences were found by pairwise comparison of groups in this respect.

The differences in Rz before and after treatment between the two groups of I (manual curette) and II (4W Er: YAG laser) were statistically significant (*P*<0.01) and no other significant differences were found after pairwise comparison of groups in this regard.

No sign of thermal alteration i.e. melting or carbonization was seen in any group. Laser irradiated root surfaces had the highest frequency of irregular and porous patterns. Root surfaces that received SRP with manual curettes were smoother than other groups. Under magnification, root surfaces that received manual scaling with curettes had shallower surface porosities with small amounts of debris. Treatment with the two powers of Er:YAG and Er, Cr:YSGG lasers yielded rougher root surfaces compared to manual curettes.

Discussion

Except for SRP with manual curettes that caused a significant reduction in roughness parameters, Ra, Rz and Rmax increased after treatment in the remaining four groups (compared to the pre-treatment values). In other words, surface roughness slightly increased in laser irradiated surfaces irrespective of using manual curettes. These increases in group II (Er:YAG alone) and group V (250 mJ Er,Cr:YSGG alone) were statistically significant.

The mechanism of dental hard tissue ablation by Er,Cr:YSGG laser is via the high photon absorption capacity of water molecules present in the intercrystalline spaces of the HA crystals (13, 14). These molecules evaporate quickly and the subsequent tissue micro-explosions facilitate the ablation of HA crystals at temperatures below their melting point via a mechanism known as photo-mechanical ablation (14, 15). Moreover, increased surface roughness in this treatment modality is likely considering the rapid ablation of the inter-tubular tissue due to its high water content (compared to tubular and peri-tubular dentin). Increased surface roughness following Er:YAG and Er,Cr:YSGG laser irradiation was evident in our study.

Clinically, it is extremely important to achieve smooth, hard and resistant root surfaces following SRP with different instruments (16, 17). This goal was not achieved in any of our study groups; conversely, the surface roughness increased in laser treated groups. Rough surfaces enhance the accumulation of large amounts of dental biofilm; especially when located supragingivally (16). Rough surfaces must be polished to minimize bacterial biofilm formation over them (17). Nonetheless, subgingival rough surfaces are actually beneficial for periodontal treatments since these areas enhance the adhesion of a stable fibrin network, induce the migration of fibroblasts and mesenchymal cells and promote periodontal regeneration (18). Accordingly, SRP combined with Er:YAG or Er,Cr:YSGG laser irradiation may increase the accumulation of dental plaque and bacterial biofilm formation.

Different instruments and clinical protocols have been used for the removal of bacterial deposits, dental plaque and necrotic cementum in non-surgical periodontal treatments. The conventional method for this purpose is using manual curettes or an ultrasonic instrument; which are routinely used in dental clinics. At the same time, considering the extensive applications of laser in dentistry, some suggest using Nd:YAG, Er:YAG or Er,Cr:YSGG laser to achieve additional clinical improvement. Diode laser has also been recommended as an adjunct to the conventional periodontal therapy (19). However, some other researchers have reported no additional clinical benefit for laser irradiation protocol in non-surgical periodontal treatments (20). In the current study, we evaluated two types of lasers with different power settings but found no additional clinical benefit attributed to their use.

The results of SEM analysis revealed variable degrees of alterations in the root surfaces subjected to SRP with manual curettes combined with Er:YAG or Er,Cr:YSGG laser irradiation. Our results confirmed those of de Oliveira *et al.* (21). In their study, all root surfaces that received Er, Cr:YSGG laser irradiation were rougher than the non-laser-irradiated specimens. However, in our study two types of lasers (Er:YAG and Er,Cr:YSGG) with different power settings were used.

Some laser irradiation parameters can significantly change the surface morphology of specimens. Ting *et al.* evaluated and compared the effects of different power output settings of laser irradiation (0.5, 1.0, 1.5, and 2.0 W) by examining the morphological changes in the root surfaces and the efficiency of calculus removal. They demonstrated that 1.0 W power of Er,Cr:YSGG laser was appropriate for root scaling. The 2W power setting was much more efficient for calculus removal; but, resulted in significant morphological alterations in the root surfaces (13). In our study, both laser types with different power settings roughened the root surfaces and consequently increased the risk of plaque accumulation and biofilm formation. Hakki *et al.* (2010) reported differences in surface roughness among laser treated groups probably attributed to the laser settings (short or long pulse) (22). Type of laser is an important factor affecting the results. Er:YAG and Er,Cr:YSGG lasers were selected in our study among different lasers commonly used for dental applications. Researchers have used different lasers *i.e.* CO2, Nd:YAG and Er:YAG for the SRP of teeth in patients with periodontal disease (23-25). Some studies have reported Er:YAG laser to be superior for SRP than other lasers (26, 27). However, in our study, Er:YAG had no superiority over Er,Cr:YSGG laser.

Our results revealed that both power settings of Er:YAG and Er,Cr:YSGG lasers yielded rougher root surfaces compared to manual curettes. The degree of porosity and the depth of craters have a direct correlation with the energy or power of laser, pulse length, fiber optic shape and angle of laser irradiation relative to the root surface.

In our study, the greatest reduction in surface roughness was seen in the manual curette group (I); this finding is in accord with the results of Amid *et al.*. In their study, the greatest reduction in surface roughness occurred in the manual curette and ultrasonic instrument groups (28, 29). Schwarz *et al.* showed that the efficacy of calculus removal by Er:YAG laser irradiation was equal to that of SRP by hand instruments in the clinical setting but diode laser irradiation was not suitable for calculus removal due to causing significant surface changes (27). Ting *et al.* reported that 1.0 W power output setting of Er,Cr:YSGG laser can be used for root scaling because it did not cause significant morphological alterations on the root surface and efficiently removed dental calculus . However, Frentzen *et al.* reported that Er:YAG laser irradiation increased the loss of cementum and dentin and increased surface roughness; they expressed doubts about its efficacy in the clinical setting (26). In a study by de Mendonca *et al.* scaling with manual curettes produced rougher surfaces than Er:YAG laser and ultrasonic system. In their study, all the tested techniques increased the roughness of dentin root surfaces after treatment (30). According to Crespi *et al.* Er:YAG laser irradiation in the clinical setting results in efficient plaque and calculus removal and yields a rough surface morphology (31). Tsurumaki *et al.* also reported that ultrasonic instrumentation and Er,Cr:YSGG laser irradiation alone or in combination with hand SRP yielded rougher root surfaces compared to the use of manual curettes, alone. These results are in agreement with our findings (32). Therefore, despite the available reports regarding the similar efficacy of laser irradiation to that of manual curettes and ultrasonic systems for SRP, some evidence shows the lack of success of this treatment modality.

Conclusion

Two different power settings of Er:YAG and Er,Cr:YSGG laser irradiation alone or in combination with the use of manual curettes for SRP increased the roughness of root surfaces compared to the use of manual curettes alone. The possible clinical impacts of laser irradiation for SRP require further investigations in the clinical setting.

Conflict of Interest: None declared.

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