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Comparison of the Effects of Er, Cr: YSGG Laser and Super-Saturated Citric Acid on the Debridement of Contaminated Implant Surfaces

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Abstract

Introduction: Several techniques such as using citric acid, plastic curettes, ultrasonic devices, and lasers have been suggested for debridement of contaminated implant surfaces. This comparative investigation aimed to assess and compare the effects of Er, Cr: YSGG laser and super-saturated citric acid on the debridement of contaminated dental implant surfaces.

Methods: In this in-vitro study, 12 contaminated failed implants were collected and randomly divided into 2 groups (6 in group A, and 6 in group B). Also, one implant was considered as the control. The implants were horizontally sectioned into coronal and apical portions and subsequently irradiated by Er, Cr: YSGG laser in coronal and citric acid in apical in group A and the opposite in group B. In order to evaluate the effect of water spray on the laser section, half the laser portion of the implants was irradiated using water, while the other half was irradiated without water with an irradiation time of 1 minute.

Results: Results revealed that calculus and plaque removal was greater in the laser part of both groups (with and without water) compared to citric acid parts and the correlation between calculus removal and surface roughness were statistically significant. Furthermore, the surface roughness in the citric acid parts was significantly higher than in laser parts. Water spray during irradiation had a very small influence on understudy factors.

Conclusion: Based on the results of this study, the Er, Cr: YSGG laser was more effective in calculus removal and caused less surface roughness compared with citric acid application.

Keywords: Contaminated implant; Er, Cr: YSGG laser; Citric acid.

Introduction

Dental implants are considered as a well-accepted treatment modality for tooth replacement with high success rates and expectable outcomes.[1] Presently, there is a solid body of evidence to support the causative relationship between microbial contamination and pathogenesis of implant failures. Bacterial colonization on implant surfaces can irritate the peri-implant mucosa resulting in progressive destruction of the alveolar bone.[2-4] Up to now, several techniques, such as the use of citric acid, plastic curettes, ultrasonic devices, and lasers have been recommended for the treatment of peri-implant infections and debridement of implant surfaces.[5,6]

Lasers have the ability to present excellent tissue ablation and have high bactericidal effects; thus, laser application can open a new window in the treatment of failing implants. The Er,Cr:YSGG (erbium, chromium: yttrium, scandium, gallium, garnet) laser, operating at 2780 nm, removes tissue through a hydrokinetic process in collaboration with water spray that inhibits temperature rise.[7,8] The Er,Cr:YSGG laser is an FDA-approved laser device for osseous apical and periodontal surgeries, cleaning, shaping and enlarging root canals and decreasing total bacterial count. Moreover, it can increase bone-implant contact, accelerate healing and decrease postoperative pain.[9,10] A study conducted at

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Temple University, Philadelphia, PA showed that within a confined space, laser was able to significantly reduce the bacterial count.[11] A report by Crespi et al indicated that the use of erbium lasers can debride the root surface without damaging the walls.[12]

Citric acid is another increasingly popular agent for debridement and detoxification of implant surfaces. In the past, it was used for conditioning of root surfaces in regenerative osseous surgeries. Since the advent of implants, it has been used for detoxification of implant surfaces as well. However, extensive studies have not been carried out to assess the effect of citric acid on the surface of dental implants.[6]

The aim of the present in vitro study was to evaluate and compare the effect of Er,Cr:YSGG laser and supersaturated citric acid on the debridement and roughness of contaminated dental implants using scanning electron microscopy (SEM) analysis.

Methods

This in vitro study was conducted in Shahid Beheshti University of Medical Sciences in 2010. In this investigation 12 contaminated failed straight-walled tissue-level blasted with hydroxyapatite implants (due to severe peri-implantitis) with similar characteristic (Swiss Plus, Zimmer Dental Inc, USA) were collected and randomly divided into 2 groups (6 in group A, and 6 in group B). Also, one new implant was considered as the control (Swiss Plus, Zimmer Dental Inc, USA).

