Smear layer removal with laser in drilled implant holes

A pilot study

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Introduction

Dental implants form a new opportunity window for individuals who have lost their teeth due to various reasons such as trauma, dental caries and periodontal diseases.[1,2] According to published papers, less than 8 % of dental implantation surgeries have failed.[3,4] Formation of smear layer after usage of dentistry tools or by bacterial flora surrounding the implant cavity may, however, result in implant fracture.[5–7]

Smear layer refers to a remainder of bone tissue after usage of dentistry tools which may challenge the success of relief, joints and penetration of materials to bottom layers such as the root canal. This layer includes different materials like bone and soft tissue lesions, blood cells and microorganisms. These lesions are not limited to inter-dental or bone septum, but may penetrate to bone tubules and do not solve related negative effects.[5,8] Formation of this layer defects the sealing process and creates an environment for growth of microorganisms and bacteria to bone tissue which may decrease the probability of deep cleansing and result in fracture of the implant.[5] Therefore, it is highly required to discover safe and inexpensive methods to remove this layer.

Laser is abbreviated from "Light Amplification by Stimulated Emission of Radiation" and is effectively used in dentistry interventions.[9] Various types of lasers have different impacts on bacteria, depending on type of radiation, conditions of radiation and bacterial density. Vercruyssen et al. conducted a study in which they applied pulsed Nd:YAG laser radiation on teeth root in *in-vitro* environment. The results indicated that density of *E. coli* and *Staphylococcus aureus* was significantly reduced and when the application of sodium hypochlorite was added to the treatment, the bactericidal effect was increased.[10] Meral et al. reported that Nd:YAG laser radiation exhibits various levels of lethality rates for different bacteria. As their results shown, the lethality rate for *Staphylococcus alpha* hemolytic was higher compared to *Staphylococcus nicira*.[11] In another study conducted by Lee et al. with diode laser applied on *Staphylococcus mutans* colonies with a thickness of 500 microns, a lethality rate of 97.7 % was observed. With increase in thickness of the bacteria colony, the lethality rate was reduced.[12]

Many types and categories of laser instruments are being introduced to the worlds of dentistry and medicine, but their application and effectiveness are yet to be evaluated and studied. Among these instrument, Er,Cr:YSGG laser is widely used for bone incisions and soft tissues surgeries in dentistry.[13] Compared to conventional mechanical drills, this particular type of laser exhibits minimised tissue damage and does not increase the tissue temperature to intolerable ranges.[14] The bactericidal effects of Er,Cr:YSGG laser is another important aspect of this type of laser. Schoop et al. observed in their research that Er,Cr:YSGG laser managed to remove the layer of bacteria from smear layer on the root.[15] Miller et al. stated that this type of laser has an appropriate impact in disinfecting the dental implant surface.[16] Since this type of laser has been accepted as a conventional disinfecting instrument,

operations for removing the smear layer show better results.[17]

As our researches indicated, none of the studies carried out an evaluation of the effects of radiation conditions of Er,Cr:YSGG laser on removing the smear layer of the bone cavity for dental implants that report optimum radiation conditions. Hence, the objective of the current study is to evaluate various conditions of radiation of this particular laser for the removal of smear layer from bone cavity in *in-vitro* conditions.

Materials and methods

This is a semi-experimental *in-vitro* study performed on bone cavities drilled on the femur of a bovine calf.