In group A, the threads of 6 implants were sectioned into coronal and apical portions and then the regions between coronal threads were irradiated using Er, Cr: YSGG laser (WaterLase, iPlus, Biolase, USA) operating at 2.5 W average power, a wavelength of 2780 nm, 25 Hz, 100 mJ per pulse, H mode (pulse duration of 60 μs), 1600 W peak power with 600 micron tip, 1 mm distance and time irradiation of 2 minutes. To evaluate the effect of the water spray system, half of the coronal section was irradiated using 55% water (WL) and 50% air and the other half irradiated without water (L) with the same air percentage with time irradiation of 1 minute. Moreover, with one thread interval from the coronal threads, the apical threads were covered with super saturated citric acid 3% (SSCA, Sigma-Aldrich, USA) for three minutes (citric acid was prepared in the Biology Laboratory of Shahid Beheshti University of Medical Sciences). After laser irradiation and citric acid application, all implants were washed with normal saline.

In group B, similar to group A the threads were sectioned into apical and coronal portions and the apical section was irradiated using Er,Cr:YSGG laser, operating at 2.5 W power, a wavelength of 2780 nm and 25 Hz with time duration of 2 minutes. Similar to group A, half of the apical section was irradiated using water and the other half irradiated without water by pulse duration of one minute. The coronal threads were covered with supersaturated citric acid 3% for three minutes. A new implant fixture was used as the control and similar evaluations were done for it using SEM (scanning electron microscope, Philips XL 30, FEI Philips Electron Optics, The Netherlands). All specimens were evaluated in terms of intervals between threads using SEM at 15×, 25×, 100×, 250×, 1000× and 5000× magnifications.

Then the level of calculus removal from the implant surfaces, 0 = no change, 1 = barely (up to 25%), 2 = slight (25%-50%), 3 = strong (50%-75%) and 4 = complete removal (100%) and change in surface roughness (0 = decreased, 1 = no change, 2 = increased) and also the released amounts of aluminum (Al), potassium (P), titanium (Ti) and calcium (Ca) were measured, with the aim of assessing the effect of decontamination methods (lasers and citric acid) on the surfaces of implants and changes in the surface chemical composition by means of SEM applying semi-quantification methods.

The collected data were entered into SPSS (version 16) software (IBM SPSS software, USA). Data were expressed as mean ± standard deviation (SD). Non-parametric Friedman test was used to compare the differences between the three techniques. Non-parametric Wilcoxon signed-rank test was used to compare the 2 techniques.

We also used Friedman and Wilcoxon signed-rank tests to measure the AL, P, Ti and Ca content on the surface of implants after treatment.

Results

We evaluated a total of 12 implants in 2 groups. According to the Friedman test, the difference between the three treatment techniques in terms of calculus removal was significant in both groups ($P = 0.04$ for group A and $P = 0.01$ for group B). Using Wilcoxon signed-rank test, the only significant difference in group A in terms of calculus removal was between supersaturated citric acid and water + laser ($P = 0.03$). The differences between WL and L ($P = 0.18$) or between citric acid and L ($P = 0.12$) were not statistically significant (Table 1).

In group B, the differences between WL and L with acid citric were significant ($P = 0.03$ and $P = 0.04$, respectively) (Table 1); but the difference between WL and L was not statistically significant ($P = 0.5$) (Table 1).

In group A, WL and L decreased the surface roughness of implants, while acid citric increased the surface roughness (Table 2; Figure 1). In the group B, WL and L decreased the surface roughness but citric acid did not impact half of the implants. The difference between the three techniques in this respect was significant in both A and B groups ($P = 0.04$ and 0.03, respectively).

In group A, using Wilcoxon test, the difference between citric acid and L in changing surface roughness was significant ($P = 0.05$) but the differences between L and WL ($P = 0.3$) or citric acid and WL ($P = 0.06$) were not statistically significant.

In group B, the difference between citric acid and L in

Table 1. Comparison of Calculus Removal by 3 Techniques in 2 Groups

Calculus Removal	Group A No. (%)			Group B No. (%)			Total No. (%)		
	WL	L	Acid	WL	L	Acid	WL	L	Acid
0	0	0	0	0	0	1 (16.7)	0	0	1 (8.3)
1	0	1 (16.7)	3 (50)	0	0	2 (33.3)	0	1 (8.3%)	5 (41.7)
2	2 (33.3)	1 (16.7)	2 (33.3)	1 (16.7)	0	2 (33.3)	3 (25)	1 (8.3)	4 (33.3)
3	2 (33.3)	4 (66.7)	1 (16.7)	2 (33.3)	5 (83.3)	1 (16.7)	4 (33.3)	9 (75)	2 (16.7)
4	2 (33.3)	0	0	3 (50)	1 (16.7)	0	5 (41.7)	1 (8.3)	0
Total	6 (100)	6 (100)	6 (100)	6 (100)	6 (100)	6 (100)	12 (100)	12 (100)	12 (100)

Abbreviations: WL, laser with water irrigation; L, laser without water irrigation.

Table 2. Comparison of Change in Surface Roughness by 3 Techniques in 2 Groups

Surface Roughness	Group A N (%)			Group B N (%)			Total N (%)		
	WL	L	Acid	WL	L	Acid	WL	L	Acid
Decrease	4 (66.7)	5 (83.3)	1 (16.7)	5 (83.3)	6 (100)	2 (33.3)	9 (75)	11 (91.7)	3 (25)
No change	2 (33.3)	1 (16.7)	2 (33.3)	1 (16.7)	0	3 (50)	3 (25)	1 (8.3)	5 (41.7)
Increase	0	0	3 (50)	0	0	1 (16.7)	0	0	4 (33.3)
Total	6 (100)	6 (100)	6 (100)	6 (100)	6 (100)	6 (100)	12 (100)	12 (100)	12 (100)

Abbreviations: WL, laser with water irrigation; L, laser without water irrigation.

changing surface roughness was significant ($P = 0.05$) but the difference between L and WL ($P = 0.3$) or citric acid and WL ($P = 0.1$) were not statistically meaningful.

The difference between the 2 groups A and B in terms of changing the surface roughness by the three techniques was statistically significant ($P = 0.002$). The differences between citric acid and L ($P = 0.01$), and citric acid and WL ($P = 0.01$) were significant in this respect but L and WL were not significantly different in this regard ($P = 0.31$) (Table 2).

Aluminum

In group A, the greatest Aluminum content was observed after treatment with citric acid, while the lowest value was observed in the L group. In group B, the greatest Al content was observed after treatment with citric acid; while the lowest value was observed in the WL group. The difference in this regard between the three techniques was not significant neither in the group A nor in the group B ($P = 0.1$ for group A and $P = 0.5$ for group B). The difference between the 2 groups of A and B was not

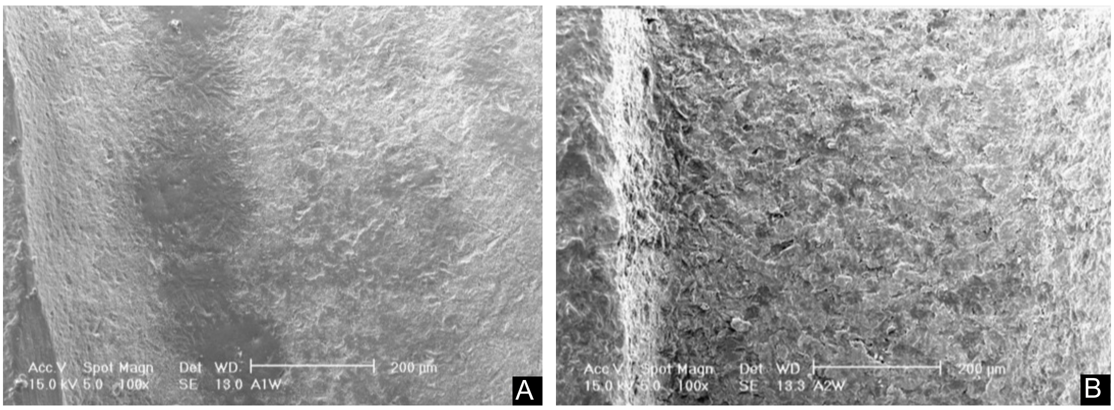

Figure 1. SEM Analysis (×100) Laser (A) Versus Super Saturated Citric Acid (B) in Debridement of Contaminated Implant Surface.

significant either ($P = 0.6$).

Phosphorous

In groups A and B, the highest P content was noted in the citric acid group; while the lowest was in the LW group. The difference between the 3 techniques in this regard was statistically significant in both groups ($P = 0.009$ for group A and $P = 0.03$ for group B). In group A, the differences between citric acid and L ($P = 0.02$) and also between citric acid and WL were statistically significant in this respect ($P = 0.02$). The difference between L and WL was not statistically significant ($P = 0.4$).