Bone preparation

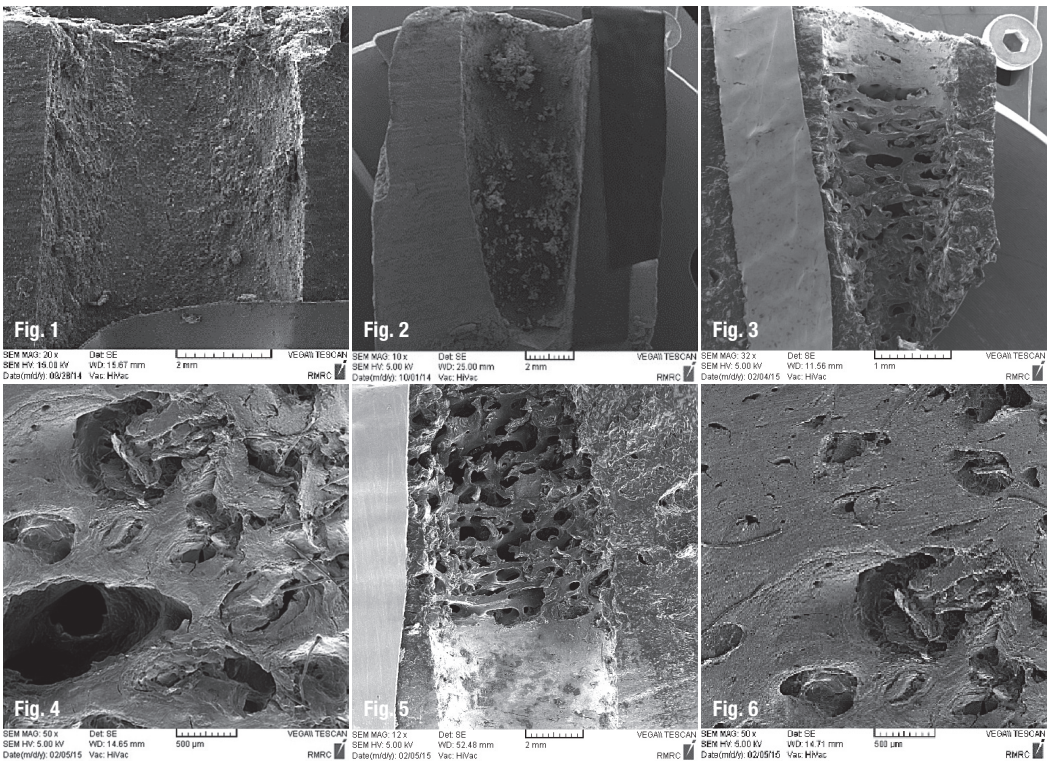
Initially, the femur bone of recently a slaughtered bovine calf was removed and kept in water of a temperature of 4 °C. Prior to the commencement of the tests, the bone surface was placed in ambient temperature for twelve hours to be completely dried and then all residues were removed from the bone surface using sand paper, then washed by tab water and again placed in ambient temperature for the next twelve hours. In the next stage, 102 holes were drilled with a depth of 15 mm on the femur bone on the basis of NEOSS system implant protocol for Pro Active Tapered implants with a diameter of 4.5 Ø, using Pilot Drill 2.2 Ø and a speed of 1,000 to 1,200 rpm.[18] The space between the holes is 2 centimeters. Then the holes were categorised in 17 six-member groups which include 16 direct radiation groups and one control group. Then the holes were washed with water and placed in ambient temperature for twelve hours to be used in the laser intervention.

Laser instrument

In this study we applied a radiation of an Er,Cr:YSGG laser instrument configured with 16 settings (Figs. 1–6) on the bone cavity. The exposure conditions include power configuration rage

Table 1: Number of drilled cavities with smear layer in 16 studied groups.

No.	Power (W)	Frequency (Hz)	Mode (H/S)	Air (%)	Water (%)	Tip	Time (S)
1	4.5	50	H	10	80	RFTP5	60
2	4.5	50	H	10	80	RFTP5	120
3	4.5	40	H	10	80	RFTP5	60
4	4.5	40	H	10	80	RFTP5	120
5	4.5	30	H	10	80	RFTP5	60
6	4.5	40	H	10	80	RFTP5	180
7	3	15	H	10	90	RFTP5	20
8	3	15	H	10	90	RFTP5	40
9	1.5	30	H	10	90	RFTP5	20
10	1.5	30	H	10	90	RFTP5	40
11	1.5	30	H	10	70	RFTP5	60
12	1.5	30	H	10	70	RFTP5	120
13	1.25	50	H	10	50	RFT2	60
14	1.25	50	H	10	50	RFT2	120
15	0.75	20	H	10	50	RFT2	60
16	0.75	20	H	10	50	RFT2	120



Figs. 1–6: SEM images of settings 13 to 16 and control group before intervention.

of 0.75 to 4.5 Watts with frequencies of 20 to 50 Hertz, an air percentage of 10 % and water cooling percentage of 50 to 90 with a radiation time ranged from 20 to 180 seconds. Before radiation on each cavity, the other cavities were covered with aluminum paper. Radiation was commenced by locating the laser fibre in each cavity. Time was also measured by watch on the basis of different settings. Laser radiation was accompanied with water spray as abolisher. Samples of the control group were also rinsed with tab water using a 10 cc syringe after drilling the related cavities.