In group B the difference between citric acid and WL was significant ($P = 0.02$); while the differences between citric acid and L ($P = 0.1$) and also L and WL ($P = 0.2$) were not significant.

The difference between groups A and B was statistically significant in this regard ($P = 0.001$).

Titanium

In groups A and B, the lowest Ti content was observed in the citric acid group. The differences between the three techniques were statistically significant in both A and B groups ($P = 0.009$, and $P = 0.006$, respectively). In group A, the differences between citric acid and L ($P = 0.02$) and also between citric acid and WL (0.02) were statistically significant, but the difference between L and WL was not statistically significant in this aspect ($P = 0.4$).

In group B, the differences between citric acid and WL ($P = 0.02$) and also between citric acid and L ($P = 0.02$) were significant, but the difference between L and WL ($P = 0.3$) was not statistically meaningful. The difference between A and B groups was significant as well ($P = 0.001$).

Calcium

In group A, the greatest Calcium content was observed in the citric acid group, while the lowest rate was observed in the WL group. The difference between the three techniques was not significant in group A ($P = 0.1$) or B ($P = 0.7$). The difference between groups A and B was not statistically significant in this regard ($P = 0.1$) (Table 3).

Discussion

In this in vitro study, we evaluated the effect of citric acid and Er,Cr:YSGG laser on 12 failed implants in terms of calculus removal and surface roughness. We found that laser (WL, L) application was more effective than citric acid for calculus removal. Using WL technique, acceptable calculus removal was achieved in 25%, extensive calculus removal in 33% and complete removal in 41.7% of the cases. Extensive calculus removal was achieved in 75% of implants using L technique, while in implants treated with citric acid complete removal did not occur in any case.

Similar to our investigation, in a study, Miller compared the efficacy of Er, Cr: YSGG laser with citric acid 40% for debriding contaminated implant surfaces and reported results in line with those of ours. In Miller's study, the implants were divided into 2 groups of titanium plasma sprayed (TPS) group and hydroxyapatite (HA) group. The 2 groups were further divided based on the surface treatment into 3 groups of control (untreated), 40% citric acid washed and laser treated. Laser treatment was done for TPS and HA groups using Er,Cr:YSGG (Biolase technology, USA) laser with a 600 µm tip with a power setting of 6 W followed by an air pressure setting of 100 and water spray at 32 for 3 minutes. Citric acid 40% at pH = 1 was applied for three minutes followed by one minute of sterile rinse. The results for TPS group showed that after surface treatment there was a decrease in organic smear layer when YSGG laser was used as compared to the control group, whereas citric acid treatment failed to remove the organic smear layer. Surface analysis of HA group revealed that the YSGG laser removed the organic smear layer completely whereas citric acid showed incomplete coating removal, loss of crystalline of the remaining bioactive coating and no loss of organic smear layer. Furthermore, Er,Cr:YSGG laser showed superior debridement properties when compared to 40% citric acid used on TPS and HA implants.[13]

Conversely, Misch, in his study in contrast to ours and Miller's findings, recommended a treatment for failing implants using 40% citric acid.[14]

In our study, citric acid significantly increased the surface roughness compared to laser (WL and L). It seems that the Er,Cr:YSGG irradiation did not damage the implant surface. Similar to our survey, Schwarz et al in 2006 indicated that Er,Cr:YSGG irradiation with 2.5 W

Table 3. Comparison of Al, P, Ca and Ti Released by 3 Techniques in 2 Groups

Treatment Methods	Group A n = 6			Group B n = 6			Total n = 12		
	WL	L	Citric Acid	WL	L	Citric Acid	WL	L	Citric Acid
Al	2.37±4.2	2.11±3.4	3.76±8.3	2.42±4.4	2.46±4.3	3.43±6.7	2.39±4.1	2.28±3.7	3.6±7.2
P	2.28±0.9	2.47±0.7	5.5±1.9	2.3±0.9	2.7±0.9	5.4±2.8	2.3±0.8	2.5±0.8	5.4±2.3
Ca	0.32±0.3	0.4±0.3	0.8±0.5	0.4±0.5	0.3±0.3	0.4±0.3	0.4±43	0.4±0.3	0.6±0.4
Ti	93.1±4.6	92.6±4.2	83.2±7.4	93.4±5.8	93.1±4.5	83.9±5.7	93.2±5.0	92.8±4.2	83.5±6.3

power did not damage the surface of titanium implants; moreover, the authors divulged that this laser wavelength significantly removed the biofilm plaque. Additionally, they showed that laser application was very effective in bacterial decontamination and had advantages in the reduction of bleeding, swelling, and pain.[15]

During mechanical debridement, any metal to metal contact has the potential to damage the implant surface and then the roughened or scratched implant surface allows for increased bacterial colonization leading to increased risk of destruction in the supporting alveolar bone and implant failure.[16] Matarasso et al showed that ultrasonic metal tip scalers caused pitting, marked morphological alterations and subsequent bacterial colonization on the surface of titanium implants.[17] On the other hand, failure to complete surface detoxification or alteration of implant surfaces can compromise the bone-implant contact leading to reduced treatment success. Thus, bacterial decontamination without damaging the implant surface is a key point in the treatment of peri-implantitis.[7,18,19]

Al, P and Ca content was greater in the citric acid group, while Ti content was higher in the laser group. However, the difference in this regard was not statistically significant.

Matsuyama et al in their report indicated that the Er:YAG laser effectively removed the calculus and plaque on contaminated abutments without damaging the titanium surface or causing major temperature rise.[20]

One limitation of the present study was the relatively small sample size. Also, we did not evaluate or compare the results at different power and frequency settings of Er,Cr:YSGG laser. Therefore, further investigations with larger sample size are required to assess the effect of different power and frequency settings of Er,Cr:YSGG laser on calculus removal, surface roughness, and peri-implant disease.

Beside the Er,Cr:YSGG, researchers have discussed the efficacy of other wavelengths of laser on peri-implantitis.[7,21] Block et al stated that an Nd: YAG laser on TPS and HA coated implant surfaces resulted in unwanted surface alterations and incomplete decontamination.[22] Diode laser such as 810 or 980 nm has been shown to provide bacteria reduction without damaging implant surfaces.[7,23,24] Co_2 and Er; YAG laser ensures a reliable decontamination of implants without altering surface morphology.[25,26] Furthermore; Recently, photodynamic therapy using a nontoxic chemical agent (photosensitizer) in combination with low power light has been proposed as a novel treatment modality in peri-implantitis.[27]

Temperature changes at the implant-bone contact should be carefully considered during laser application. Temperature rise beyond a 10°C threshold above body temperature results in bone destruction, leading to coagulation and denaturation of collagen and bone proteins and to impairment of osteoneogenesis.[28-30]

Geminiani et al declared that the irradiation of sandblasted and acid-etched implant surfaces with diode lasers (810 and 980 nm) at 2 W in continuous mode may produce a temperature rise above the critical threshold (10°C) after only 10 seconds.[31] Park et al stated that NdYAG laser irradiation on the titanium surface led to damage to the micromachined surface and coating of implant surfaces as well as an undesirable melting effect; while CO2 laser had minimum alteration on the implant surface with minor temperature increase.[32] Leja et al determined the effect of diode lasers (810/980 nm), carbon dioxide, and Er:YAG lasers with 4 different setting on the implant surface temperature and concluded that only diode lasers with a power of 1 W in pulse mode did not increase the implant temperature above the critical temperature threshold.[33] Kreisler et al indicated that Nd:YAG and Ho:YAG lasers are not proper choices for use in detoxification of implant surfaces, regardless of the power output; Er:YAG and CO2 laser irradiations can be the suitable approaches with controlled power output to avoid surface alterations.[21,34]

Stubinger et al stated that Er:YAG setting for implant surface irradiation should be limited up to 300 or 500 mJ/10 Hz[24] and it seems that ErCr:YSGG laser with refrigeration does not generate thermal increments at the apical surface.[35]

In conclusion, the Er,Cr:YSGG laser was more effective in calculus removal and caused less surface roughness compared to citric acid application and considering the limitations of this study, this kind of laser application may be used for the treatment of peri-implantitis. More studies, especially animal and clinical trials are needed in order to provide evidence for the use of this laser application in the treatment of peri-implant diseases.

Ethical Considerations

This article does not contain any studies with human or animal subjects performed by any of the authors.

Conflict of Interests

The authors declare no conflict of interest.

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