SEM imaging

For provision of the SEM images, initially all cavities were cut in half and prepared according to the study conducted by Freitas et al.[18] In summary, after cutting the cavities, samples were submersed in 2.5 % glutaraldehyde solution in combination with 0.1 molar sodium cacodylate buffer solution with acidity degree of 7.4 for 12 hours and at a temperature of 4 °C. Then all samples were dehydrated using 25 % to 100 % ethanol solution; hexamethyldilslazane solution was used for 10 minutes for drying the samples. Paper filters were used at the time of airbrushing the samples; then samples were mounted in aluminum tubes using a silver-gold colloid adhesive. Cavities were imaged using SEM before and after exposure to radiation to evaluate the condition of smear layer qualitatively.

Statistical analysis

The data were qualified according to presence/absence of smear layer which were analysed using Mann-Whitney U-Test and SPSS 17 software.

Findings

The SEM images captured from cavities exposed to 16 settings of Er,Cr:YSGG laser are presented in Figs. 1–6. The images are captured from four settings after 100 % removal of smear layer.[1] Images are demonstrated on the basis of different settings. Series (a) of images are taken prior to application of radiation and series (b) show the results of application. Among the mentioned 16 settings, only the numbers 13 to 16 (Figs. 1–6) revealed an appropriate removal of smear layer. SEM images of settings 13 to 16 and control group are illustrated here.

Discussion

The main objective of this study is to evaluate the bactericidal effect of various settings of Er,Cr:YSGG laser radiation. According to the findings of the research, from a total of 16 settings, 1.5 and 3 Watt radiation condition, frequencies of 15 and 30 Hz and time of 20 and 40 seconds, a smear layer removal efficiency of up to 100 % was achieved in comparison to the control group.

Er,Cr:YSGG laser is a safe instrument with a high level of tissue adaptive capability; compared to conventional drills used for preparation of the bone bed of the implant, application of this instrument results in a much smaller temperature raise in the tissue, which is within the tolerance range of the tissue.[19] It seems that the application of this particular type of laser imposes mitochondrial osteoblastic function with no significant impact;[20] in other words, the osteoblastic function necessary for bone formation around the implant area is preserved using this method. Additionally, according to the findings of Secilmis et al., using power configurations of 1 and 2 Watts imposes minerals of hard tissue with not significantly change and superficial strength, connectivity capability is not reduced.[21] Additionally, histo-pathological evaluations indicate that various radiations of this laser with lesser powers do not trigger inflammatory response; the application of laser radiation does not elevate inflammatory response to ranges that affect the tissue healing process with negative effects.[22] Few studies are conducted on disinfection capabilities of Er,Cr:YSGG laser. Ishizaka et al. found that lower power used in Er,Cr:YSGG laser radiation preserved the smear layer removal performance. In their study, all three power configurations of 1, 3 and 5 Watts removed the smear layer properly; also, the performance was related to the diameter of the tip of the fibre and flatter tips proved to be more efficient in disinfection.[23] Yamakazi et al. did not find significant differences in the smear layer removal performance using power configurations of 1 to 6 Watts; however, in contrast to dry radiation, cooling the target at the time of radiation resulted in better performance of smear layer removal.[24]

Microorganisms are an important part of the smear layer that may have a specific role in reducing the success rate of dental implants. Several studies were focussed on the bactericidal effects of the Er,Cr:YSGG laser radiation. Generally, these studies did not focus on different settings of laser radiation, bur investigated tooth root canal and implant surface. Moreover, specific germs that participate in implant infection are similar to oral microbial flora and pathogens.[24,26] Gordon et al. studied 15 settings of Er,Cr:YSGG laser (175 to 325 mW and exposure times of 15 to 340 seconds) and their results were compared to the results of

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application of 2.5 % hypochlorite solution for the removal of *Enterococcus faecalis* colonies from root canals. Their findings showed that the disinfection capability of the laser radiation is increased through the elevation of power and exposure time; as for their study, the best result was achieved by a power of 325 mW with an application time of 120 seconds without using water cooling. This setting managed to achieve a 99.7 % success in disinfection; disinfection processes using water showed better results compared to dry disinfection.[64]

Arnabat et al. evaluated the effects of laser radiation with power configurations of 1 and 2 Watts for application times of 30 and 60 seconds; they reported similar results in relation with power and time of the application in the removal of *Enterococcus faecalis*. In their study, 5 % sodium hypochlorite solution treatment had the best disinfection performance and 2 Watts for 60 seconds, and 1 Watt for 120 seconds respectively showed second and third best disinfection performances.[27] Various conventional chemical treatments are used as mouthwashes, dryer or disinfectants that sometimes are used as bactericides for the implant cavity. The most common agents are EDTA, Chlorhexidine and sodium hypochlorite. Difference in disinfection capability, restriction to some particular bacteria and cytotoxicity are among the limitations of such chemicals.[17,28,29] However, application of laser radiation can be considered as an alternative means for the removal of bacteria or a supplementary method used with chemical disinfectant agents.

Conclusion

In this study, findings were interpreted qualitatively to introduce best radiation condition. Despite the potential relation between application power and time to effectiveness, the removal of smear layer by laser showed no regular pattern. In our study, power configurations ranged from 0.75 to 4.5 Watts with various application times were studies featuring an application of 1.5 and 3 Watts of power achieved better results.

However, research was subject to some limitations; in the study we did not evaluate bacterial or fungus germs that contaminated the cavities. Other negative aspects of the study were *in-vitro* environment and lack of comparison of effects of laser application and effects of mentioned chemical treatment. Addressing such defects in future studies can result in more comprehensive results.

In the end, our findings indicated that the application of Er,Cr:YSGG laser with power configurations of 1.5 and 3 Watts accompanied by air brushing and water cooling, with application times of 20 and 40 seconds, result in the most effective removal of smear layer. These conditions lead to better results in comparison with higher powers and exposure times; as the exposure time is reduced, the probability of tissue damage diminishes._

Editorial note: A list of references is available from the publisher.

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Kurz & bündig

Im vorliegenden Artikel vergleicht der Autor eine Vielzahl von Studien zur Reduktion der Schmierschicht in Implantatbohrungen durch Laserbestrahlung sowie konventionelle Desinfektionsmethoden mit den Ergebnissen seiner eigenen Forschung. Im Anschluss an die Auswertung von fast 70 Quellen der zeitgenössischen Literatur zum Thema sowie der eigenen Studienergebnisse gelangt der Autor zu dem Fazit, dass die Entfernung der Schmierschicht durch den Dentallaser keine regulären Muster aufweise. Obwohl potenziell eine Abhängigkeit zwischen Applikationszeitpunkt, -dauer und Effektivität bestünde, konnte in der vorliegenden Studie keine Relation zwischen diesen Faktoren nachgewiesen werden. Der Autor weist jedoch darauf hin, dass umfassendere Ergebnisse erreicht werden könnten, wenn zukünftige Studien weitere Faktoren in die Auswertung einschlössen. Hierzu zählen Bakterien- und Pilzkeime in den Kavitäten sowie das *in-vitro* Umfeld und Vergleiche zu verschiedenen Laseranwendungen und der chemisch-basierten Schmierschichtentfernung. Die Ergebnisse der vorliegenden Studie legen abschließend nahe, dass die Anwendung eines Er,Cr:YSGG-Lasers bei 1,5 und 3 Watt, in Kombination mit Airbrush und Wasserkühlung für eine Dauer von 20 bis 40 Sekunden am effektivsten sei. Mit der Reduktion der Anwendungsdauer verringere sich dabei die Wahrscheinlichkeit für Gewebeschäden.

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